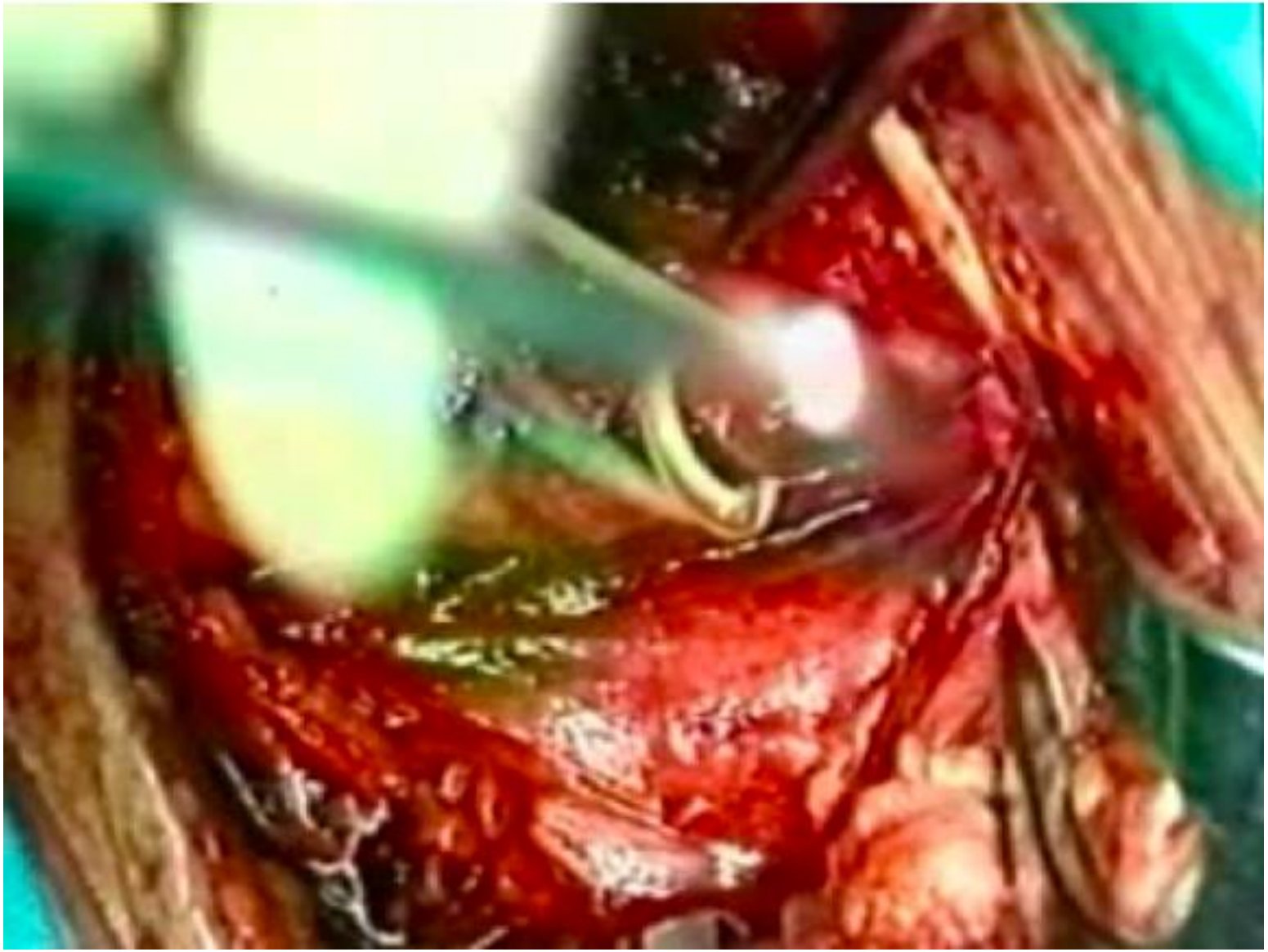
# Carotid artery disease

## Treatment (endarterectomy)



# *Carotid artery disease*

## Treatment (carotid *stent*)

VNIVERSITAT DE VALÈNCIA
Facultat de Medicina i Odontologia

# Carotid Artery Disease

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Tutorials:

# *Carotid artery disease*

## Competences

- To understand the risk of stroke and the clinical relevance of the problem.
- To acquire a solid background of the pathogenic mechanisms, drug interactions, monitoring systems and neurological protection.
- To initially assess patients with symptomatic and asymptomatic carotid stenosis.
- To understand the principles and correctly indicate the main diagnostic methods.
- To properly use the diagnostic criteria to indicate how to correct carotid artery disease.
- To learn the fundamentals of carotid endarterectomy and stenting and know the results of major clinical trials in symptomatic and asymptomatic patients.

***personal work***:

- Takayasu disease
- Moya-Moya disease

# *Carotid artery disease*

## References


★ ESVS Guidelines Committee. Management of Atherosclerotic Carotid and Vertebral Artery Disease: 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). J Vasc Endovasc Surg (2018) 55, 3e81.

★ Naylor AR. Endarterectomy versus stenting for stroke prevention. Stroke Vasc Neurol. 2018 Feb 24;3(2): 101-106.

Paraskevas KI, Mikhailidis DP, Veith FJ. Comparison of the five 2011 guidelines for the treatment of carotid stenosis. J Vasc Surg. 2012; 55(5): 1504-8.

American Heart Association/American Stroke Association. Guidelines for the Primary Prevention of Stroke. *Stroke* 2011; 42:1-50.

American Heart Association/American Stroke Association. Guidelines for the Prevention of Stroke in Patients With Stroke or Transient Ischemic Attack. *Stroke* 2011; 42:1-50.

# *Carotid artery disease*

## Clinical case

A 65-year-old man with a history of hypertension and dyslipidemia refers repeated episodes *of amaurosis fugax* in his right eye. Examination by duplex scanning and CT Angio shows stenosis > 70% in both internal carotid arteries.

# Carotid artery disease

## Topics

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- intraoperative monitoring
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# Carotid artery disease

## Introduction

★ **Incidence of stroke: 200-350/100,000 *inhabitants (Spain: 2nd and 1st cause of mortality amongst men/women)****

carotid disease: 30%

1875 Gowers: carotid occlusion -> stroke

1914 Hunt: role of extracranial carotid atheromatosis

*1937 Monitz: Cerebral Arteriography.*

★ ***1954 Eastcott, Pickering, Rob: Resection+ anastomosis carotid bifurcation*****.**

* Halliday A. Angiologia 1997;49:51-56)

** Eastcott GH. Lancet, 2:994-96, 1954

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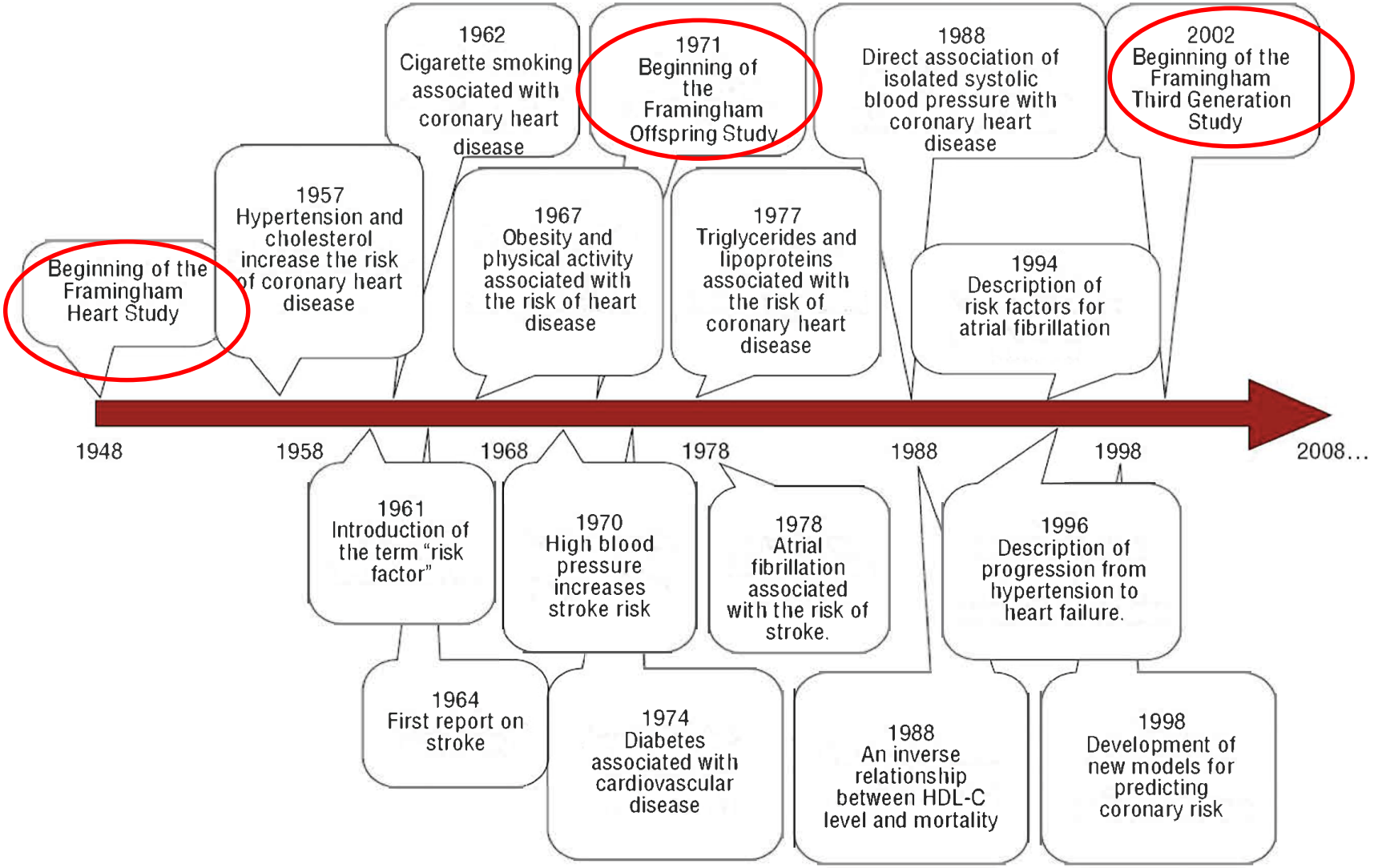
# *Carotid artery disease*

## Population studies

★ Framingham (Massachusetts) (1948-1971-2003)



## *Carotid artery disease*

## Population studies

★ Framingham (Massachusetts) (1948-1971-2003)
Rochester (1955-69)/Goulburn (Australia)
Spain: MANRESA 1996, REGICOR 1997, MONICA 2005

- **stroke**

  incidence 2x >65 years

  *mortality 40%*

★ ***recurrence: 9-10%/year***

- **TIA**

★ ***stroke incidence: 6-7%/year*** *(*50% first year?)

risk factors (TIA, HTN, coronariopathy)

*Only 30-50% of patients with CVA have a previous TIA.*

- **asymptomatic IC stenosis (ICS) (stenosis >75% (duplex-scanning):**

  *TIA incidence 18%/year*

★ ***stroke incidence 3-5%/year***

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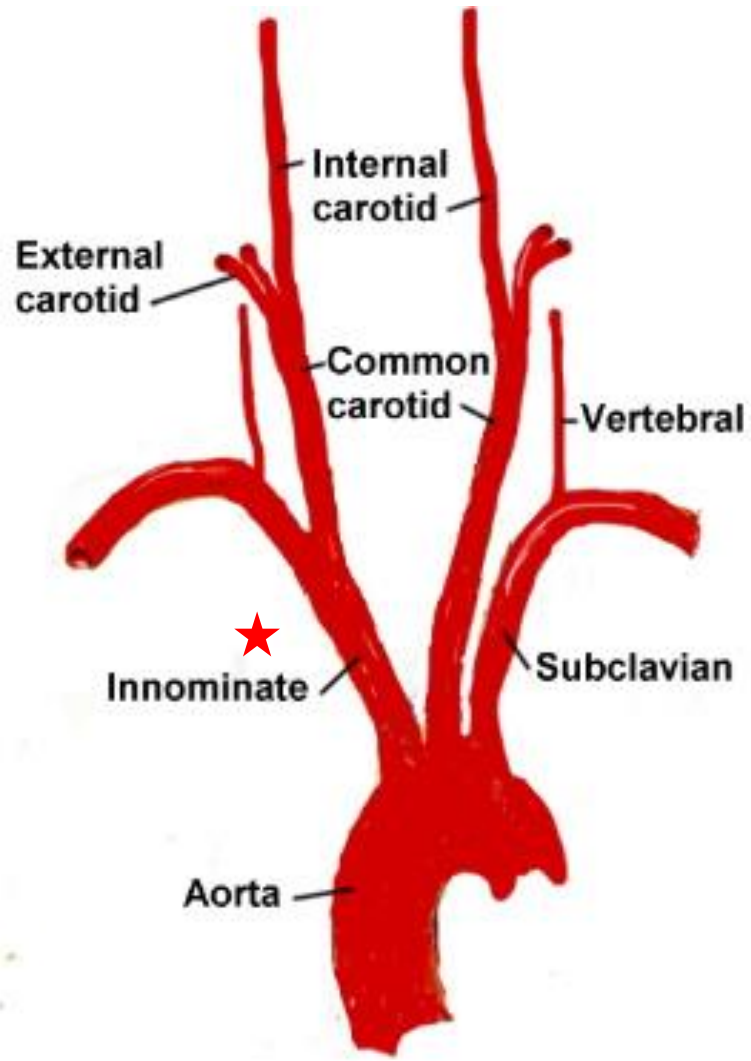
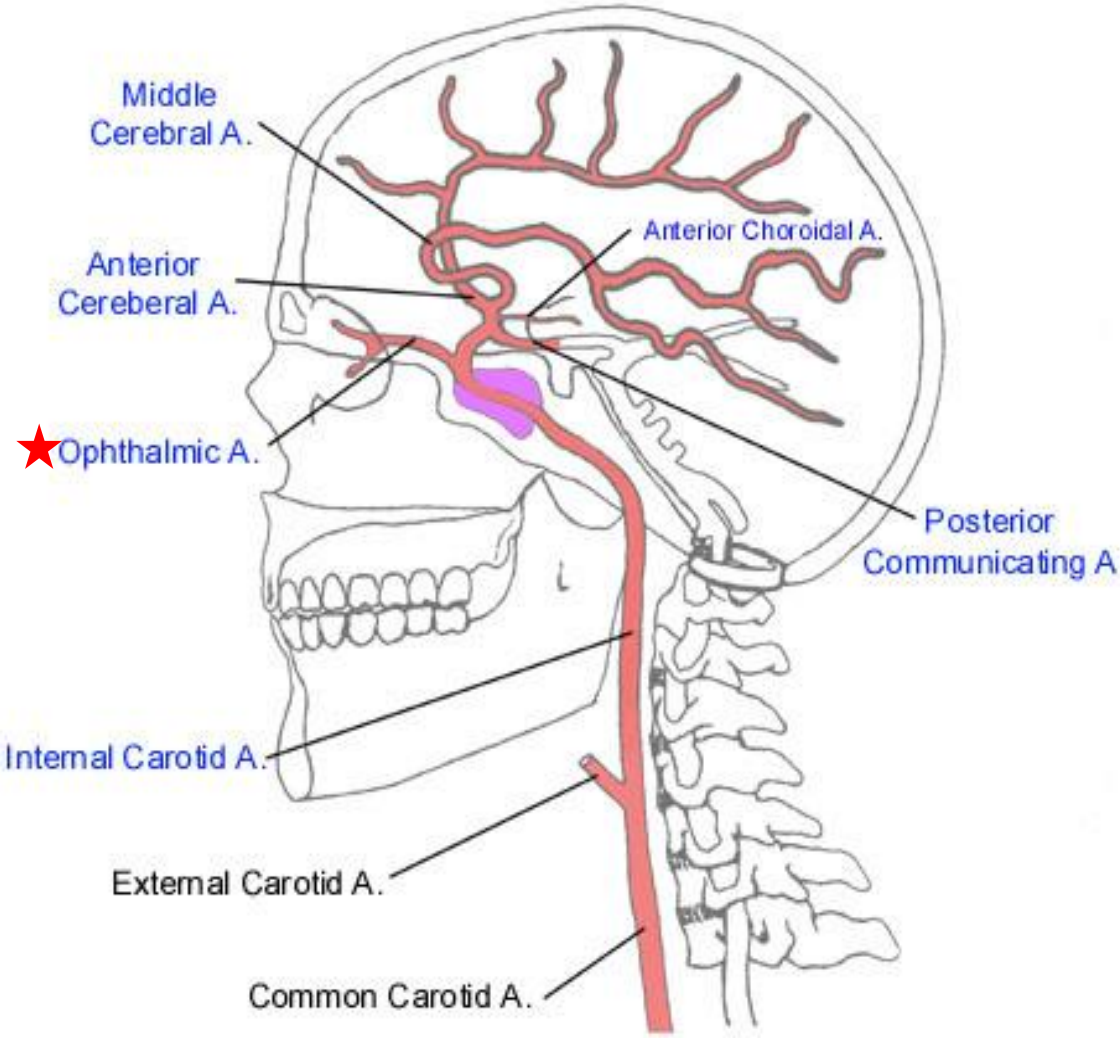
# Carotid artery disease

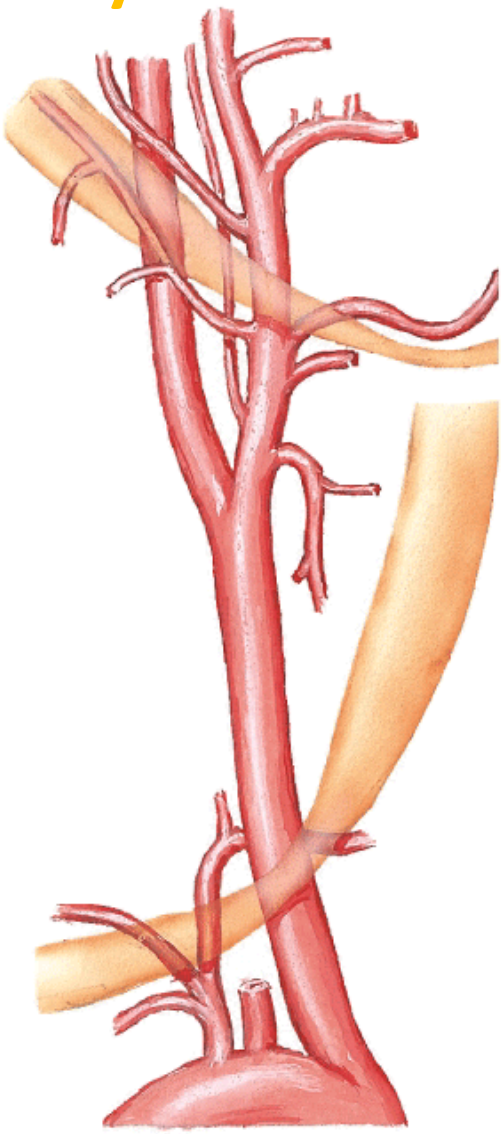
## Anatomy

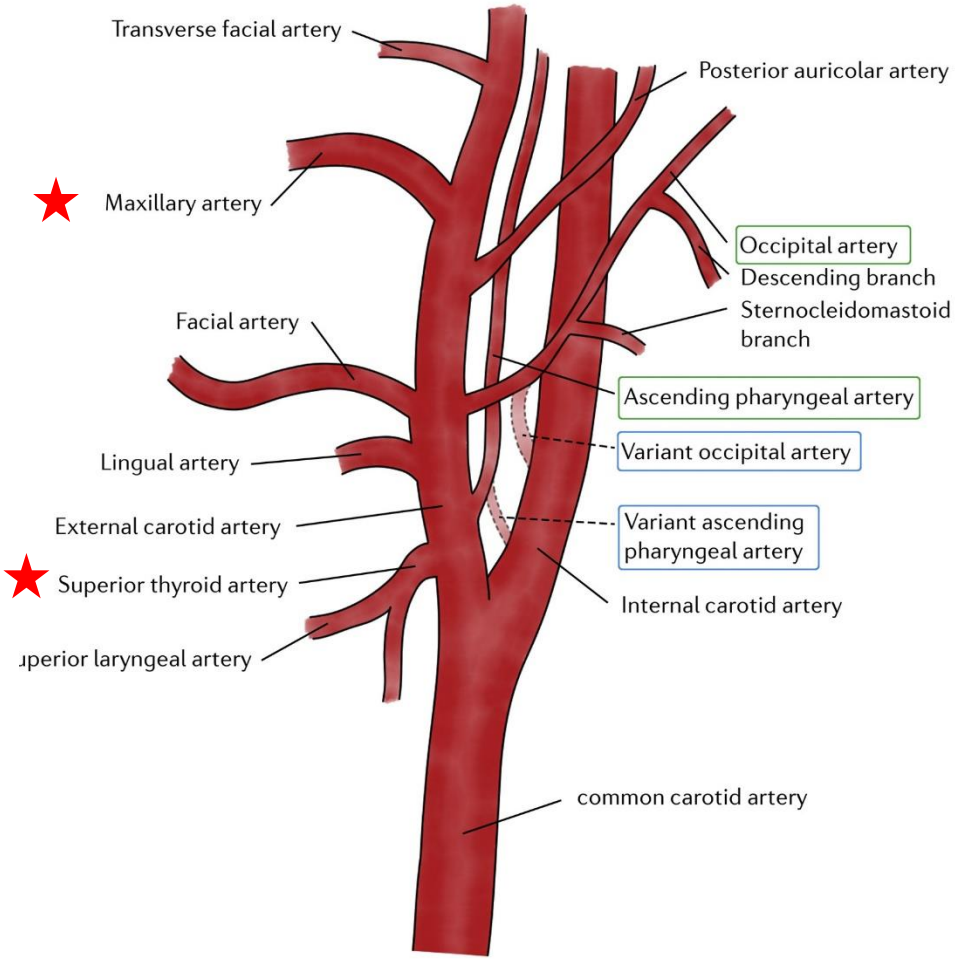


# Carotid artery disease

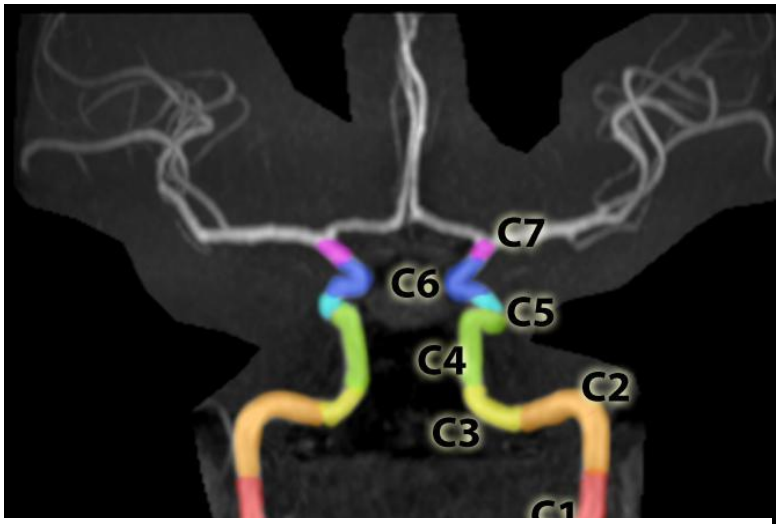
## Anatomy

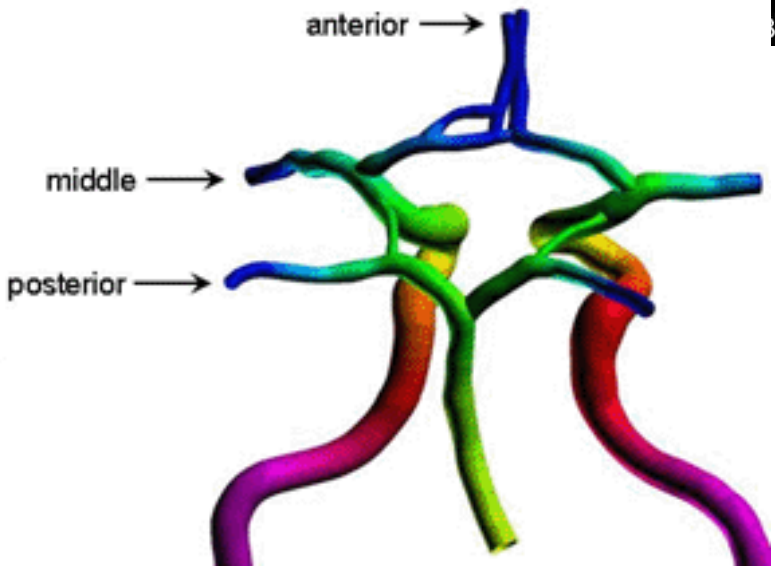


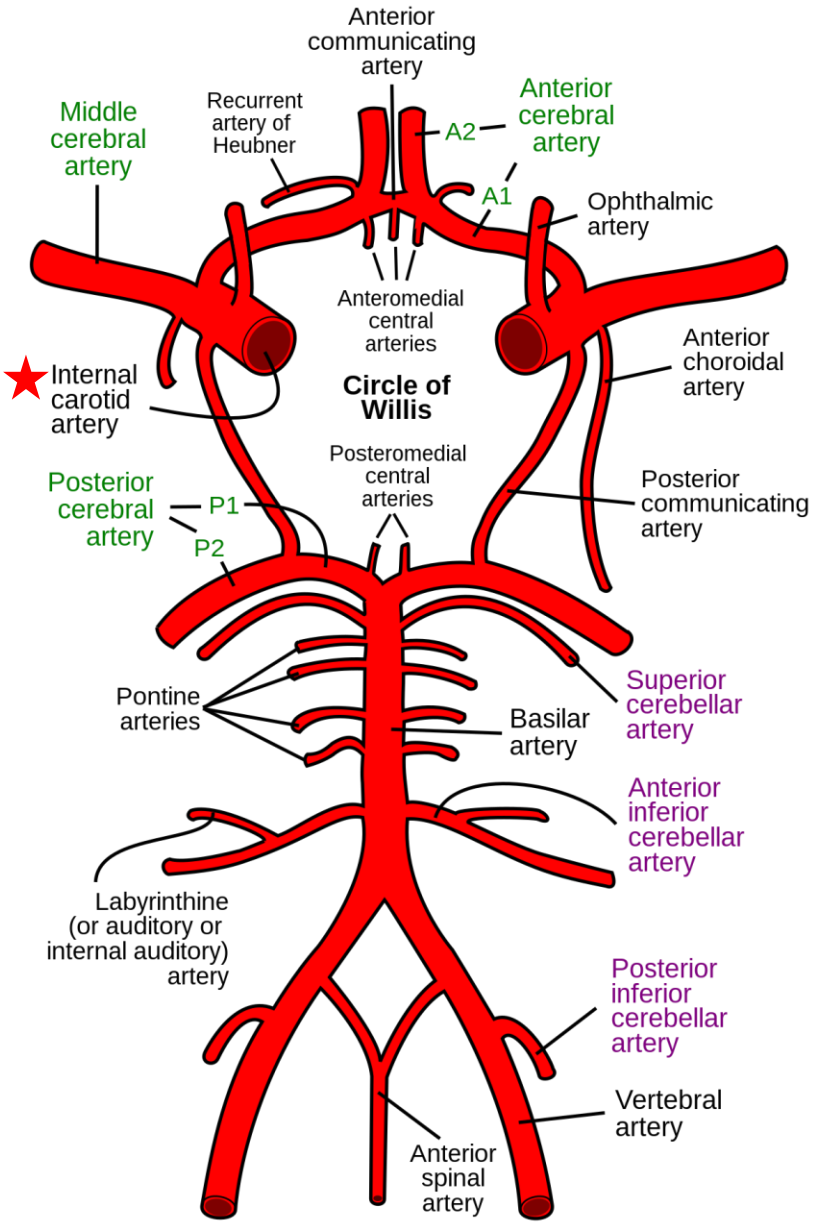


# Carotid artery disease

## Anatomy

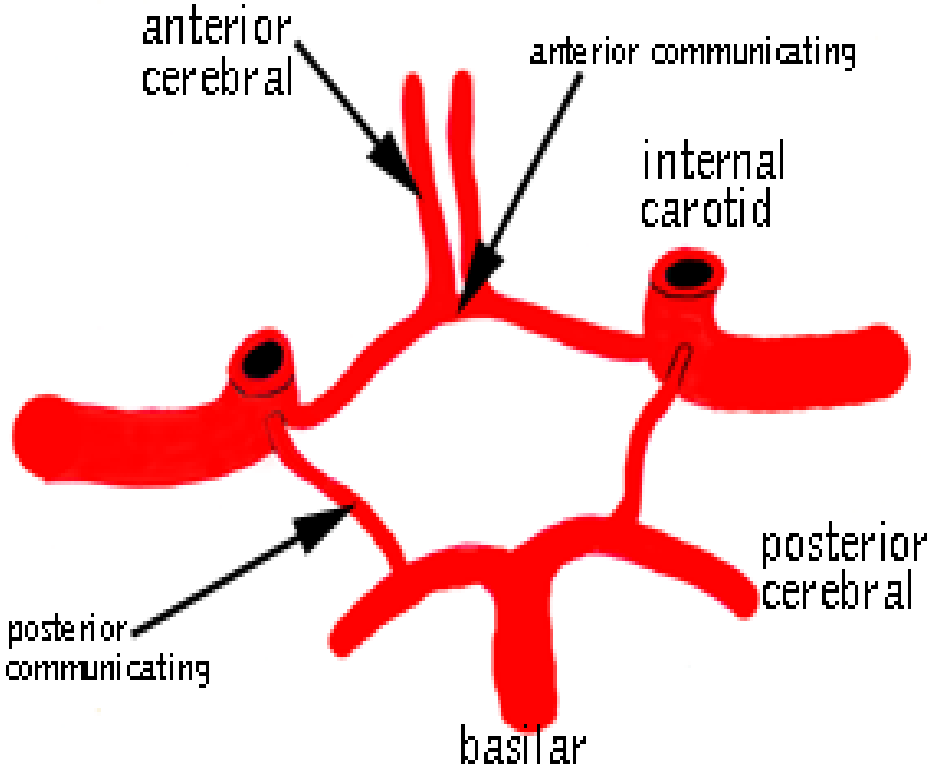


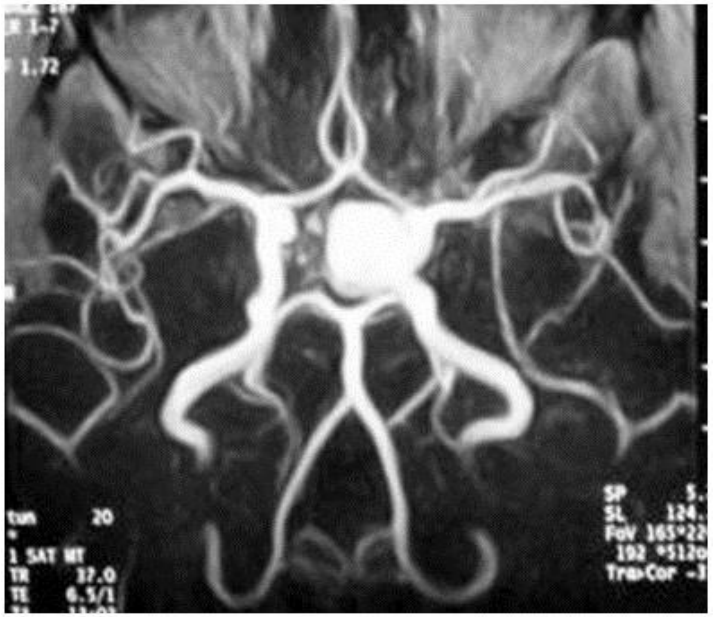



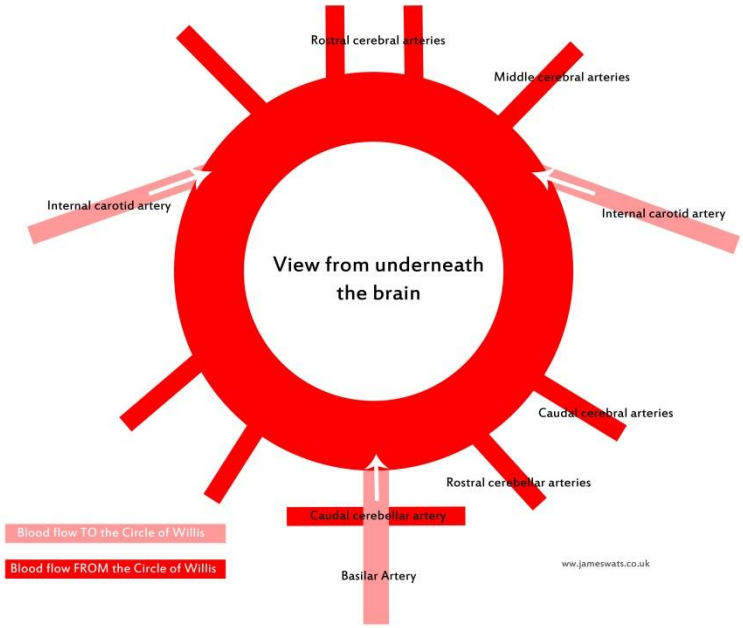



# Carotid artery disease

## Anatomy ★





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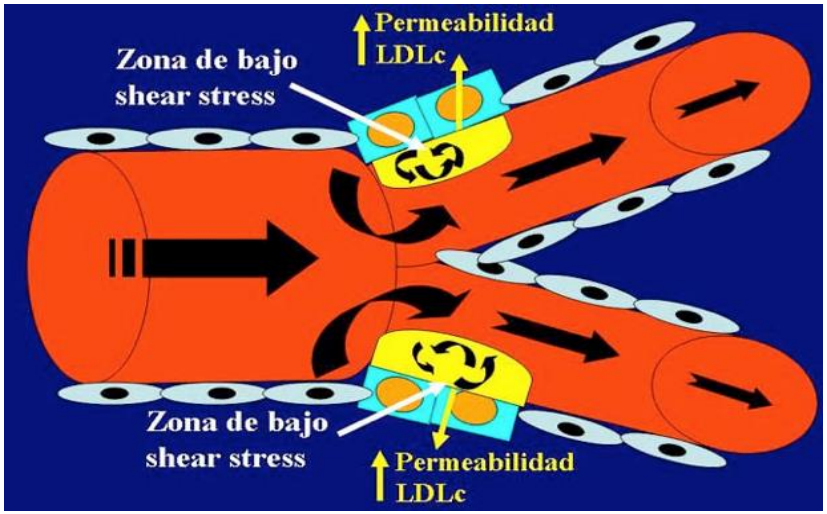
# Carotid artery disease

## Pathology

★ ***AE (90%)***
***Fibromuscular Dysplasia***
Kinking
Dissection
Traumatism
Radiation
Amyloidosis
Polyarthritis

*Giant cells* arteritis
Moya disease
Temporal arteritis
Amphetamine arteritis
Infectious arteritis




## Localization

| | |
|---|---|
| ★ ***Carotid Bifurcation*** | ***38%*** |
| Distal carotid | 33% |
| Proximal carotid | 9% |
| Vertebrobasilar | 20% |
| Circle of Willis | 5-9% |

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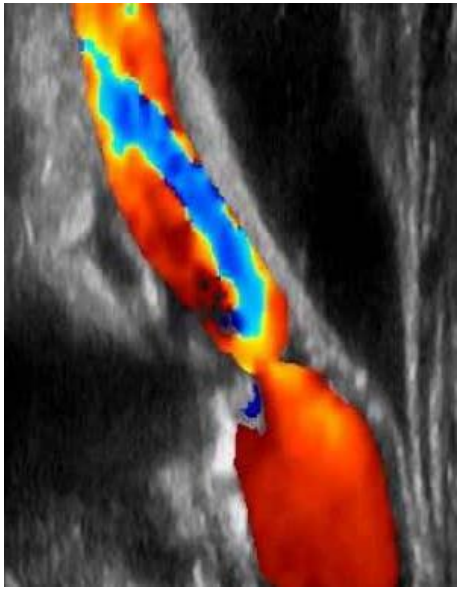
## *Carotid artery disease*
## Pathology

★***vasospasm***

***hemodynamic*** *(pressure gradient in stenosis > 50% (diameter)*



★*Objections:*

*Carotid EA -> no flow increase*

*Flow decrease only in stenosis > 84%*

*TIAs disappear after carotid occlusion*

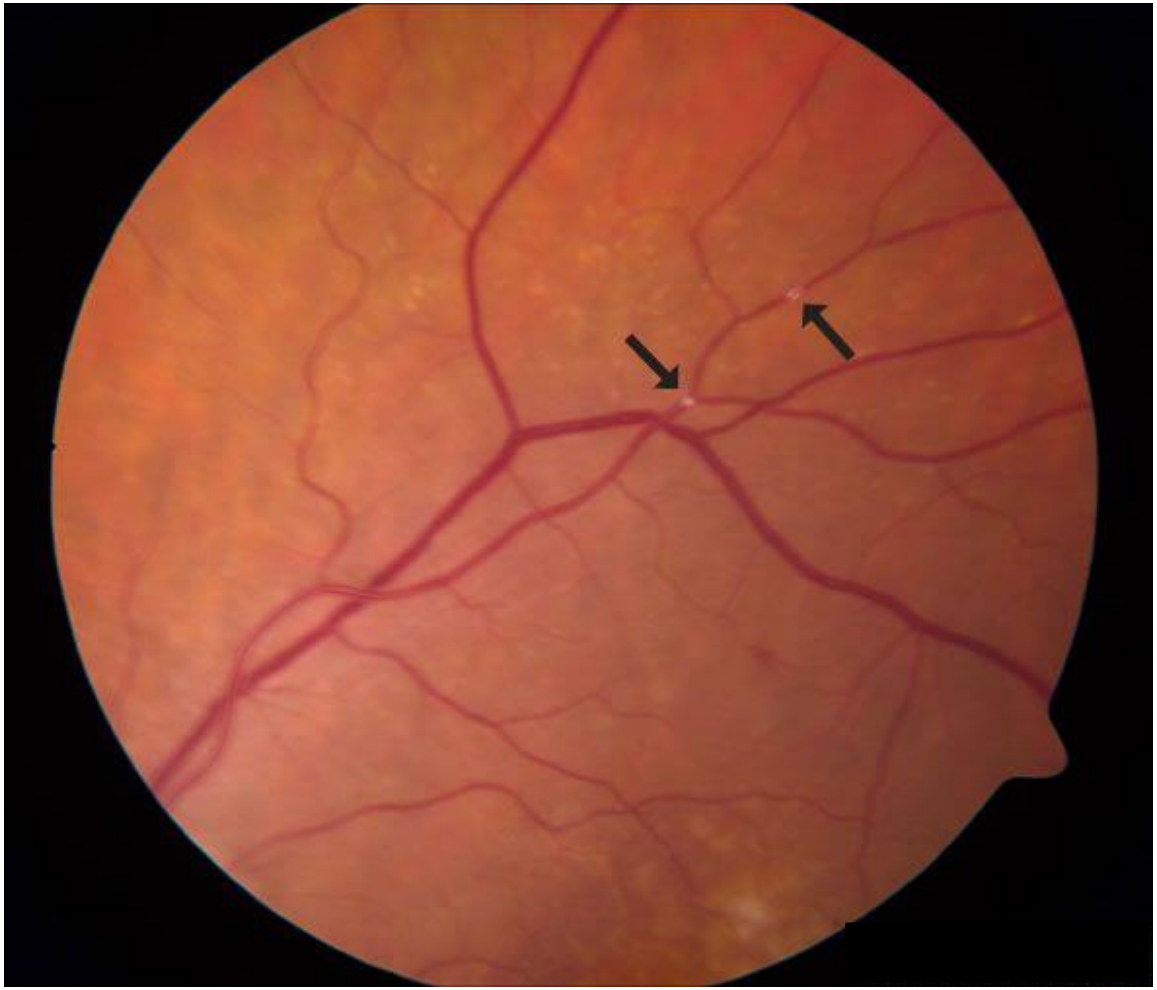
★***embolic*** *(efficacy of anticoagulants in TIAs)*

***Hollenhorst plaques*** *(1961) (cholesterol emboli in retinal arteries)*

*Harloff A. Interv Neurol 2012;1(1):44-54*

# *Carotid artery disease*

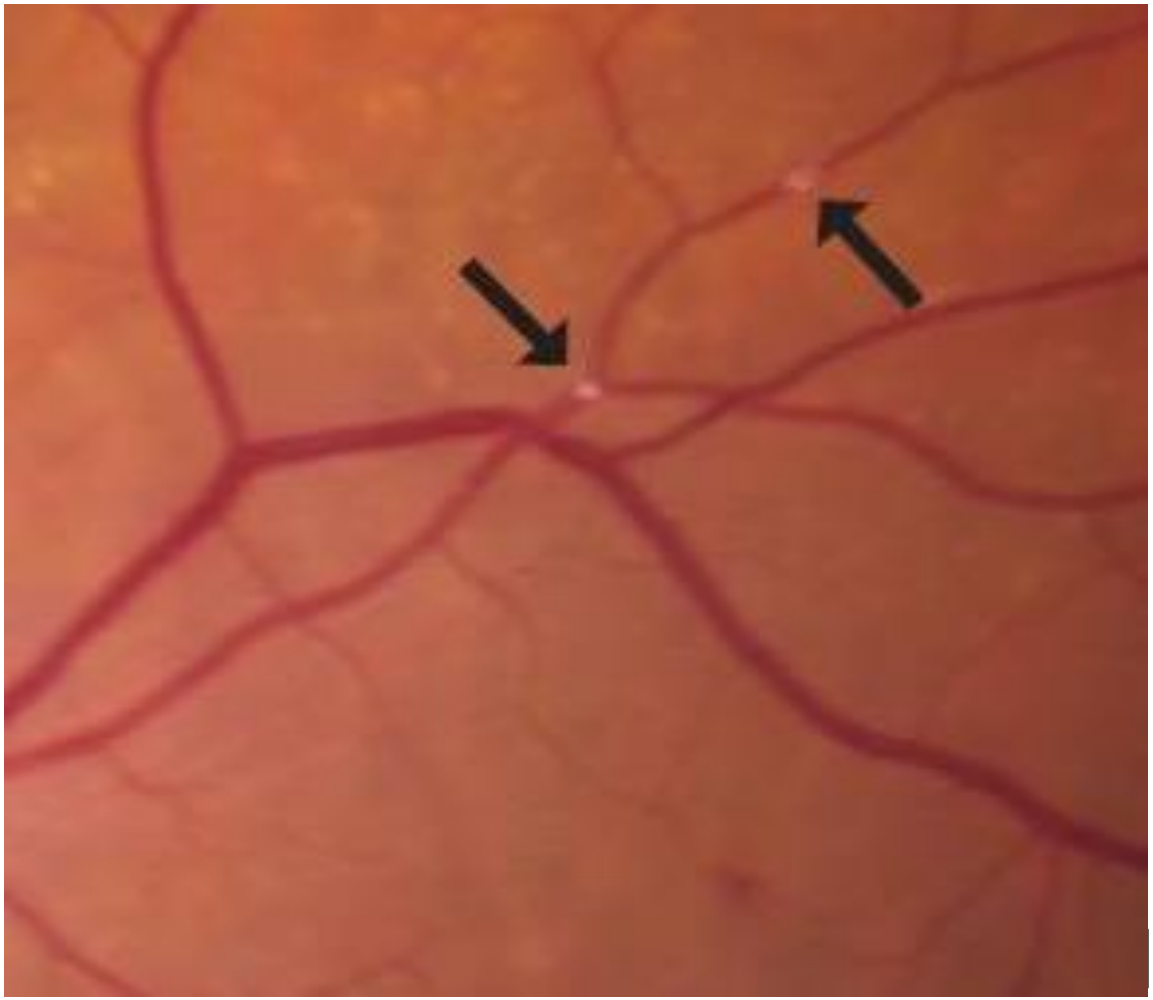
## Pathology



https://www.pinterest.com/eddieskettiqade/ophthalmology/

# Carotid artery disease

## Pathology



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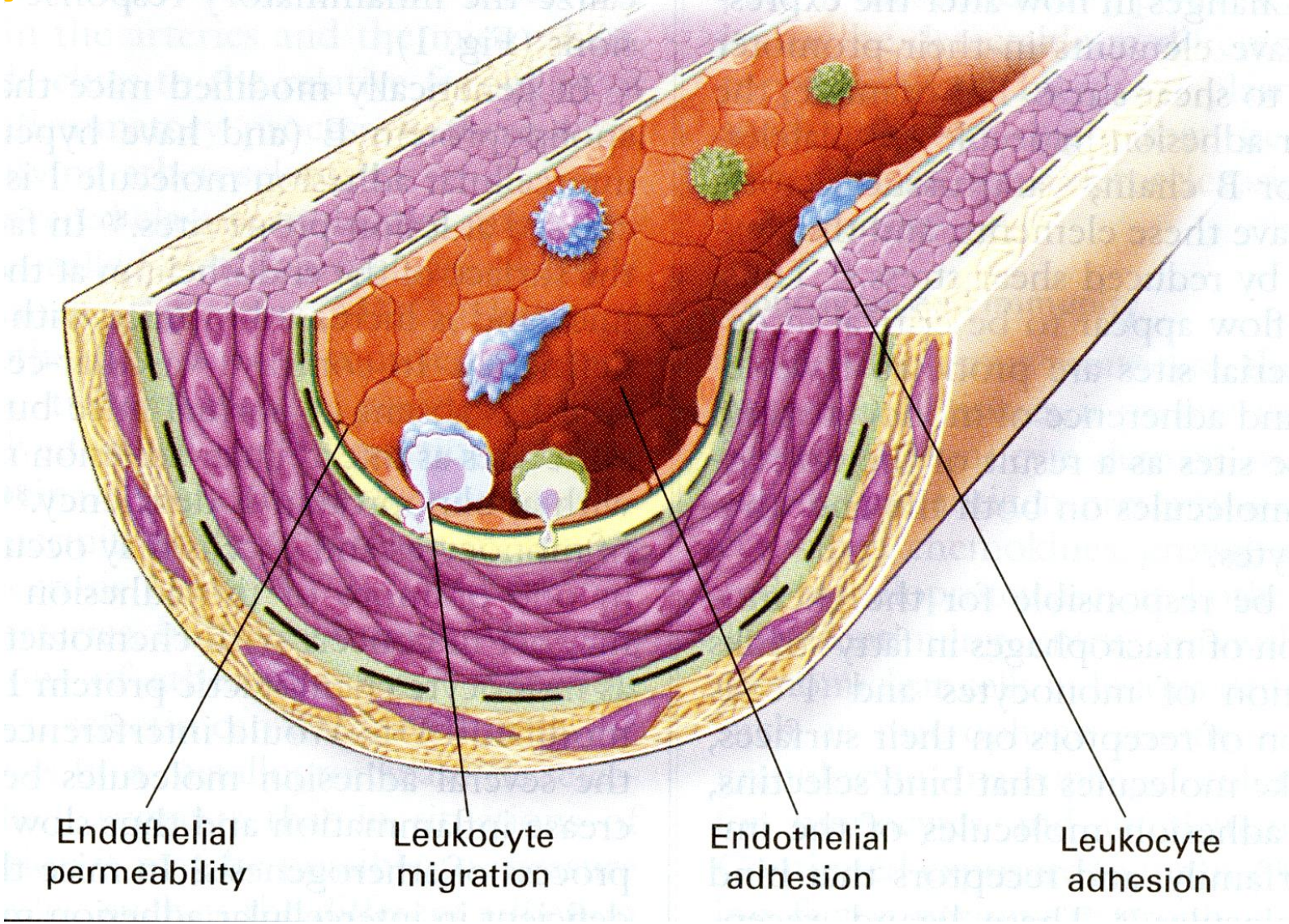
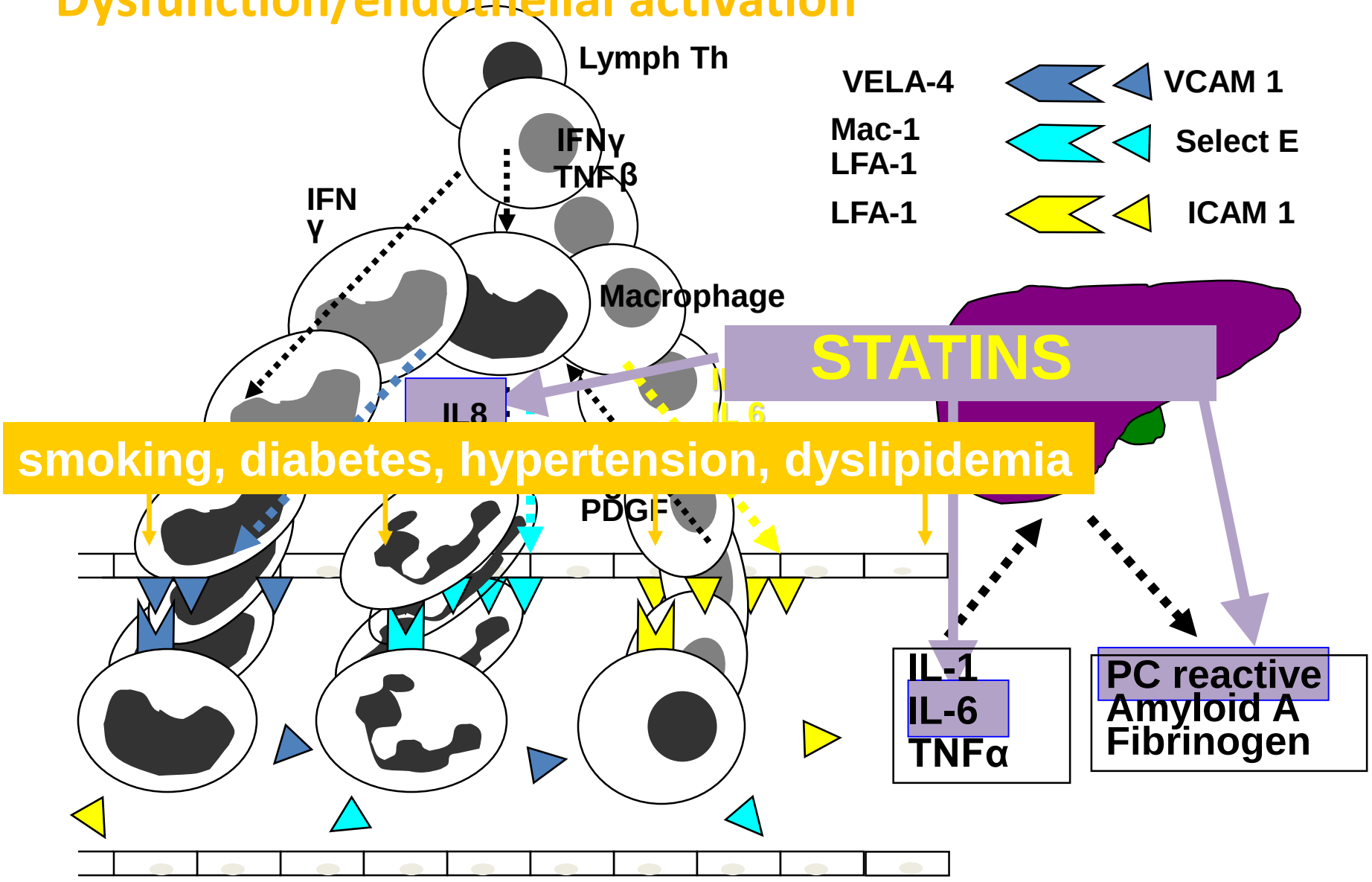
# Carotid artery disease

## Dysfunction/endothelial activation



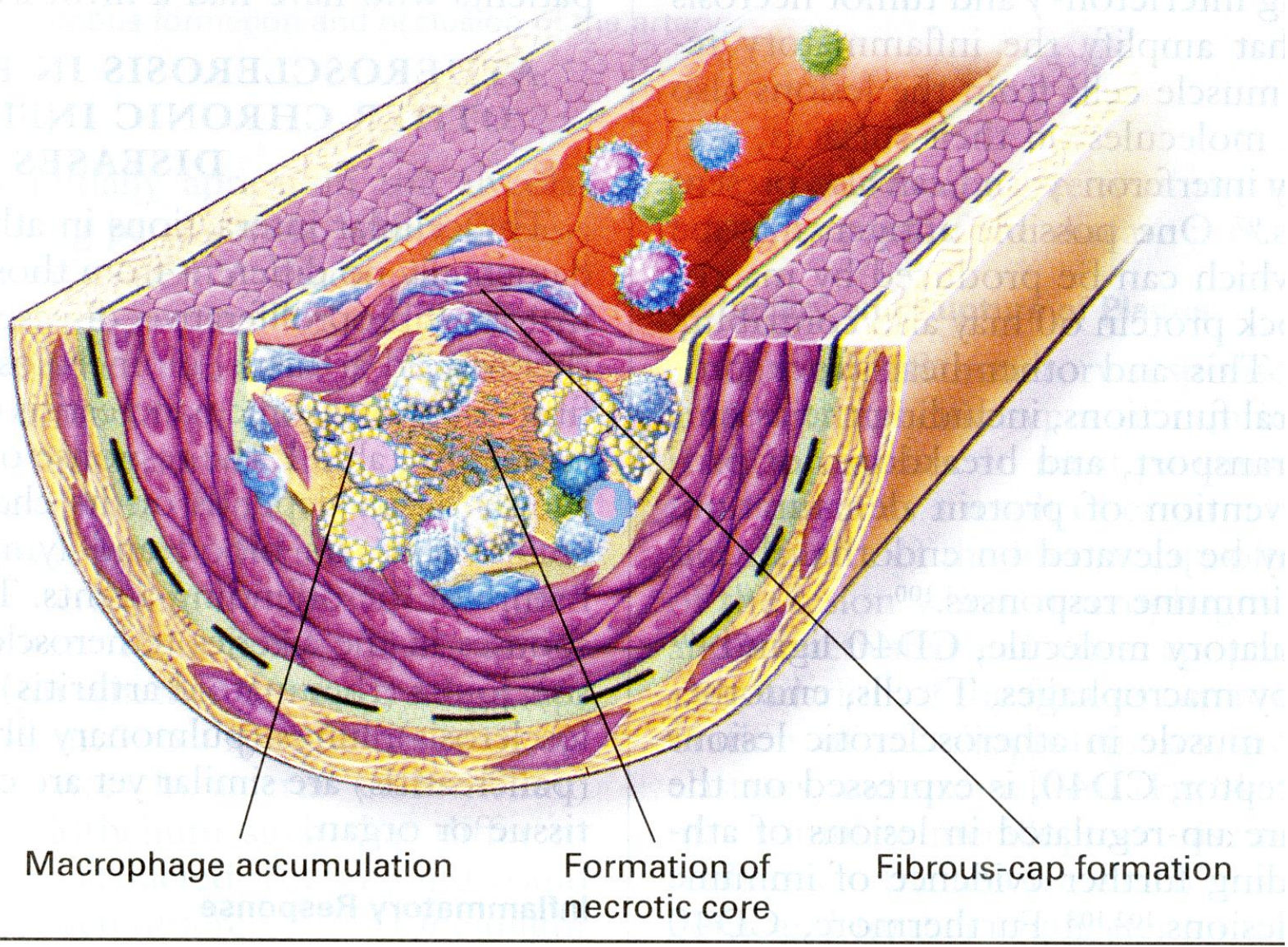
# Carotid artery disease

## Dysfunction/endothelial activation



# Carotid artery disease

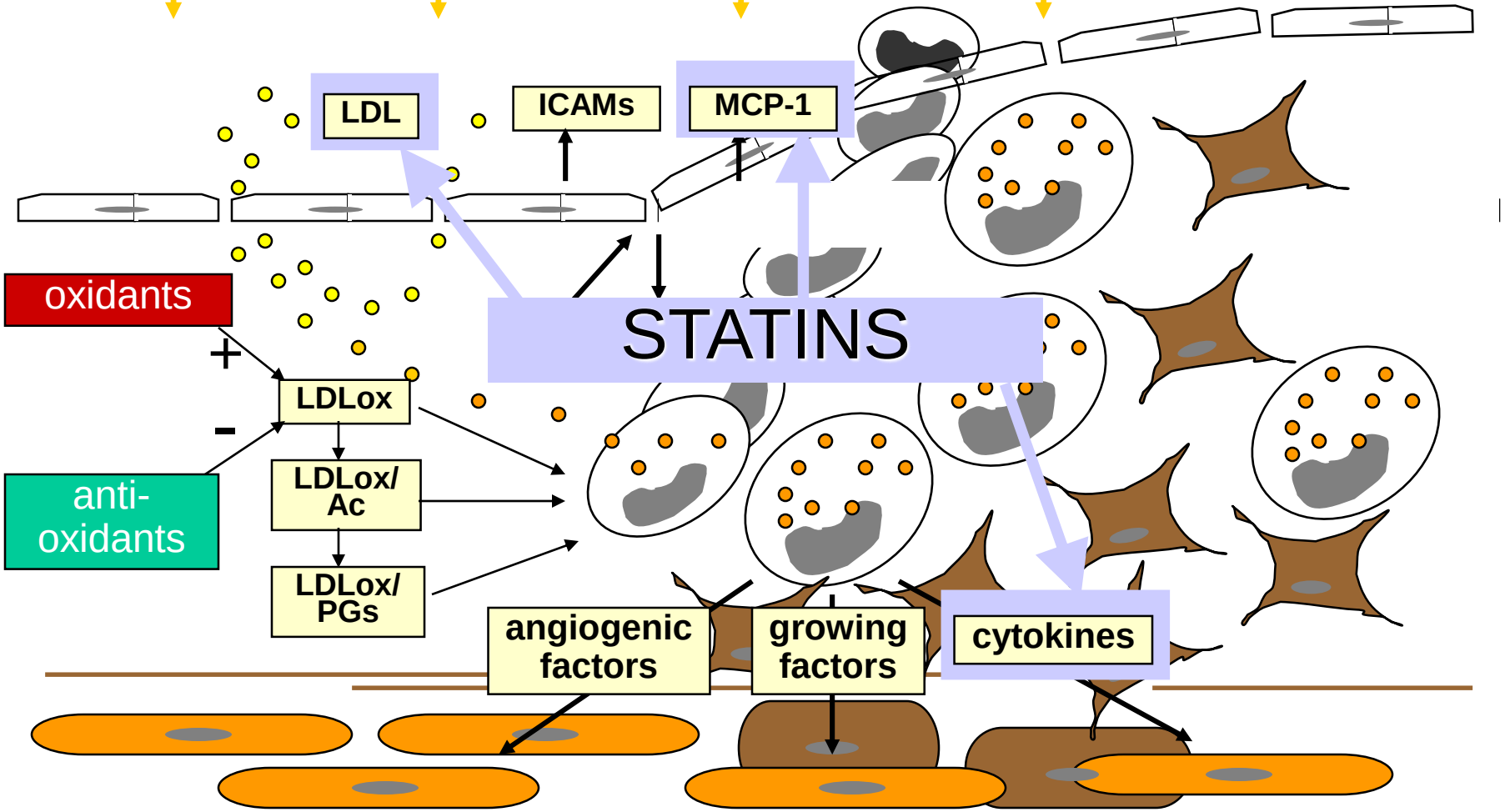
## Atherogenesis/fibrolipidic plaque



# Carotid artery disease

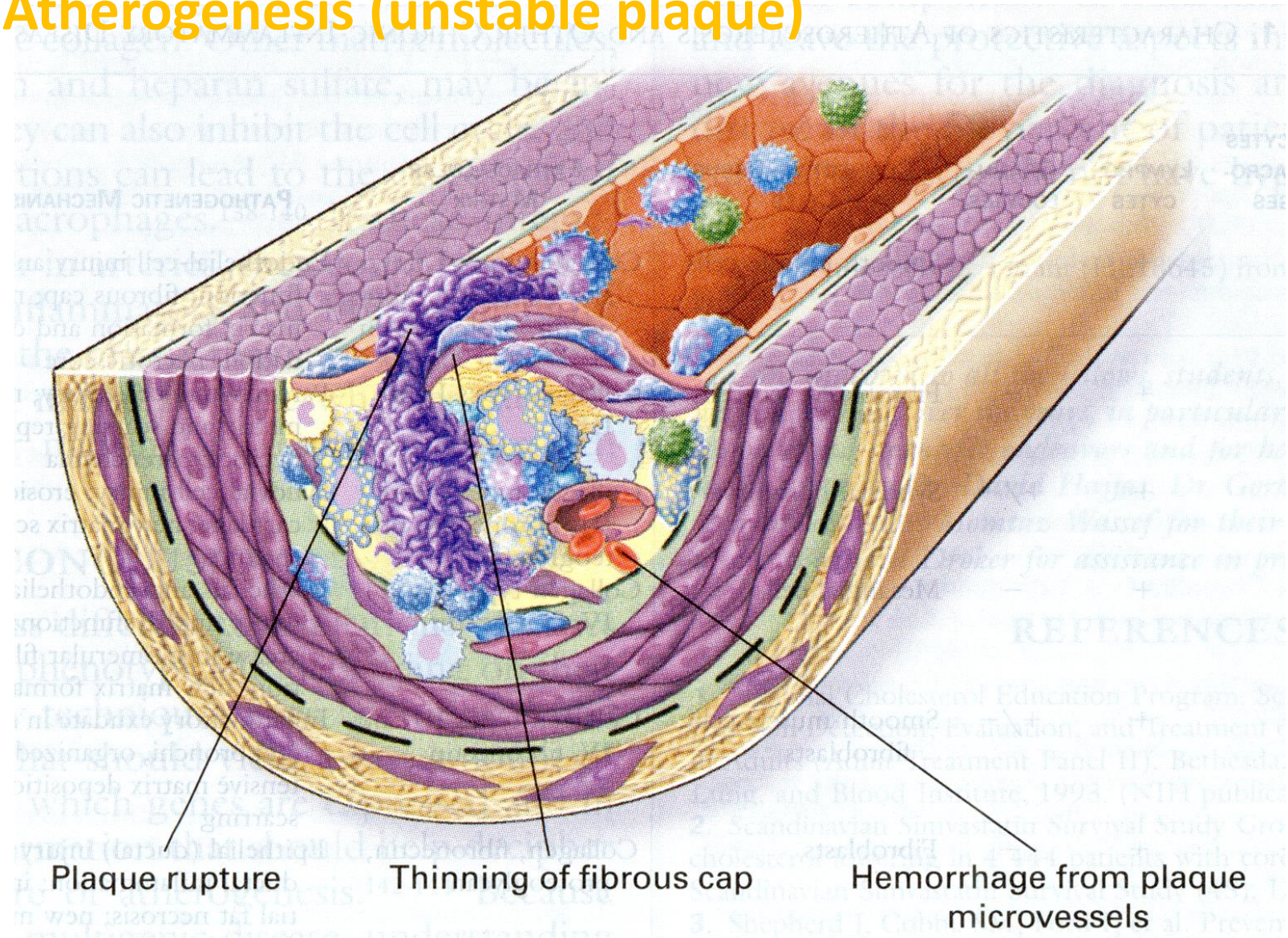
## Atherogenesis/fibrolipidic plaque

**smoking, diabetes, hypertension, dyslipidemia**



# Carotid artery disease

## Atherogenesis (unstable plaque)



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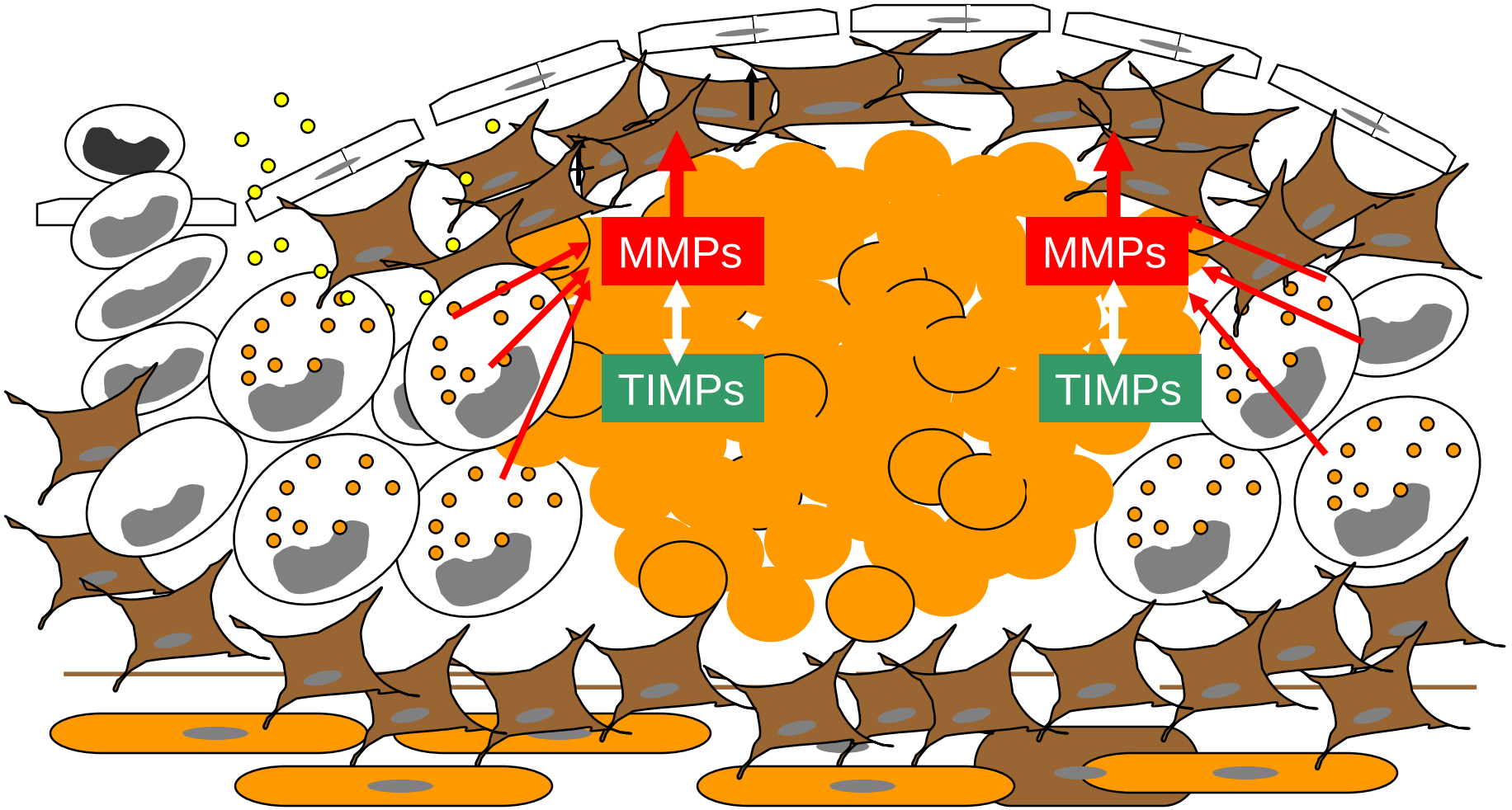

# Carotid artery disease

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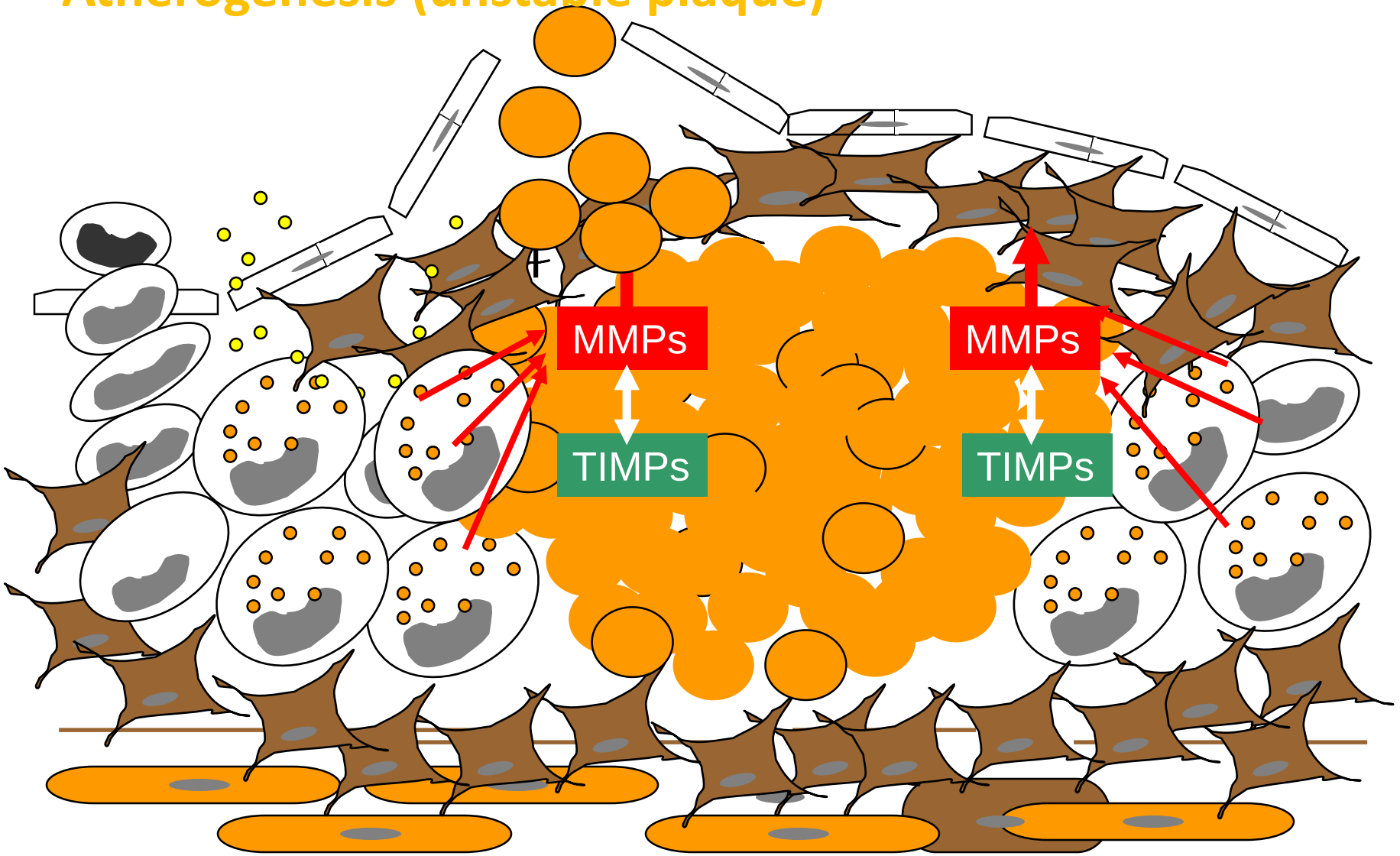
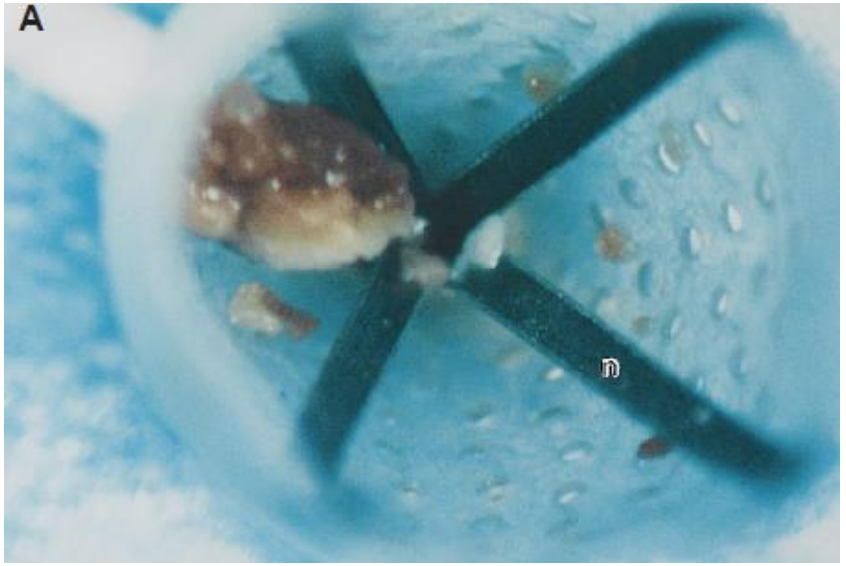
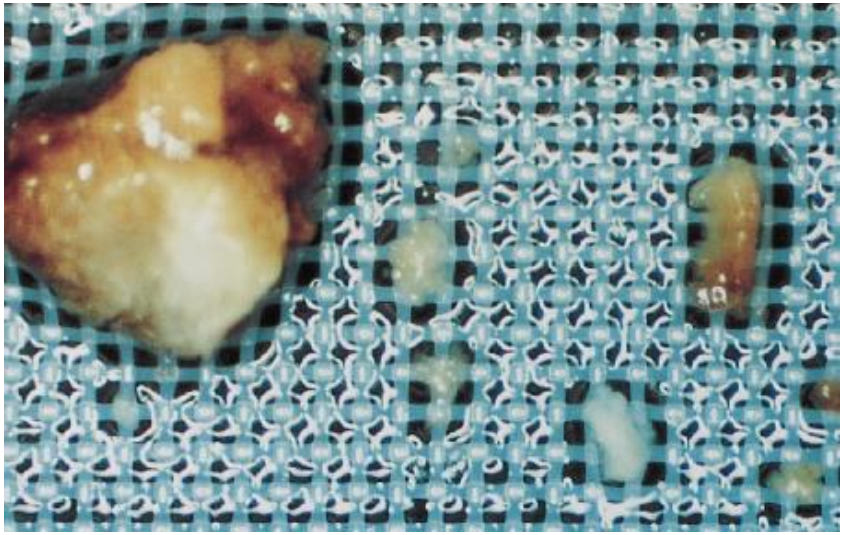


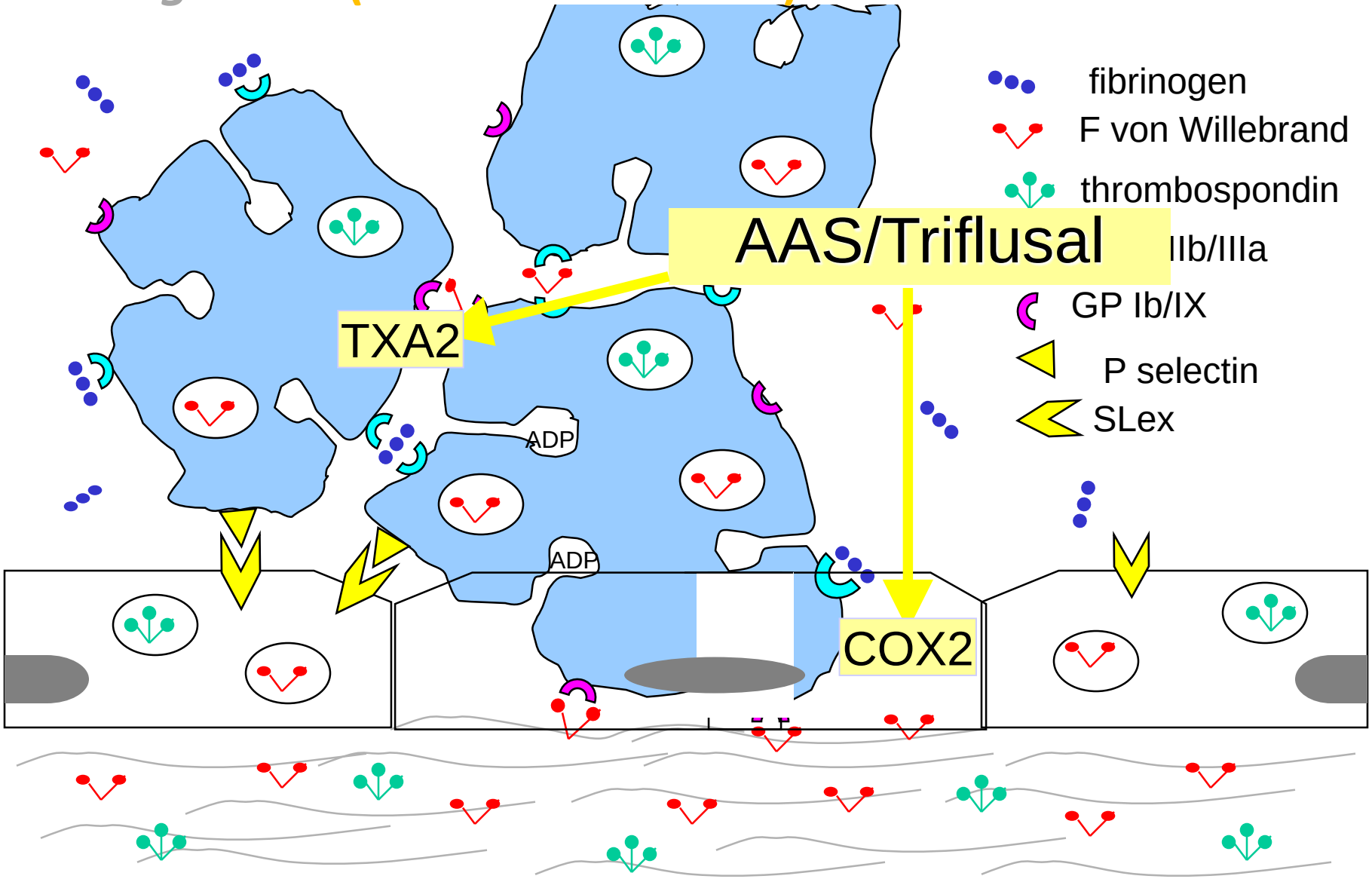
# *Carotid Artery Disease*



# Carotid artery disease

## Atherogenesis (atherothrombosis)



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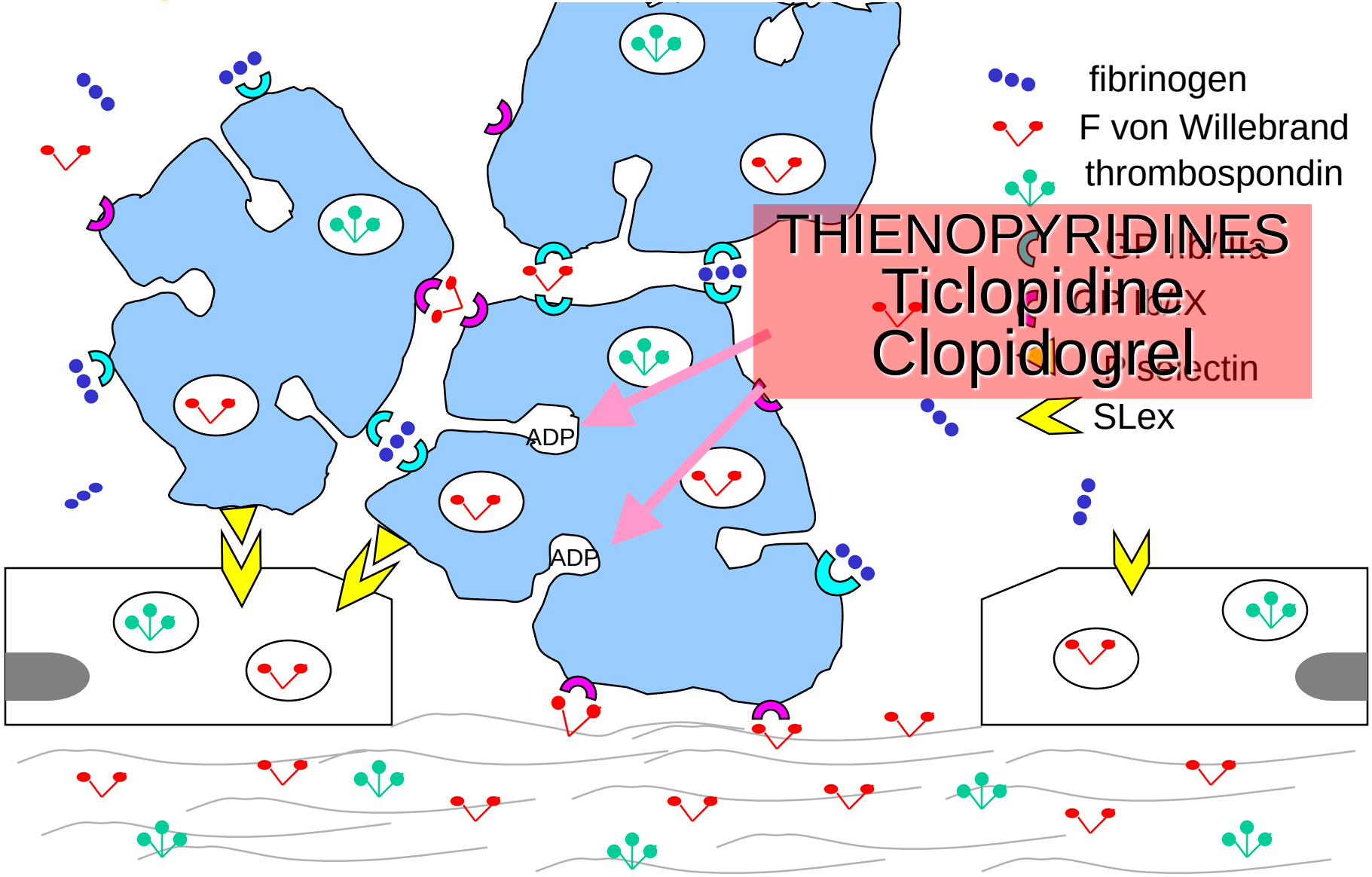

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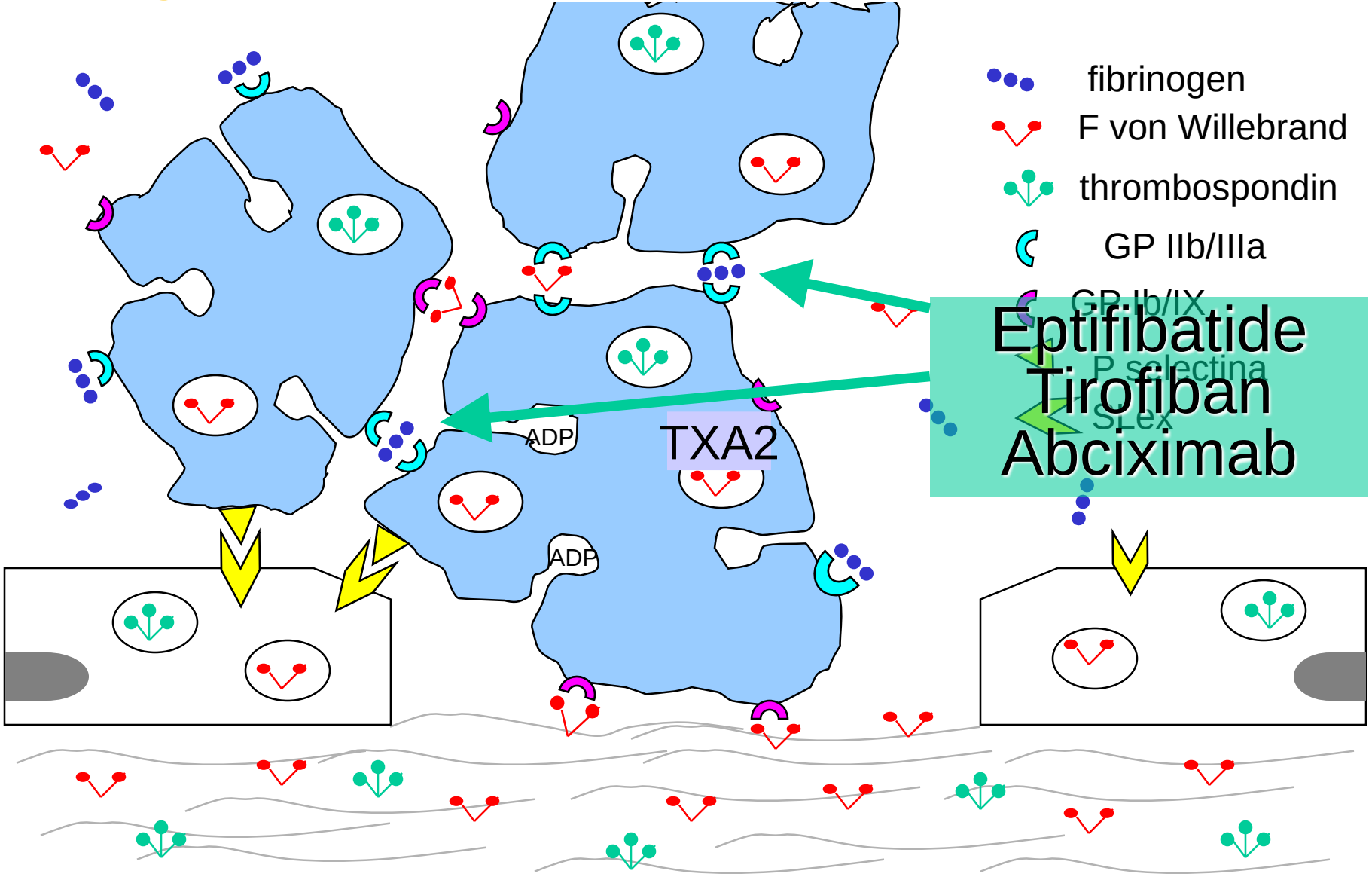

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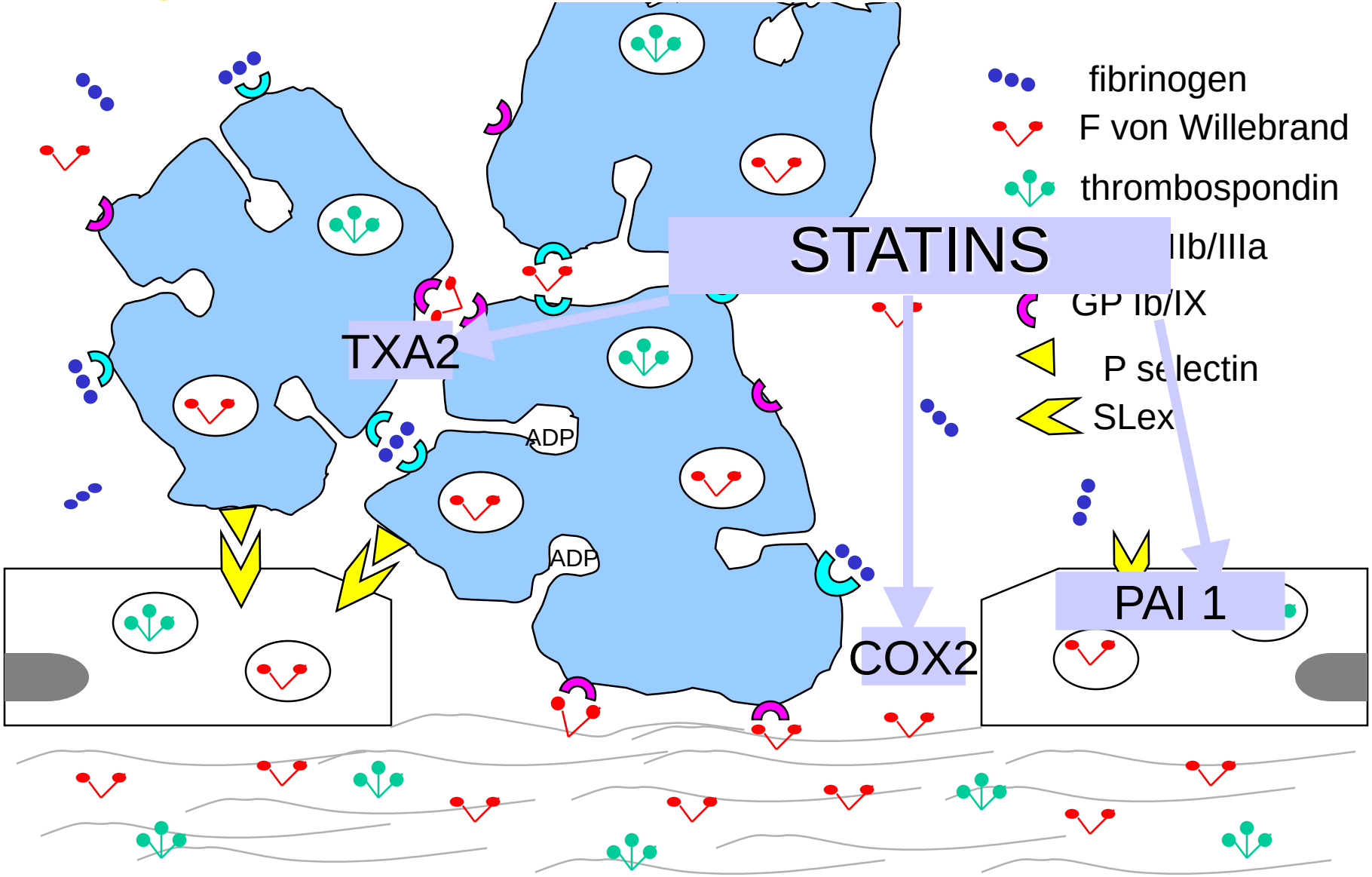

# *Carotid Artery Disease*

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# *Carotid artery disease*

## Clinical symptoms

★ neurological deficit

***TIA*** *(0-24 hours)* generally < 3 hours

72 hours vertebrobasilar

***Amaurosis fugax*** *(1-30 min)*

***TIA in evolution*** (> 2 weeks)

***Stroke*** *(established deficit*)

★***Lacunar infarction (diameter*** *< 10 mm, hypertension, diabetes)*

Motor syndrome (*Pons, internal capsule*)

Sensorial syndrome (*thalamus*)

Ataxic hemiparesis (*Pons, internal capsule*)

Clumsy hand/dysarthria

*Berman SA, et al. AJNR 1980; 1 :259-263*

# Carotid artery disease

## Clinical symptoms

**Carotid:**

★ ***Internal carotid***

***homonymous hemianopia***

***motor and sensorial deficit (arm/face/leg)***

***mixed aphasia (left)***

***anosognosia (right)***

★ ***MCA***

***similar + mouth deviation towards the lesion side***

***decrease in consciousness (25%)***

***MCA (proximal branches)***

*parietal lobe (decreased stereognosis, graphesthesia)*

***MCA (distal branches)***

*predominant parietal-occipital (Gerstmann, agraphia, acalculia, finger agnosia, left-right disorientation)*

*Berman SA, et al. AJNR 1980; 1 :259-263*

# Carotid artery disease

## Clinical symptoms

*vertebrobasilar (cerebelous syndrome + altered cranial pairs)*

★***PICA*** *(Wallenberg)*

***facial and vocal cords paresis, Horner, decreased nauseous reflex***

***ataxia***

***decreased thermal and nociceptive sensitivity***

★ ***cerebellar infarction***

***ataxia, vertigo, vomiting, cephalea, diplopia, nystagmus, decreased consciousness level***

**Basilar artery**

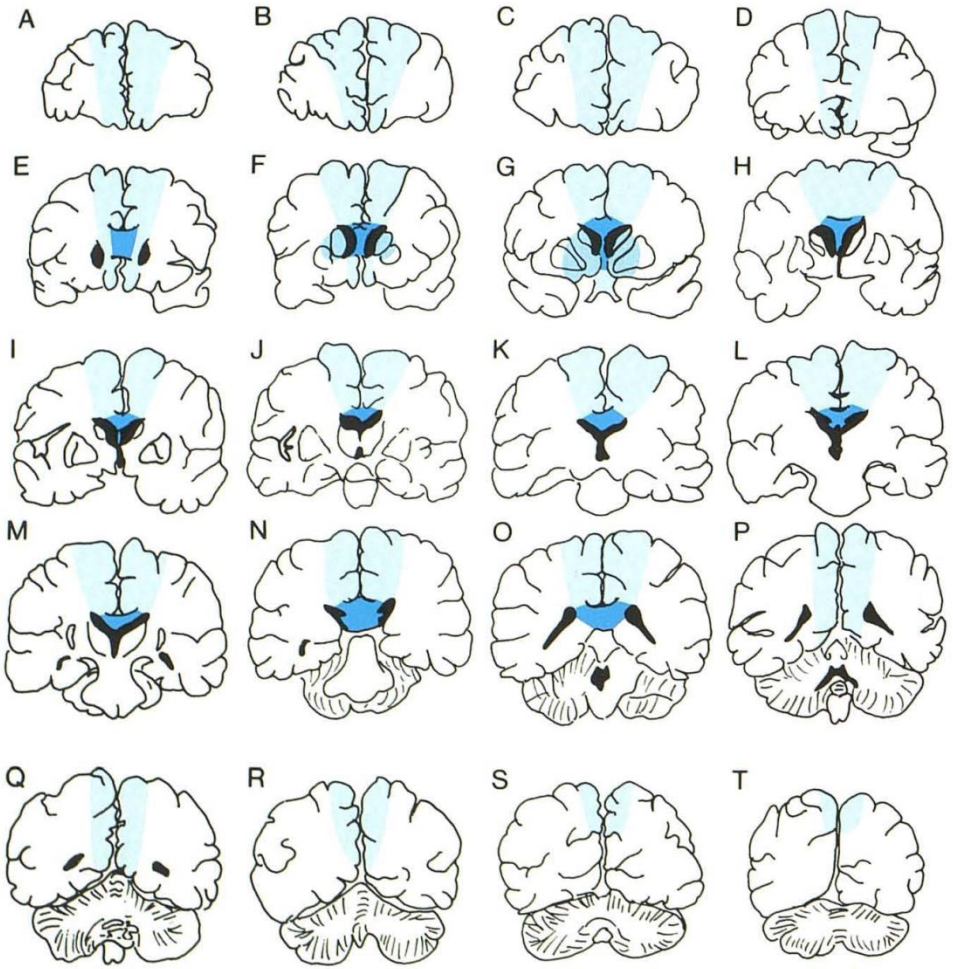
Coma, Quadriplegia, "Locked in"

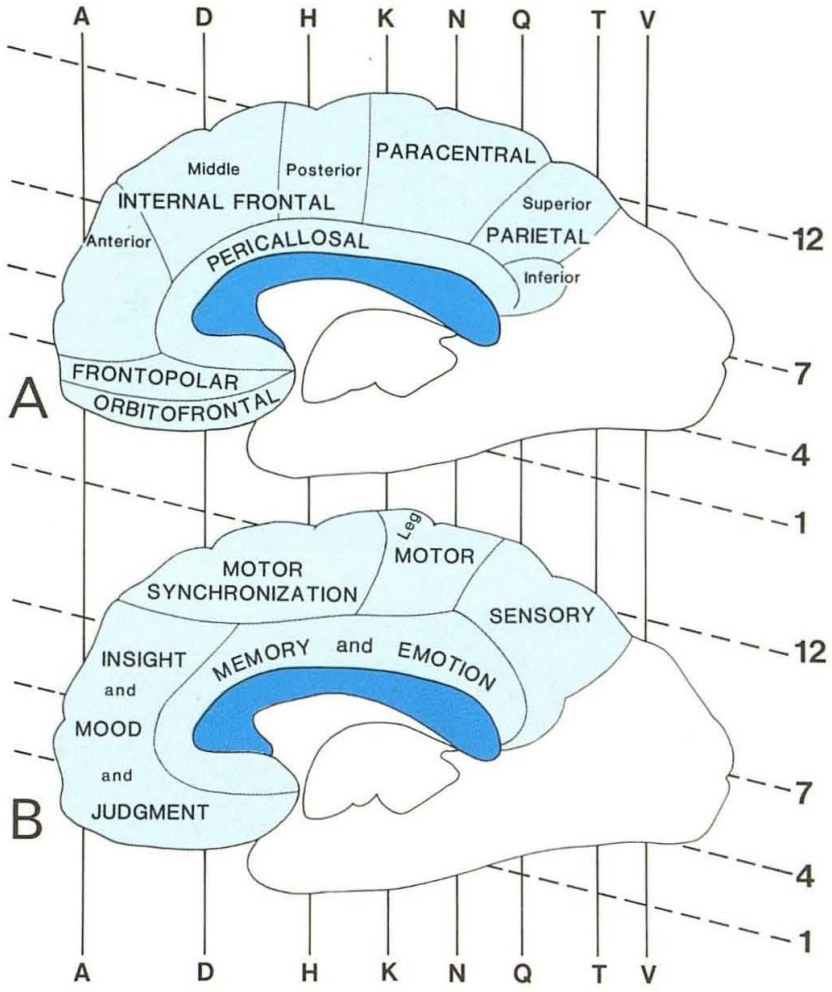
**Distal Basilar artery**

pupillary asymmetry, somnolence, peduncular hallucinations

# Carotid artery disease

## Clinical symptoms ★




**Correlation of CT Cerebral Vascular Territories with Function**

*Berman SA, et al. AJNR 1980; 1 :259-263*

# Carotid artery disease

## Diagnosis

★ ***Clinical exam*** *(general, including neurological exam, eye fundus, cervical bruits, peripheral pulses)*

★ ***Analyses*** *(include Rheumatoid Factor, ANA, VDRL, cholesterol fractions, triglycerides, HDL/LDL, Haematology, Urea, Creatinine)*

★ ***ECG*** *(Echocardiogram if embolism suspected)*

EEG ?

★ ***Cerebral CT scan*** *(at baseline and 7 days later to locate the lesion and exclude old lesions or haemorrhage/**MRI** (especially in posterior lesions)*

# Carotid artery disease

## Diagnosis

★ ***Carotid duplex scanning:*** *Velocity increases at the level of maximum stenosis and distal turbulences.*

***Angiography/CT Angio:*** *Includes cerebral parenchyma and selective imaging of supra-aortic trunks if there is clinical suspicion of lesions in the posterior territory.*

MR (MRI) ??

PET (positrons emission tomography) ??

SPECT (single positron emission tomography) ??

Trans-Cranial Doppler (TCD) ??


Sunday, 7 May 2017
The first medical diagnostic technology using artificial intelligence, tested on 1,500 patients at the Clínic de Barcelona and Clínico San Carlos hospitals in Madrid, proved to be correct in 91% of cases, according to the results released.

# Carotid artery disease

## Diagnostic imaging ★

Angiography

MR Angio

CT Angio

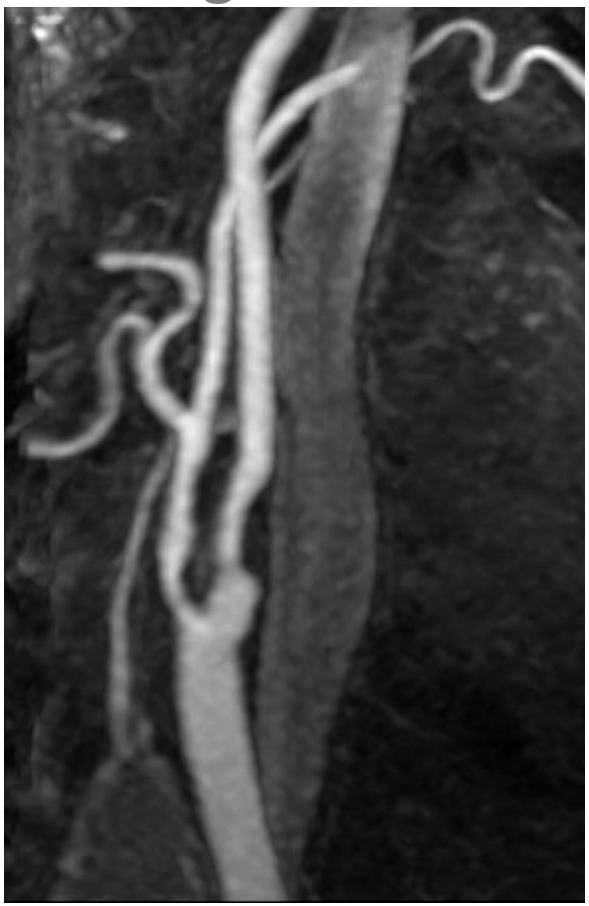
# *Carotid artery disease*

## Diagnostic imaging

ultrasonography

angiography

MR Angio



## *Carotid artery disease*

## Diagnostic imaging

spatial resolution (imaging diagnostic methods)

| Parameter | DSA | Multi-Detector Row CT Angiography | MR Angiography | US | Intravascular US |
|---|---|---|---|---|---|
| Matrix size | 1024 | 512 | ~512* | . . . | . . . |
| Frequency (MHz) | . . . | . . . | . . . | 2.5–10 | 20–40 |
| Section thickness (mm) | . . . | 0.5–1.0 | ≥1.0* | . . . | . . . |
| Spatial resolution (mm) | <0.5† | ~0.5† | >0.5† | 0.15–0.6‡ | <0.1‡ |

*Nighoghossian N, et al. Stroke. 2005;36:2764-2772*

## *Carotid artery disease*
## Diagnostic imaging

spatial resolution (imaging diagnostic methods)

| | Angiography | Angio CT | Angio MR | Eco | IVUS |
|---|---|---|---|---|---|
| **spatial resolution** | <0.5mm | ~0.5 | >0.5 | 0.15-0.6 | <0.1 |

*Nighoghossian N, et al. Stroke. 2005;36:2764-2772*

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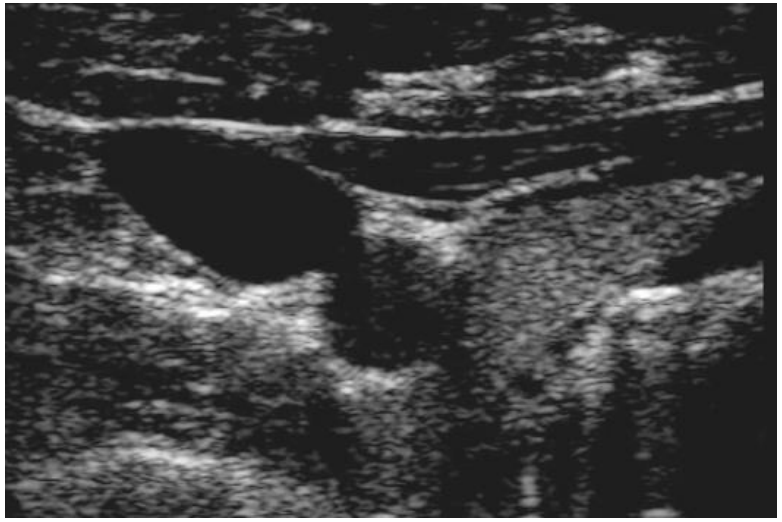
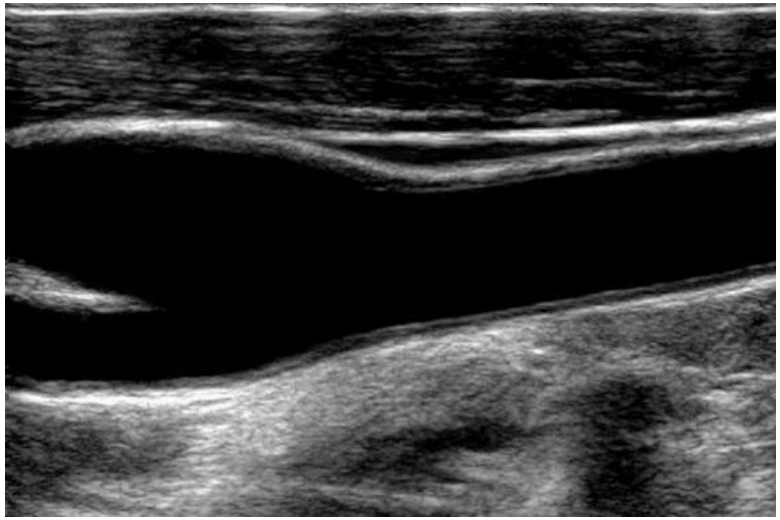
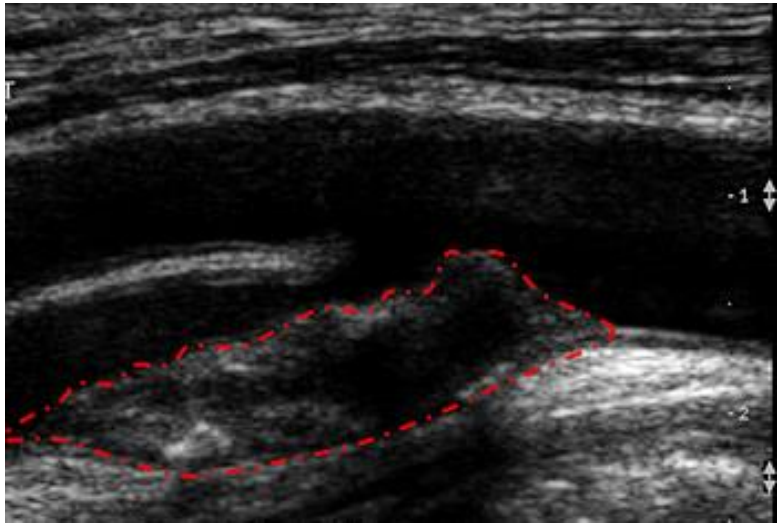
## Diagnostic imaging

carotid duplex scanning



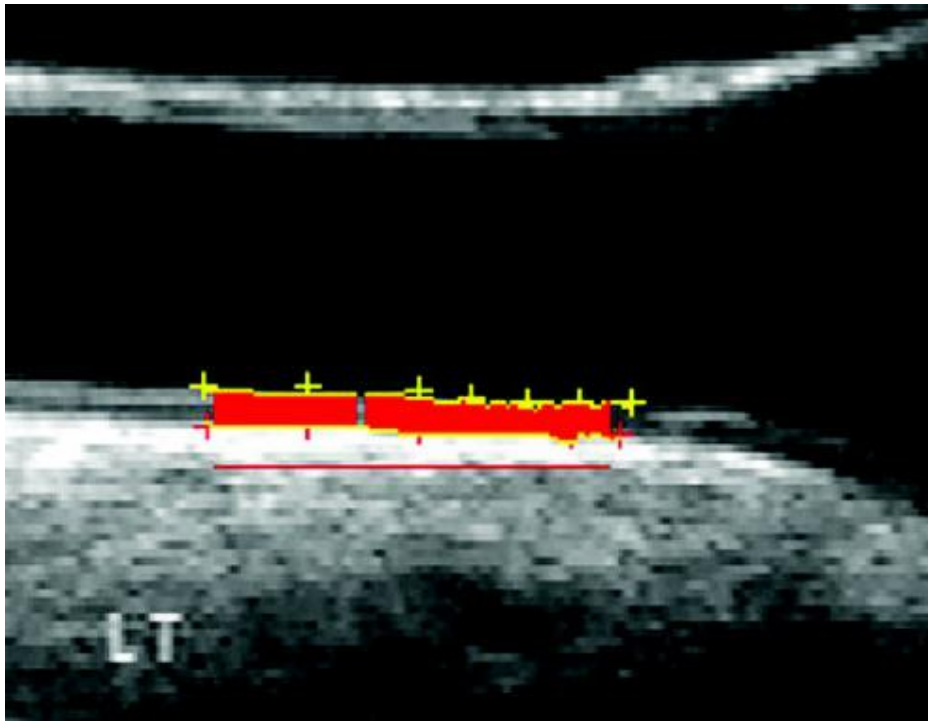


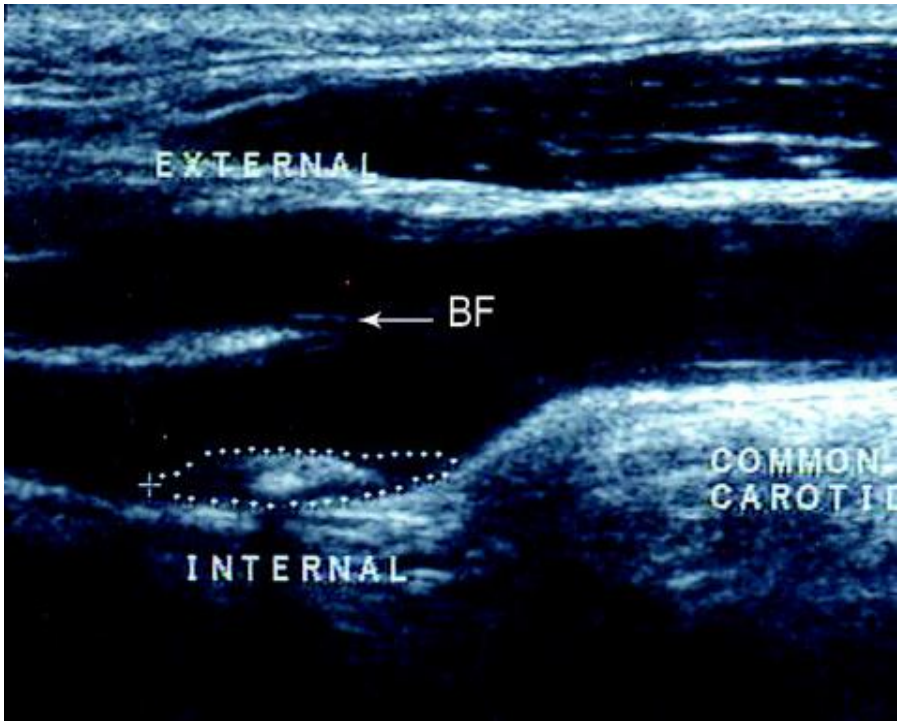


# *Carotid artery disease*

## Diagnostic imaging

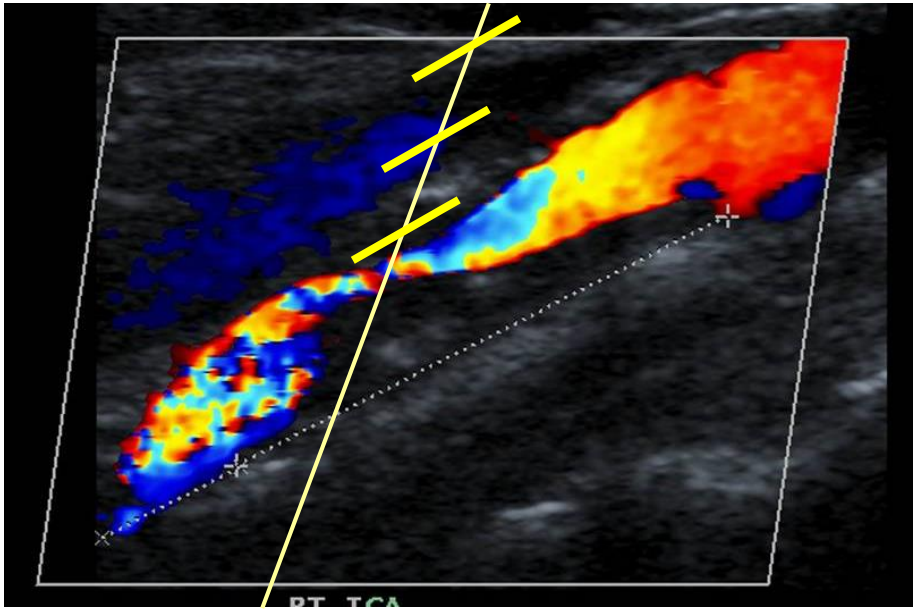
ultrasonography

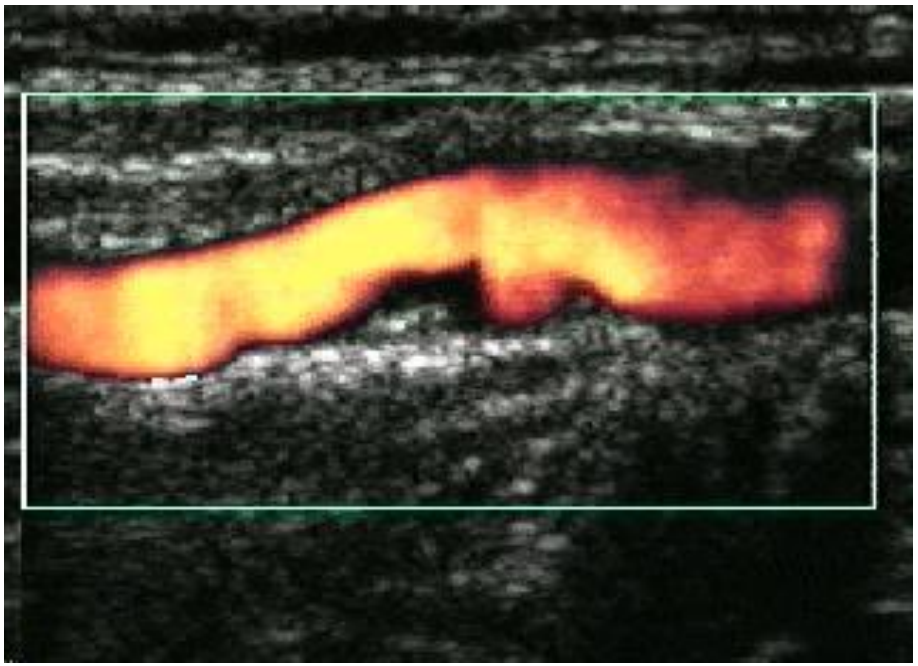


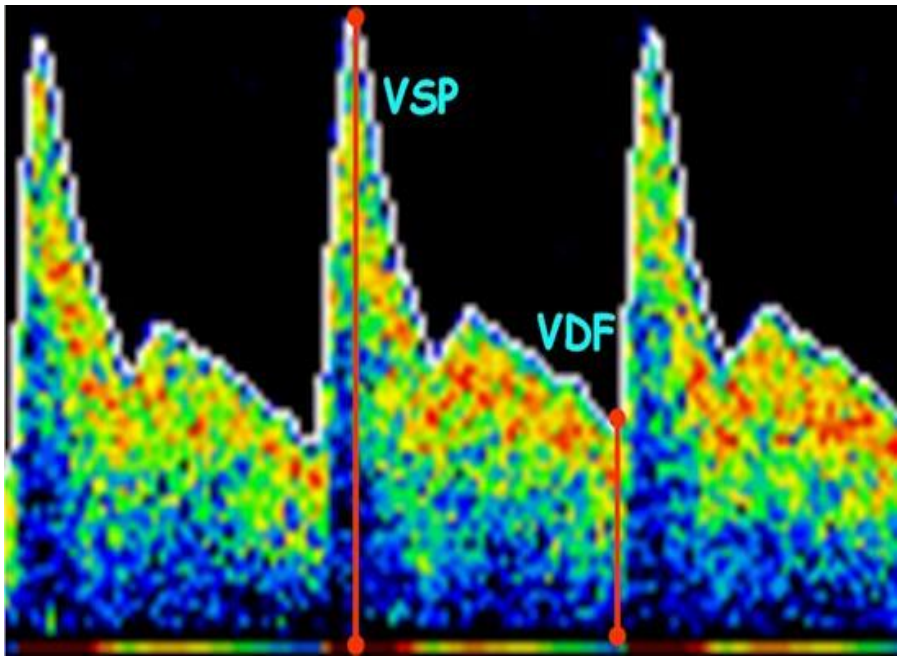




*Riccio SA et al. Cardiovasc Ultrasound. 2006 Nov 13;4:44.*

# Carotid Artery Disease





# Carotid artery disease

## Diagnostic imaging

continuity principle ★

**flow (G) = section (S)↓ x velocity (V)↑**

diagnostic criteria (University of Washington)

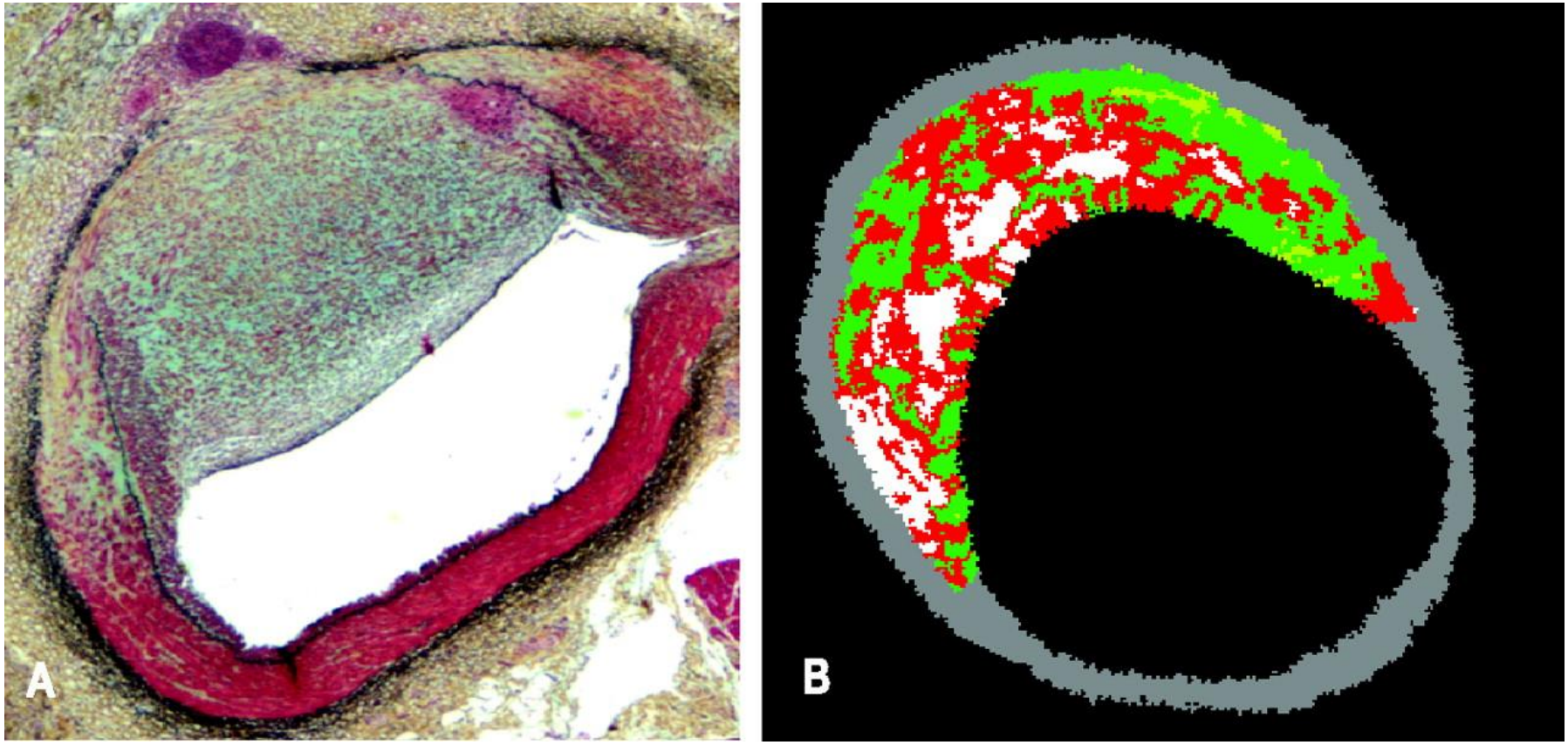
| | STENOSIS | WAVE | DESCRIPTION |
|---|---|---|---|
| | A Normal | PSV <120 | lineal waveform |
| | B 1-15% | PSV <120 | minimal spectral broadening |
| | C 16-49% | PSV<120 cm/s | spectral broadening |
| ★ | **D 50-79%** | **PSV>120 cm/s**<br>**EDV<130 cm/s** | **spectral broadening** |
| | D+ 80-99% | PSV>120 cm/s<br>EDV>130 cm/s | |

PSV: peak systolic velocity
EDV: end diastolic velocity
spectral broadening: turbulences

# *Carotid artery disease*

## Diagnostic imaging

Intravascular ultrasonography (IVUS)

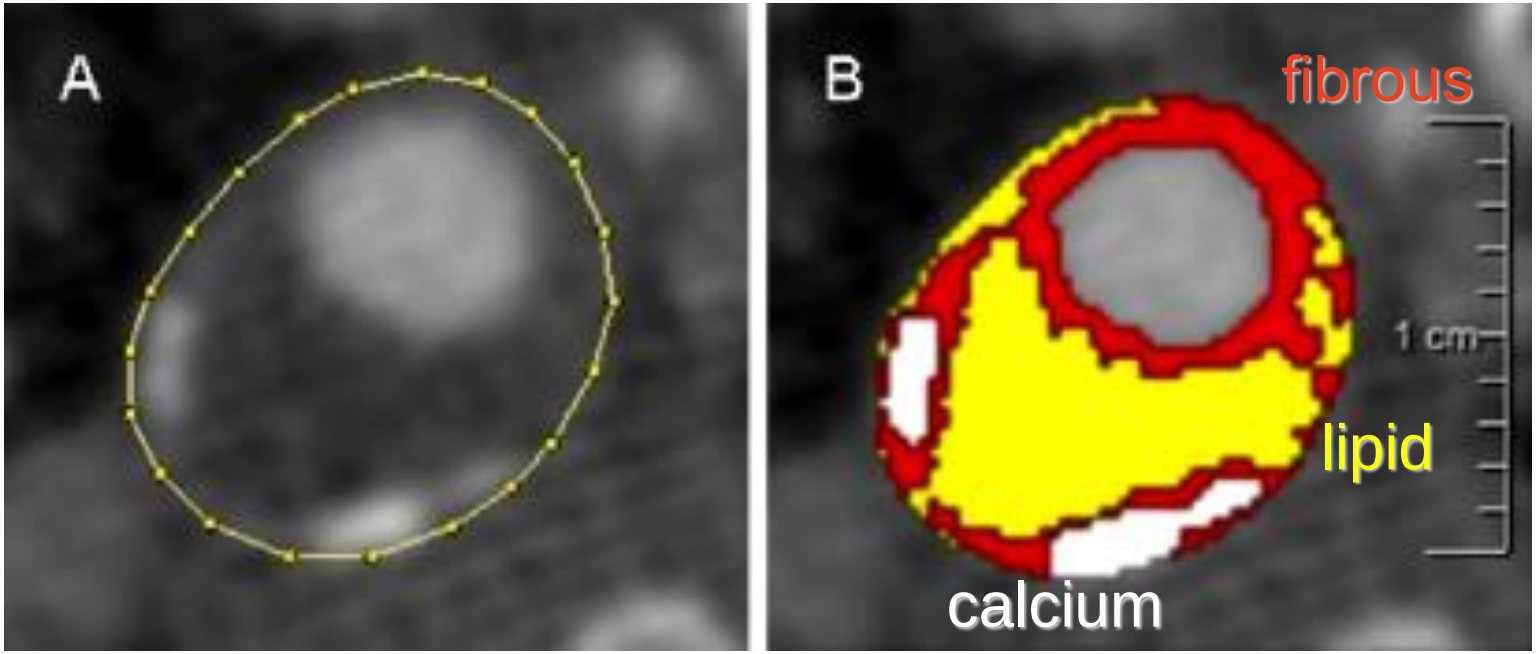



*Granada JF et al. Arterioscler Thromb Vasc Biol. 2007;27:387-393.*

# *Carotid artery disease*

## Diagnostic imaging

computerized tomography (CT)




calcification >130 HU; fibrous tissue 60-130 HU; lipid core <60 HU

*Rozie ES et al. Eur Radiol (2009) 19: 2294–2301*

# *Carotid artery disease*

## Treatment ★

***objective**: stroke prevention*

***background**: annual incidence of stroke after:*

| | |
|---|---|
| ***previous stroke*** | ***9-10%*** |
| ***TIA*** | ***6-7%*** |
| ***asymptomatic stenosis (>70%)*** | ***3-5%*** |

**medical treatment**

antiplatelets (aspirin, ticlopidine, etc.)

anticoagulants

**surgical treatment:**

carotid endarterectomy

carotid stenting

# *Carotid artery disease*

## Topics

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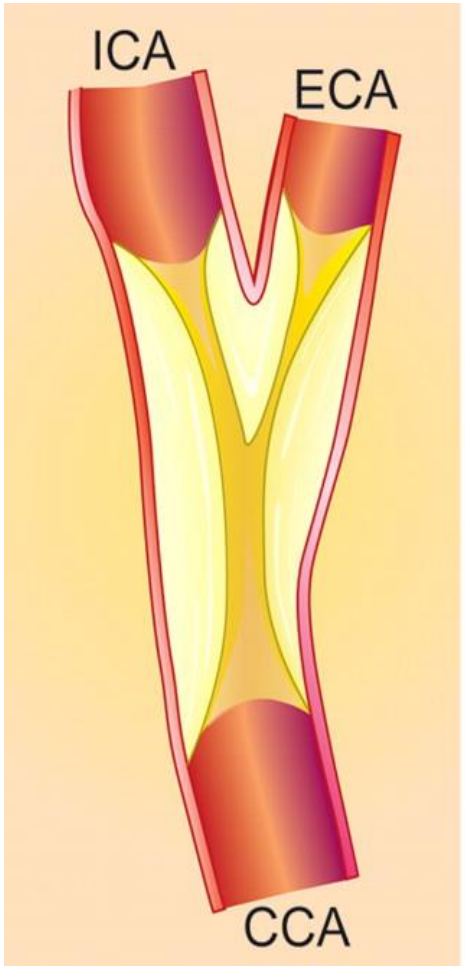
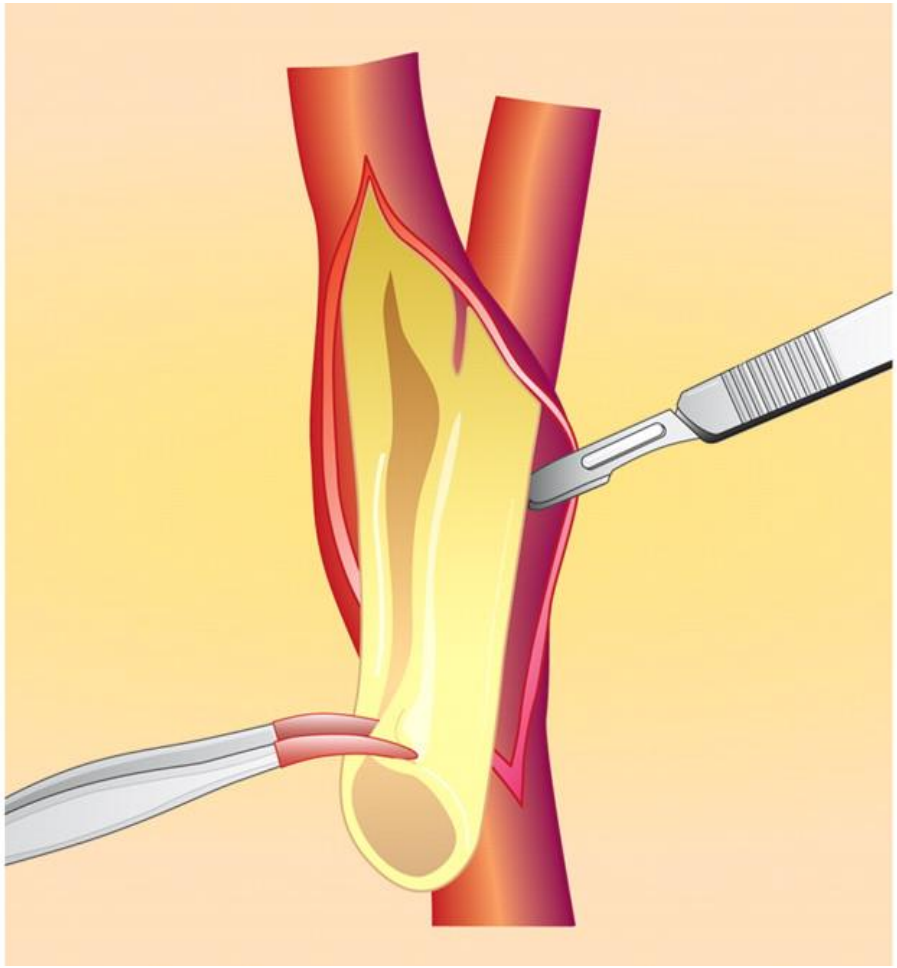
- clinical trials: carotid stenting vs endarterectomy

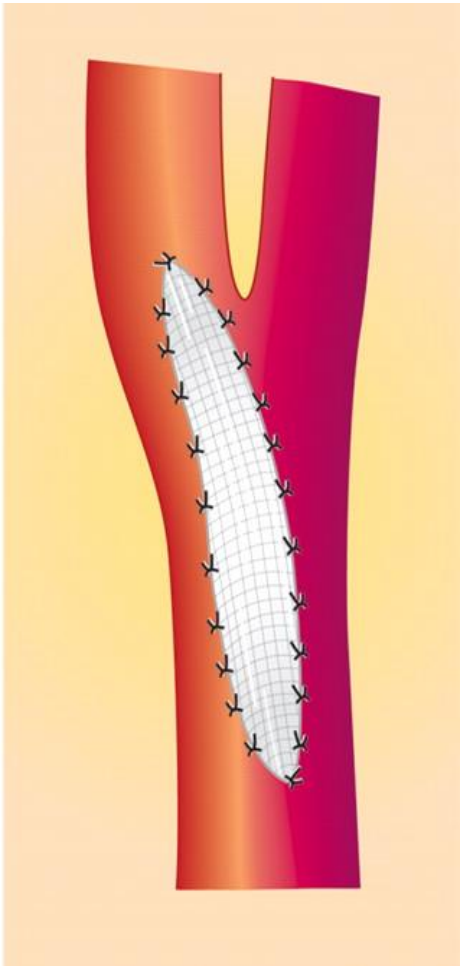
# *Carotid artery disease*

## Treatment (endarterectomy) ★

endarterectomy

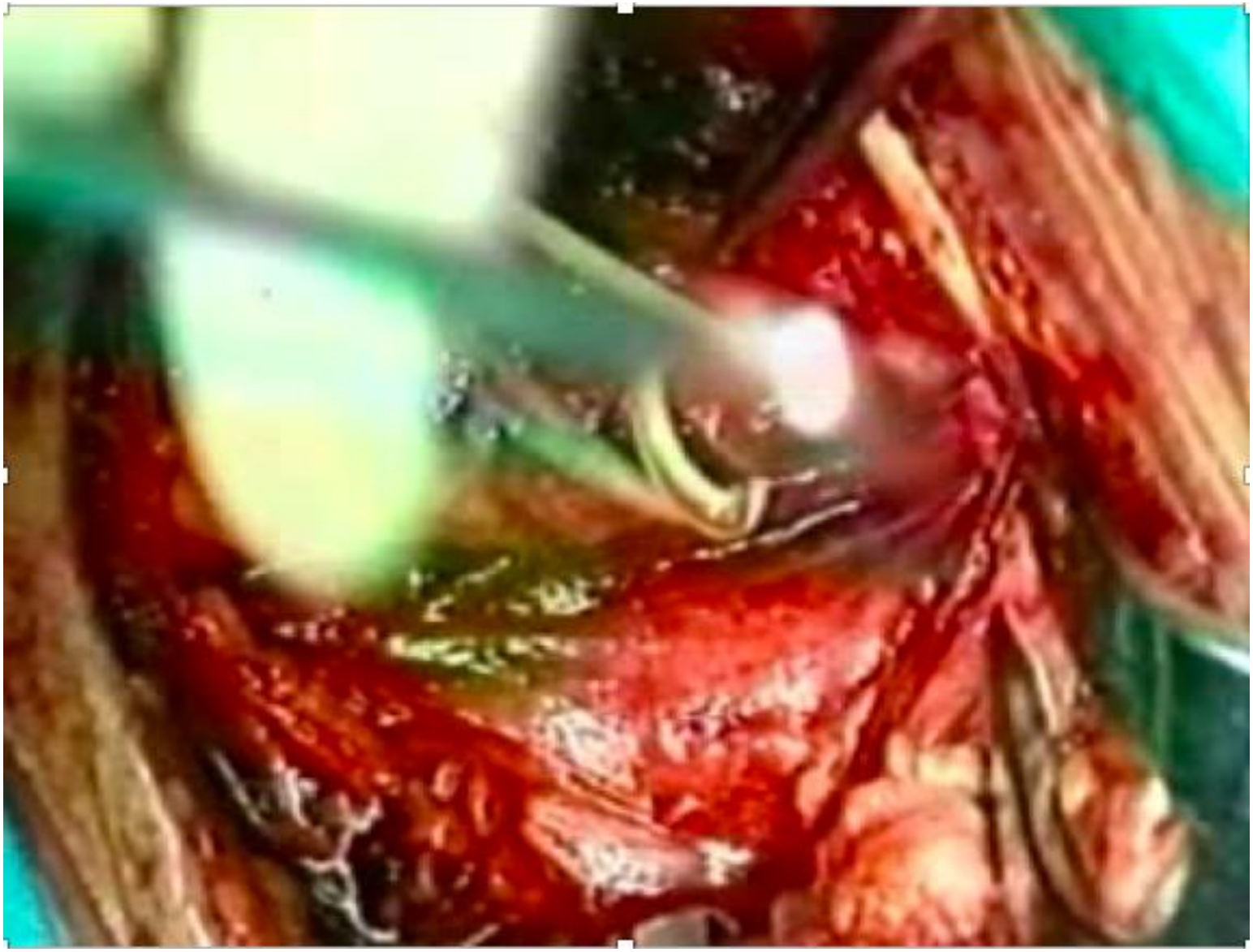




# *Carotid artery disease*

## Treatment (endarterectomy)



# *Carotid artery disease*

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# Carotid artery disease

## Intraoperative monitoring ★

***Objectives:***

*Assessment of cerebral perfusion during carotid clamping*

*indication of intraluminal shunt: 15% cases*

*1) Locoregional anaesthesia vs general anaesthesia*

*2) Stump pressure. Shunt placement if stump press <25 mm Hg*

*3) EEG*

*4) CT brain mapping*

*5) Transcranial doppler (TCD) (?)*

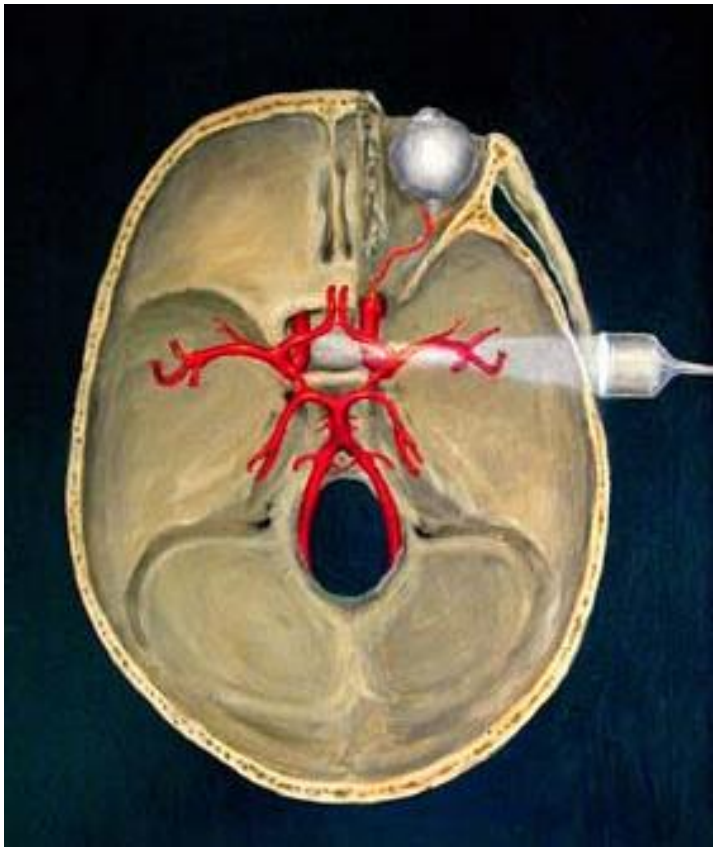
*6) Cerebral oximetry (threshold value: inter-hemispheric difference >20%)*

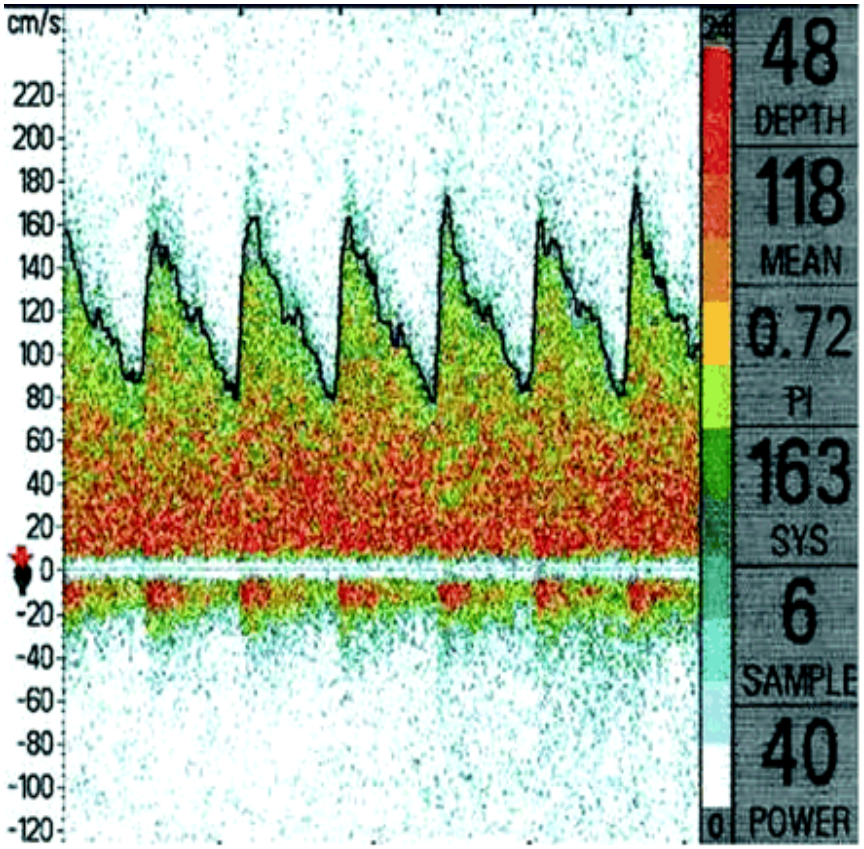
*6) Motor and Somatosensory Evoked Potentials (high sensitive, low specificity)*

# *Carotid artery disease*

## Intraoperative monitoring

Transcranial Doppler (TCD)

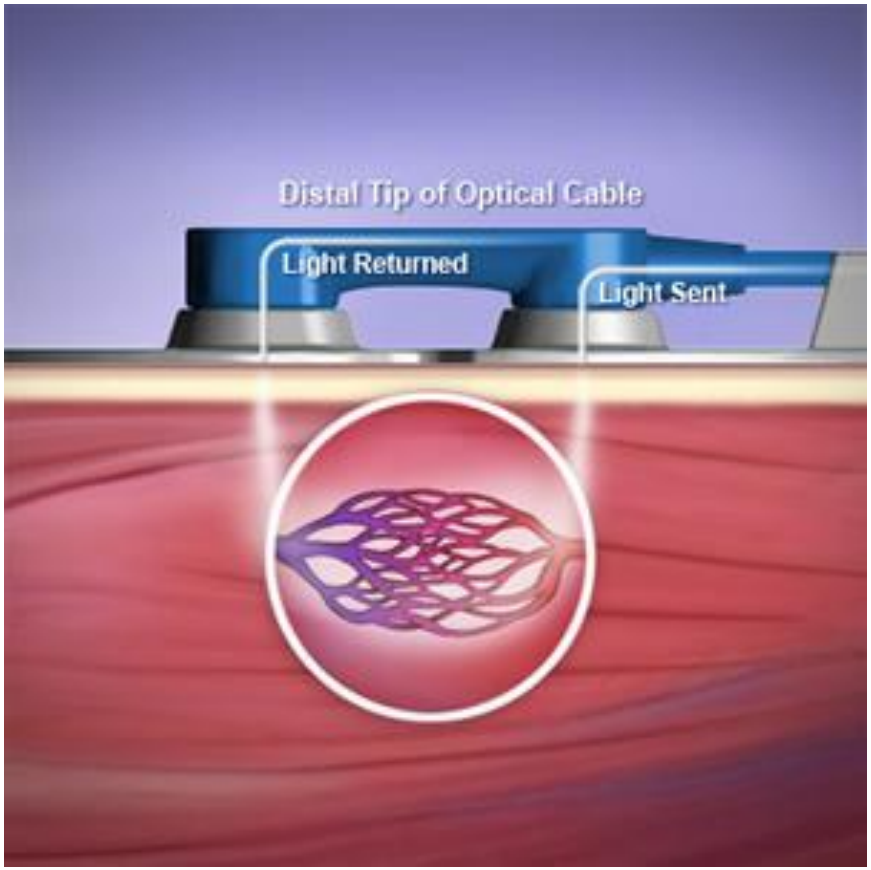


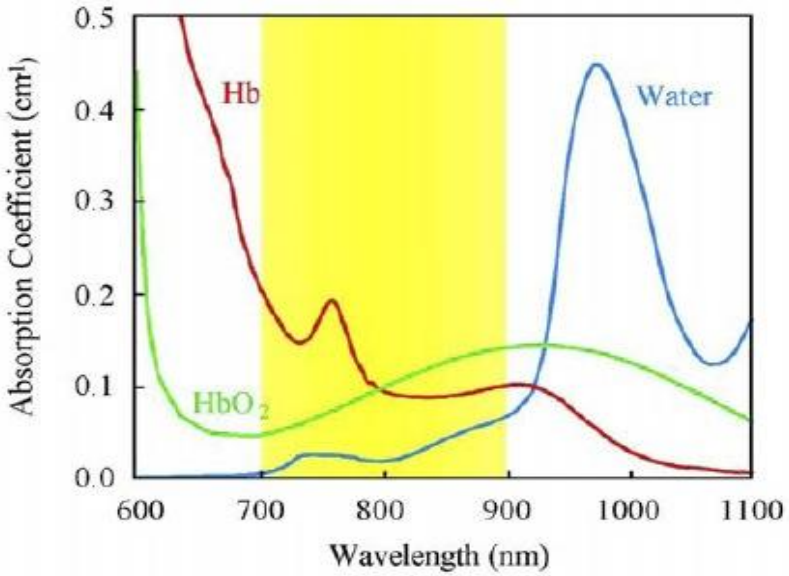


# *Carotid artery disease*

## Intraoperative monitoring

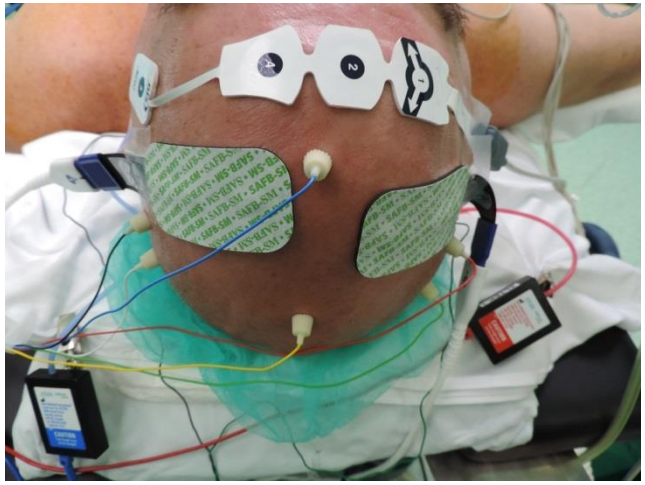
transcutaneous oximetry (NIRS)

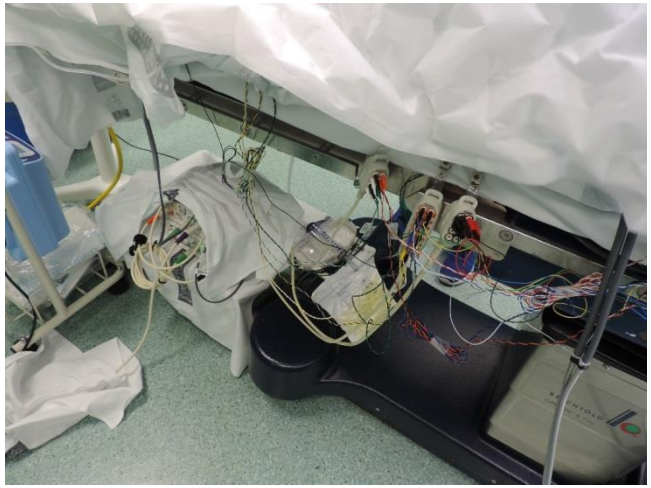



# Carotid artery disease

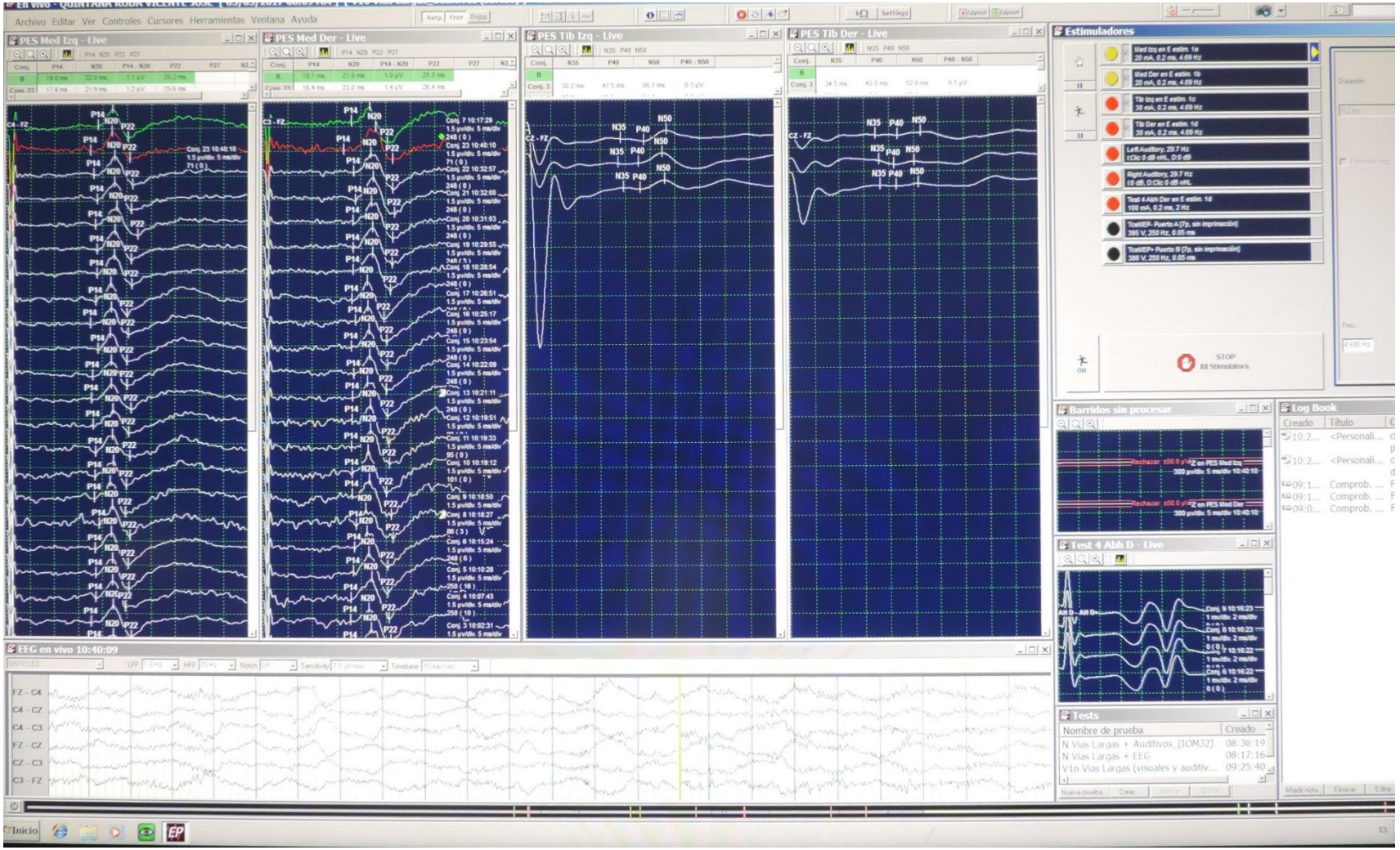
## Intraoperative monitoring (ESSP and MEP)





# Carotid artery disease

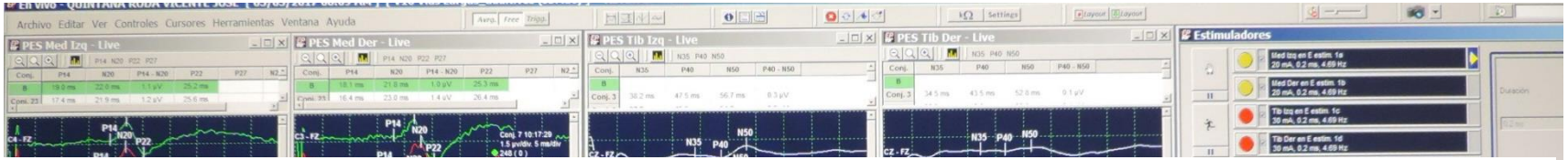
## Intraoperative monitoring (ESSP and MEP)




*Thirumala PD, et al. Neurol Res. 2016;38(8):698-705.*

# Carotid artery disease

## Intraoperative monitoring (ESSP and MEP)

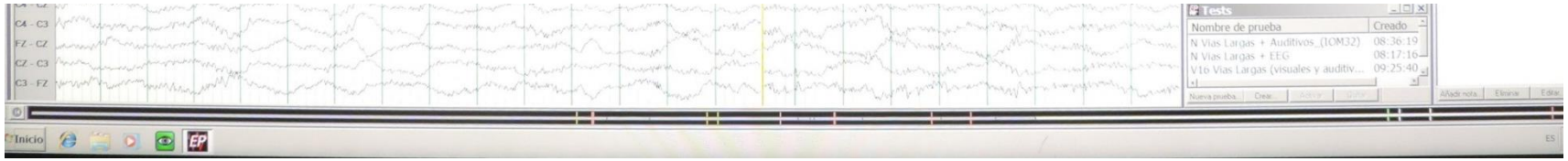



**ESSP** (Evoked SomatoSensory Potentials): cubital and median nerves

INTRAOPERATIVE ALERT: Amplitude decrease in ESSP>50% and/or increase in latencies

**MEP** (Motor Evoked Potentials): transcranial electric stimulation (4 limbs)

INTRAOPERATIVE ALERT: absent MEP.

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# *Carotid artery disease*

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# Carotid artery disease

## Treatment (clinical trials: symptomatic patients)

★***North American Symptomatic Carotid Endarterectomy Trial (NASCET)***

3,000 patients (5 years)
carotid EA vs medical treatment
grades (stenosis 30-69% and 70-99%)
**results:** ***surgical morbimortality 5%***

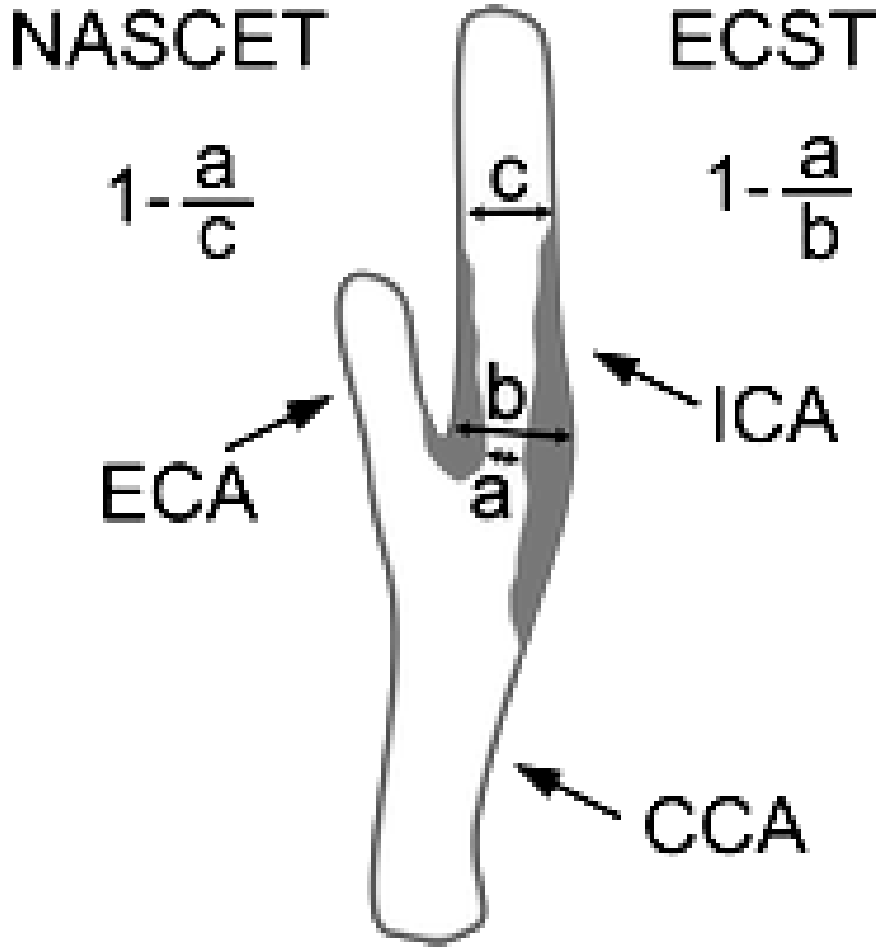
***Stroke: 7% (surgery) vs 24% (medical) 18 months follow-up in the > 70% stenosis group***

★***Medical Research Council European Carotid Surgery Trial (ECST)***

2,518 patient (10 years)
carotid EA vs medical treatment
grades (stenosis 10-29%, 30-69% and 70-99%)
**results:** ***surgical morbimortality 7.5%***
***carotid EA: decrease in stroke risk 6x at 3 years***

# Carotid artery disease

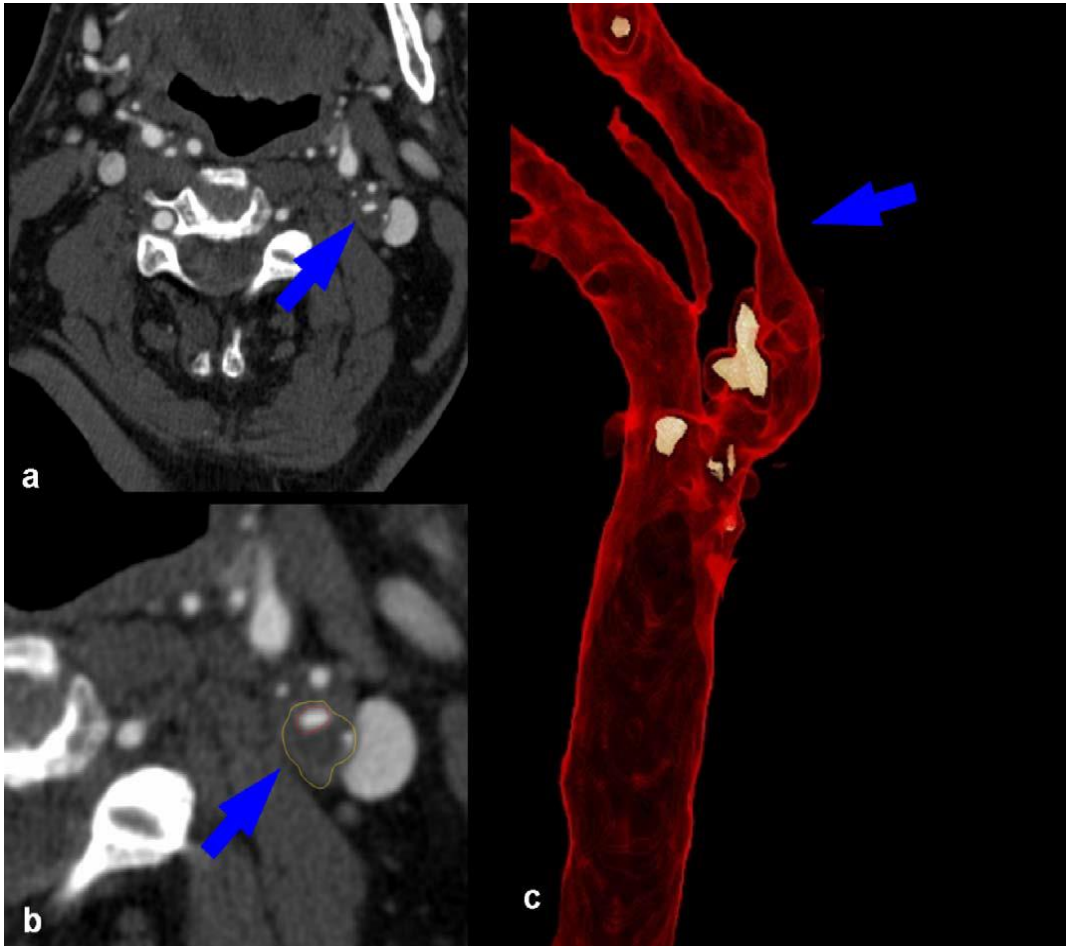
## Treatment (ICA stenosis: measurement)




Saba L. European Journal of Radiology 76 (2010) 42–47

# Carotid artery disease

## Treatment (ICA stenosis: measurement)

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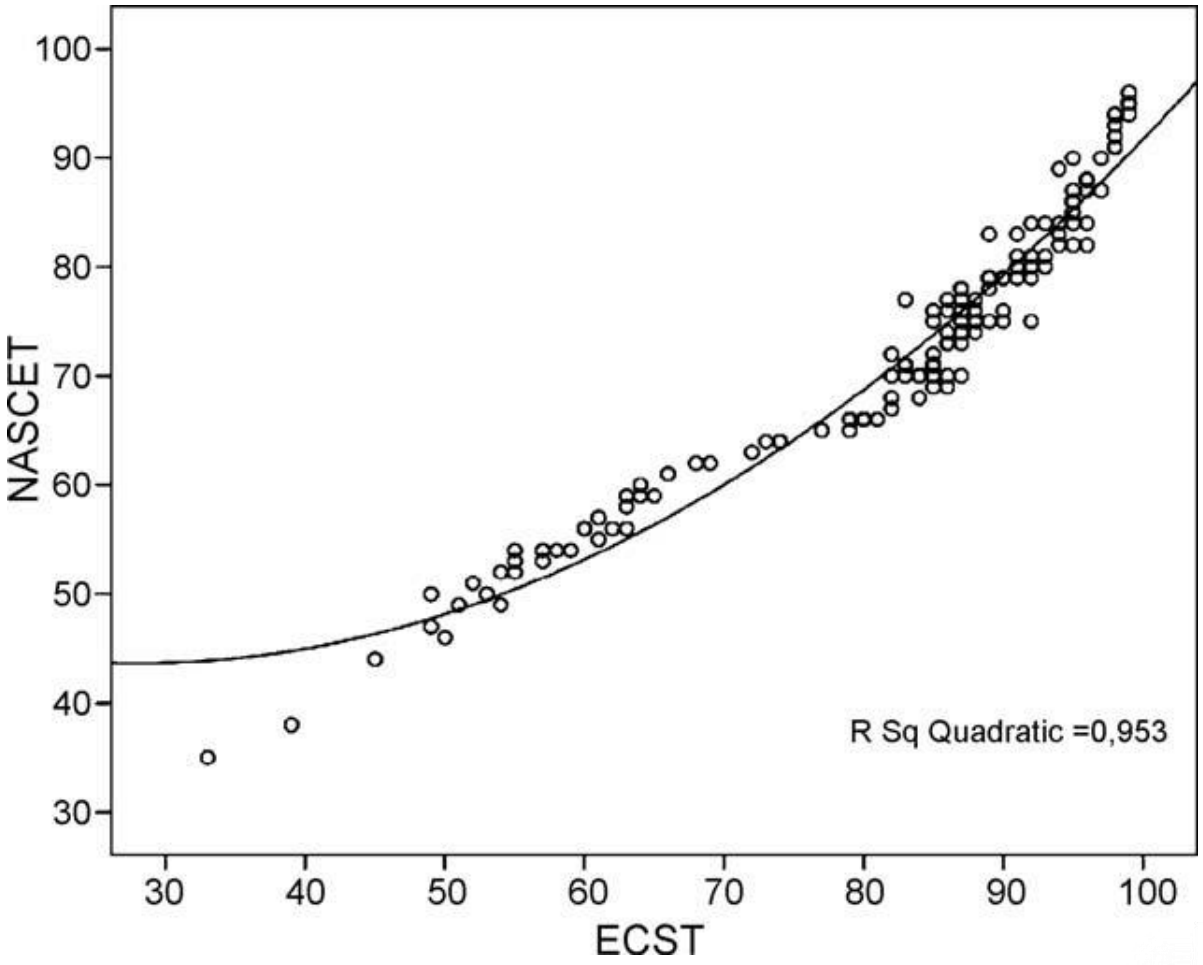
# *Carotid artery disease*

## Treatment (ICA stenosis: measurement)




*Saba L. European Journal of Radiology 76 (2010) 42–47*

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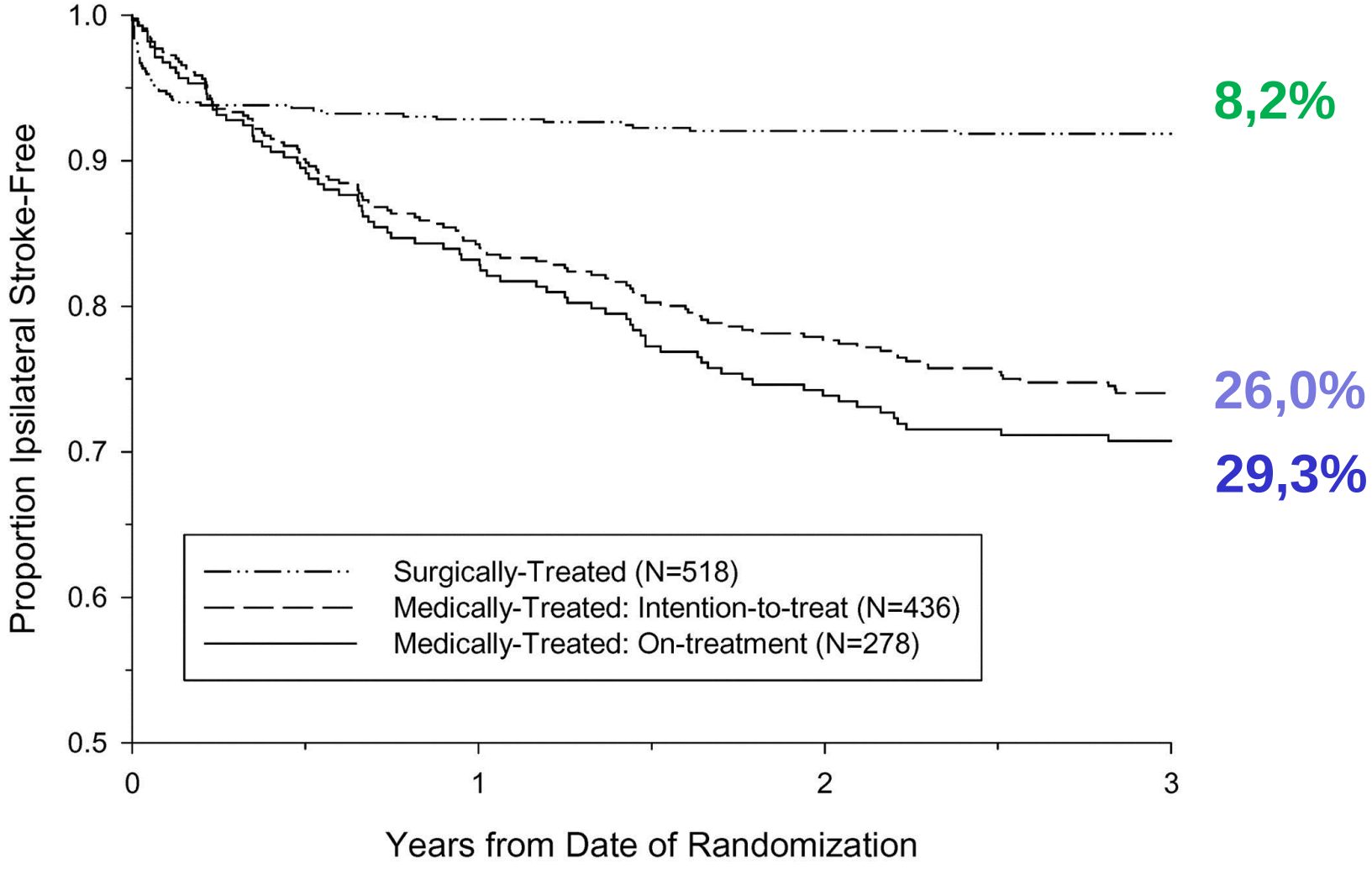
# Carotid artery disease

## Treatment (NASCET & ECST combined results) ★




*Fox AJ, et al. AJNR Am J Neuroradiol 2005; 26:2086–2094*

## *Carotid artery disease*

## Treatment (NASCET & ECST combined results) ★

**Were NASCET and ECST patients under the best medical treatment?**

**ECST2**
**CREST2**

*Fox AJ, et al. AJNR Am J Neuroradiol 2005; 26:2086–2094*

# Carotid artery disease

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- clinical trials: carotid stenting vs endarterectomy

# Carotid artery disease

## Treatment (clinical trials: asymptomatic) ★

★ ***Asymptomatic Carotid Atherosclerosis Study (ACAS)***

1,662 patients

Carotid stenosis > 60%

*Results: operative morbimortality 2.3%*

***Stroke/risk of death at 5 years:***

***5.1% (surgery) vs 11% (medical treatment)*** ??

★ ***Asymptomatic Carotid Surgery Trial (ACST)***

3,120 patients

Carotid stenosis > 60%

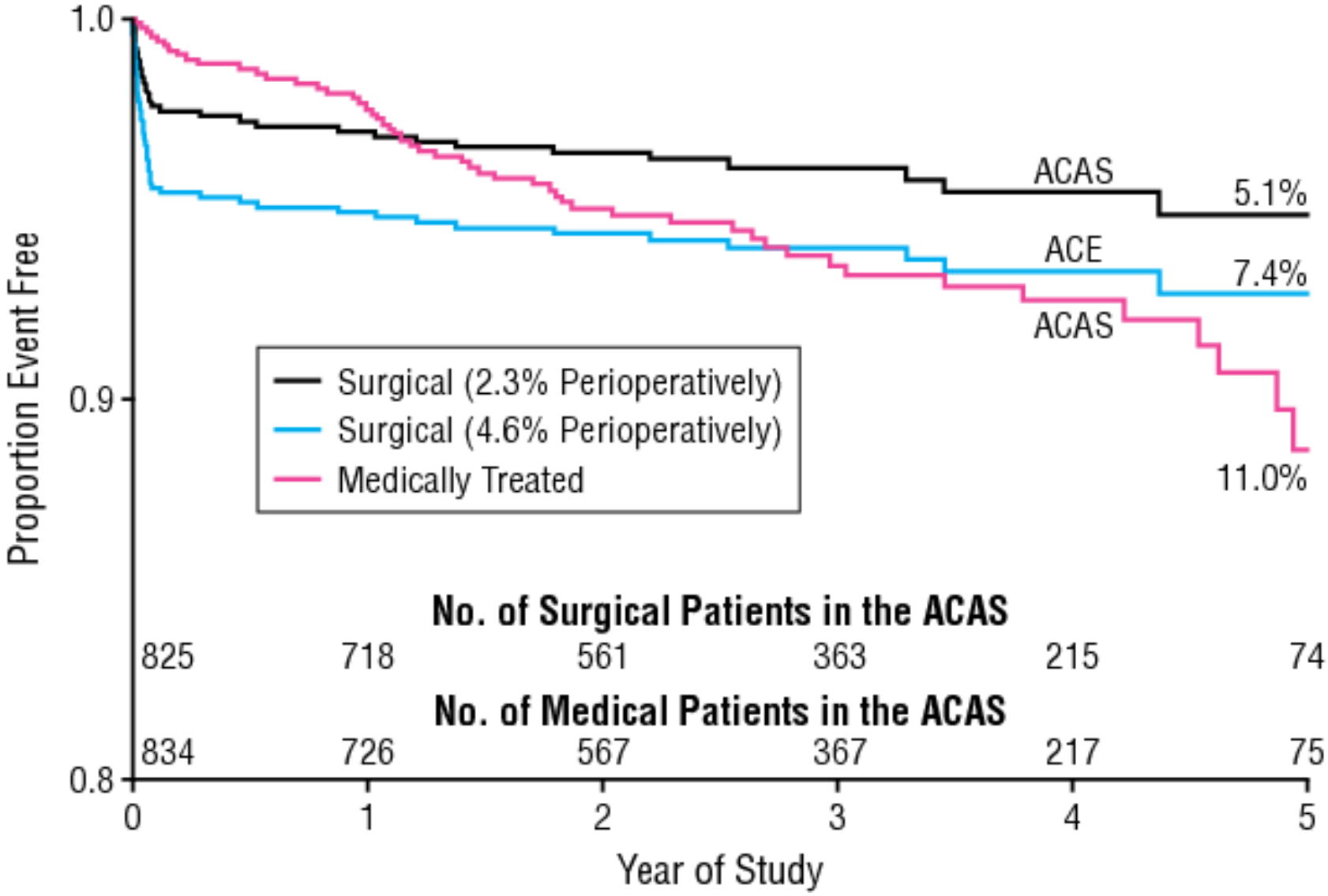
*Results: operative morbimortality 3.1%*

***Stroke/risk of death at 5 years:***

***3.8% (surgery) vs 11% (medical treatment)*** ??

# Carotid artery disease

## Treatment (clinical trials: asymptomatic) ★



## *Carotid artery disease*

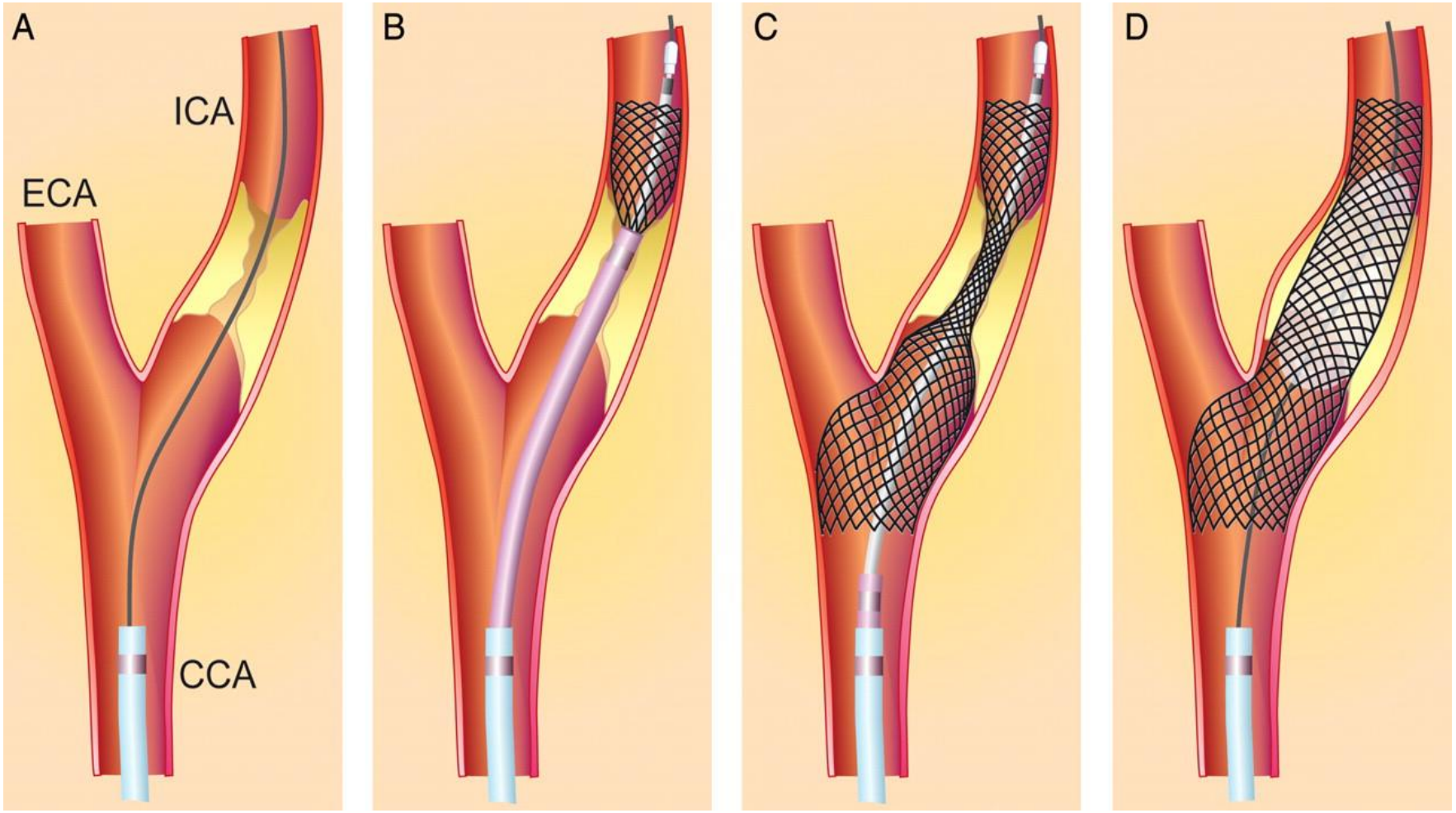
### Treatment (clinical trials: asymptomatic) ★

**Were ACAS and ACST patients under the best medical treatment?**

**ACT-1 (stopped)**
**SPACE-2 (stopped)**
**ACST-2 (ongoing)**

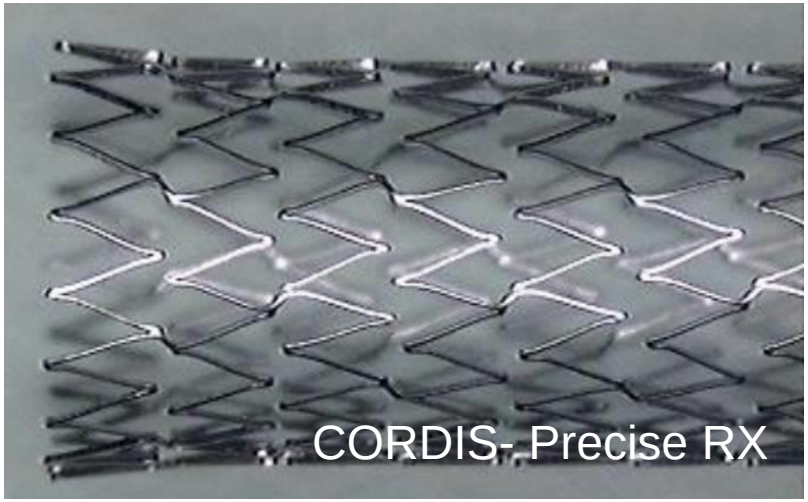
# Carotid artery disease

## Treatment (*stent*) ★

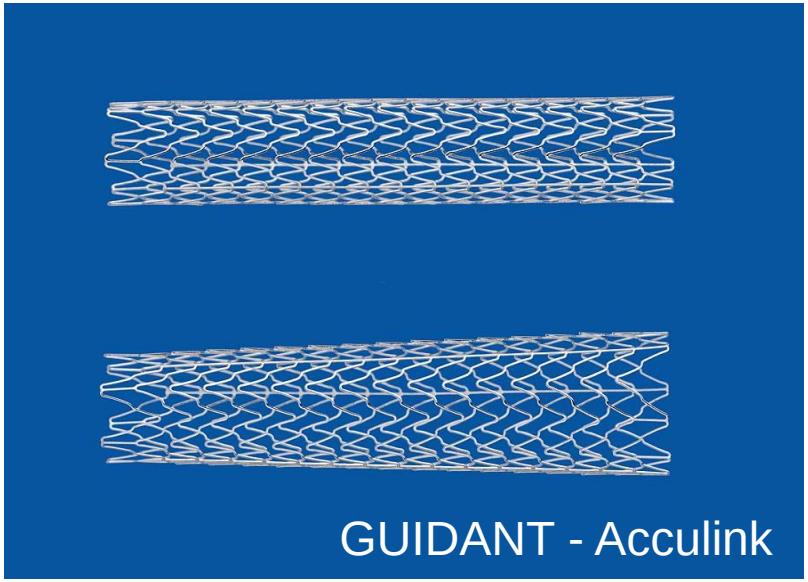


# Carotid artery disease

## Treatment (*stent*)





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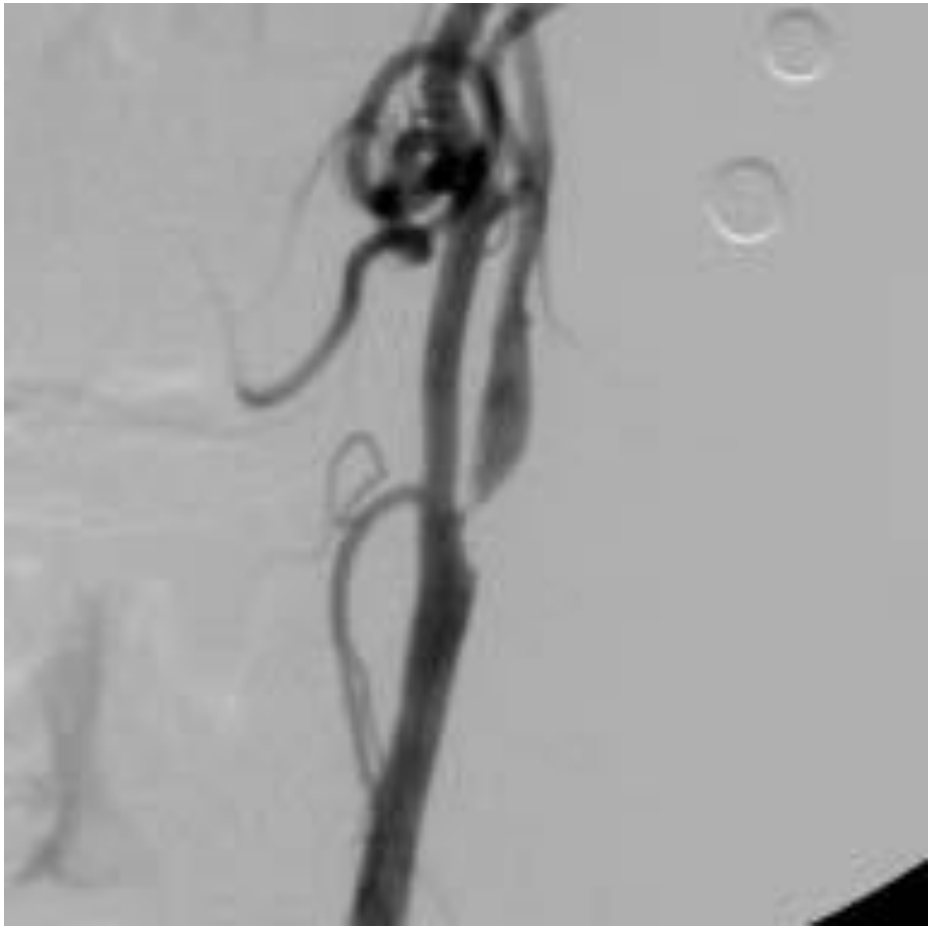
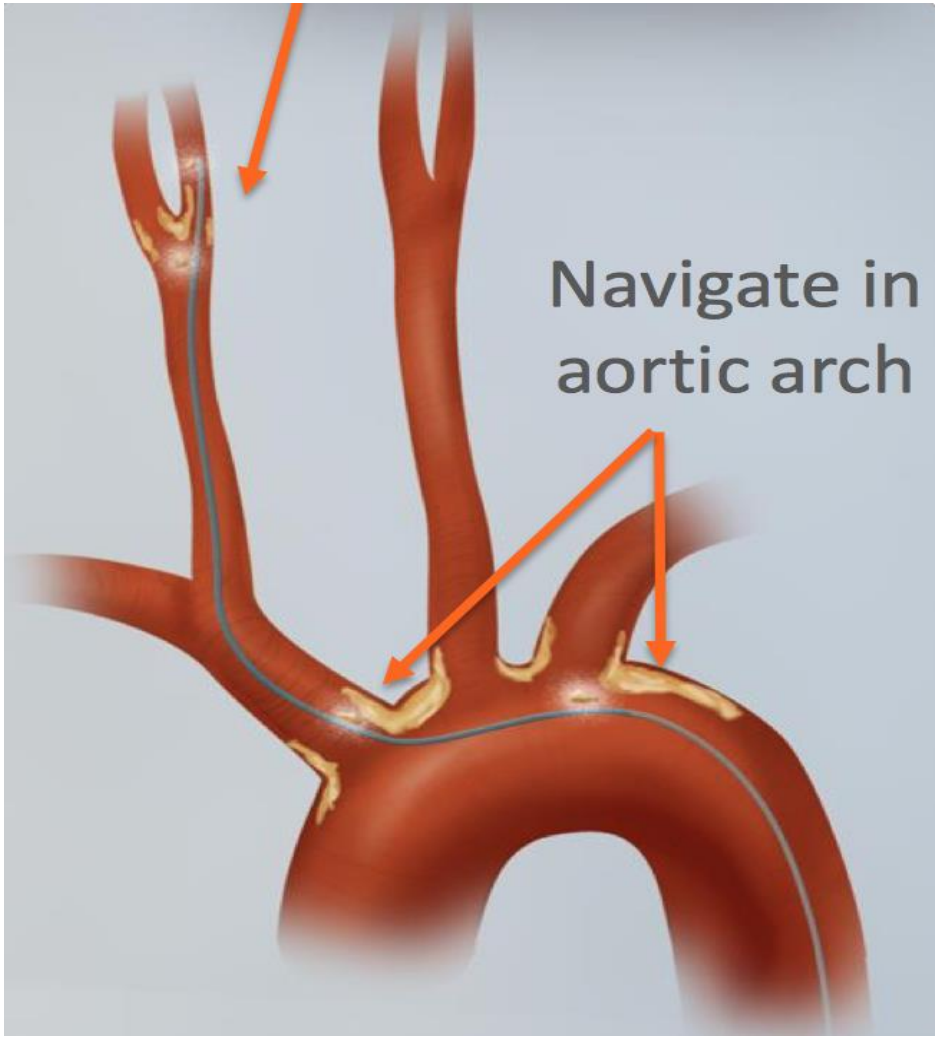
# *Carotid artery disease*

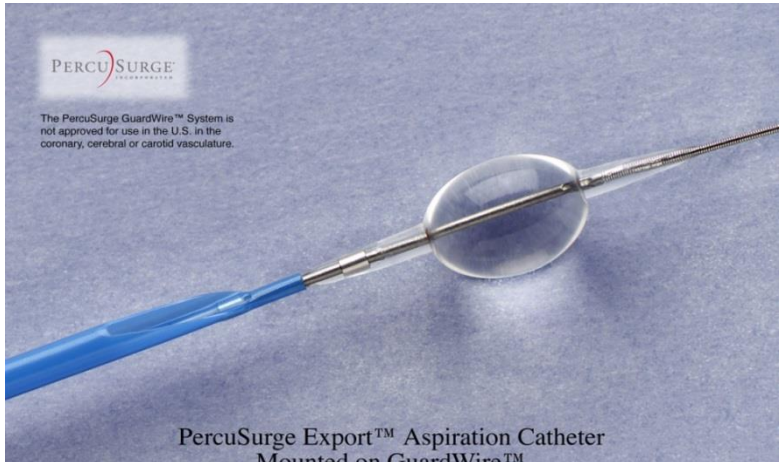
## Treatment (*stent*)

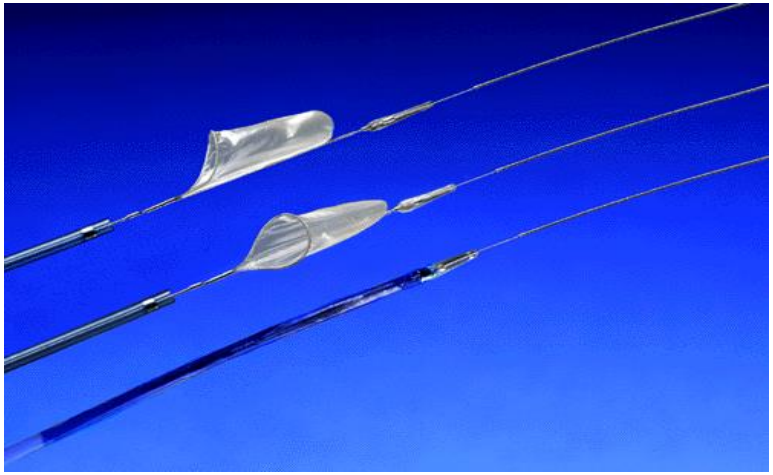


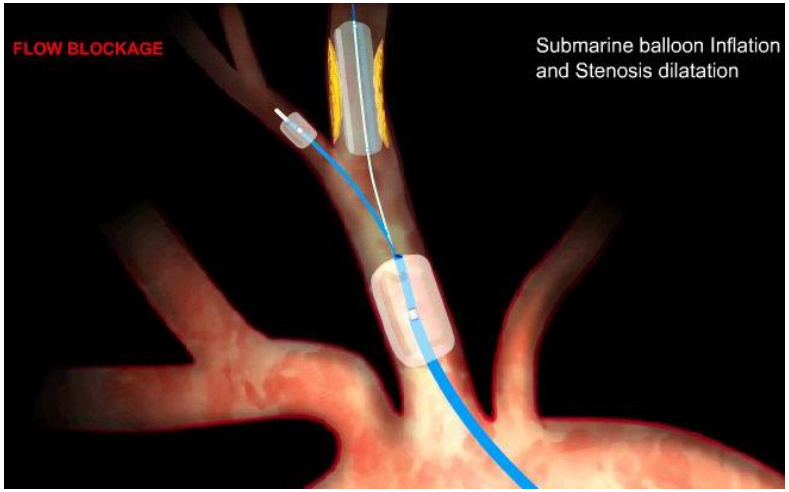


# *Carotid artery disease*

## Treatment (*stent*/protective filter)

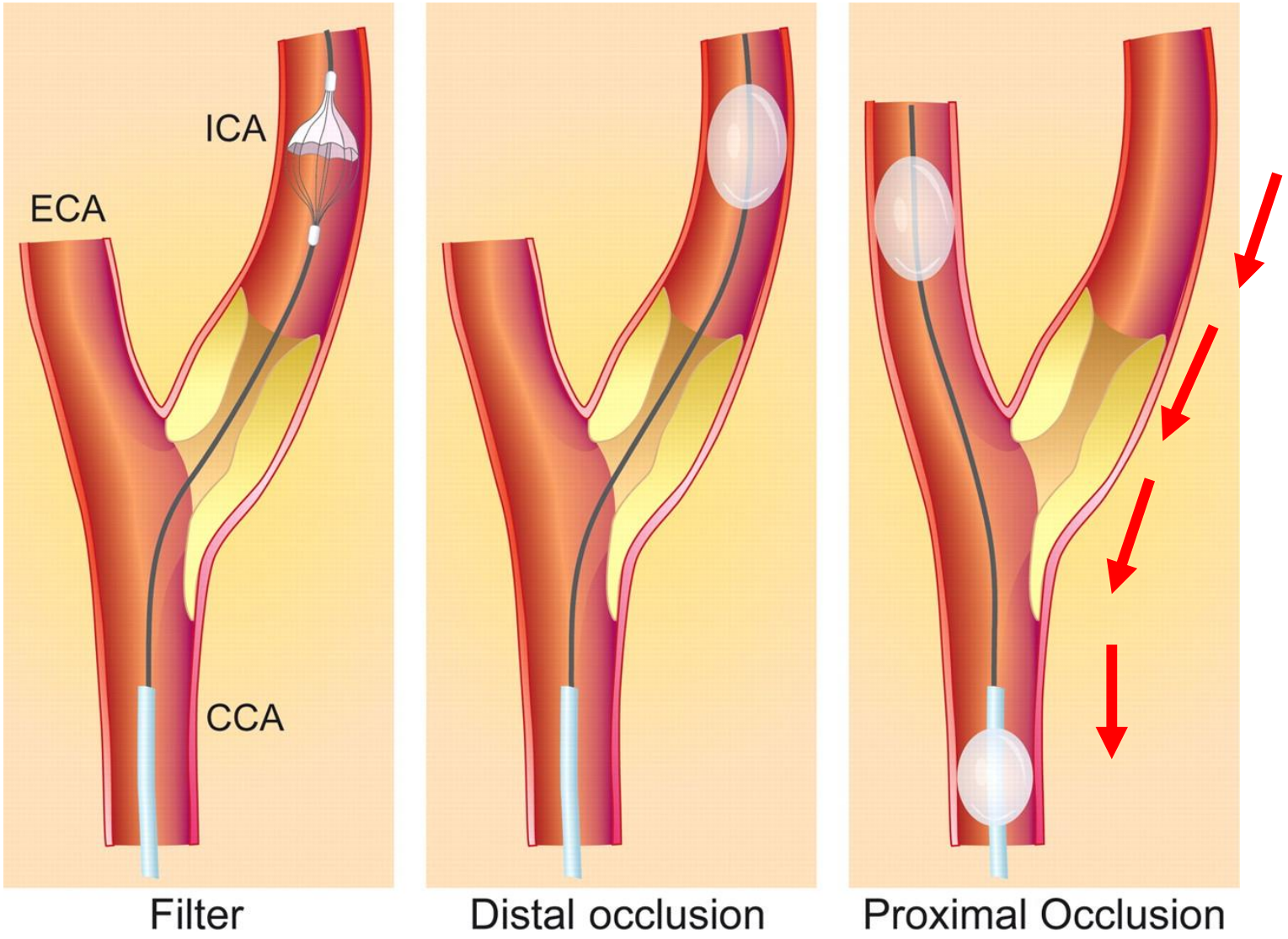




# Carotid artery disease

## Treatment (*stent*)

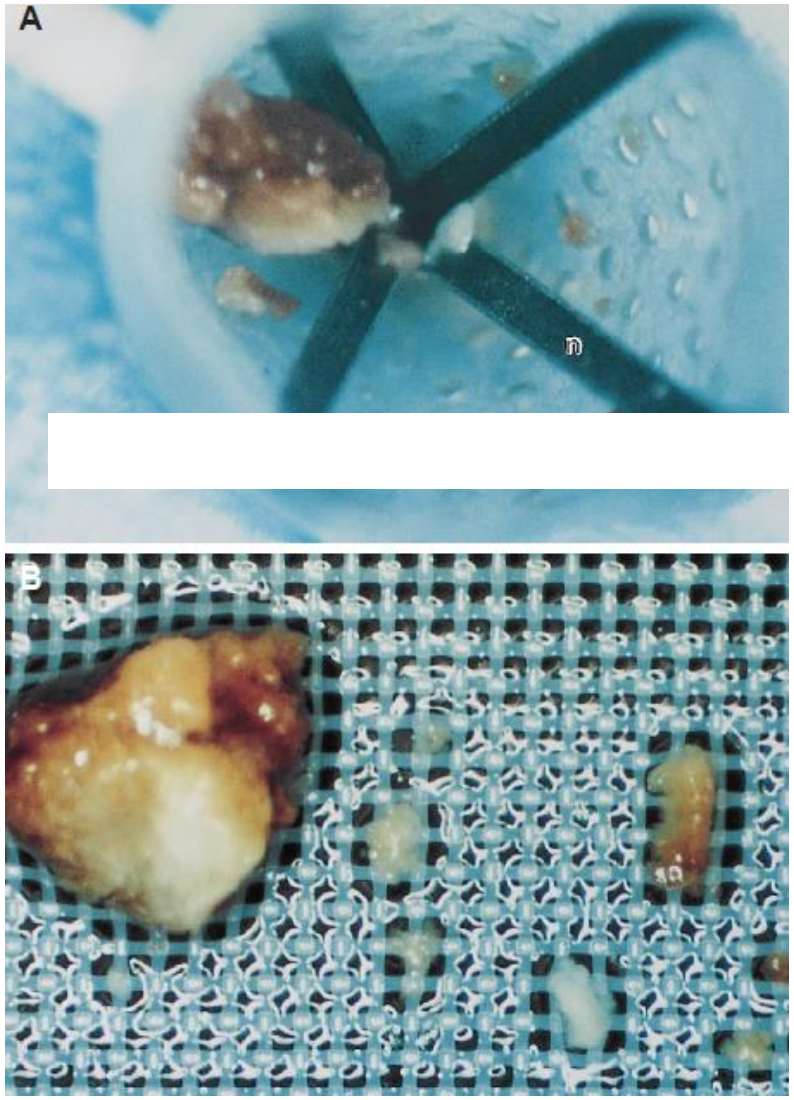


# *Carotid artery disease*

## Treatment (carotid *stent*)

# *Carotid artery disease*

## Treatment (*stent vs* endarterectomy)



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# Carotid artery disease

## Treatment (*stent vs* endarterectomy) ★

- **SPACE** (Stent-supported Percutaneous Angioplasty of the Carotid Artery vs Endarterectomy)

  1,183 patients (symptomatic ICA stenosis)

  ***stroke** (30 days): **6.8% (stent) vs 6.3% (CEA) nonsignificant***
- **EVA-3S** (Endarterectomy vs Angioplasty in Patients with Symptomatic Severe Carotid Stenosis)

  527 patients (asymptomatic ICA stenosis)

  ***stroke** (30 days): **9.6% (stent) vs 3.9% (CEA)***
- ***CREST** (Carotid Revascularization Endarterectomy vs Stenting Trial)*

  2,502 patients ICA stenosis > 50% symptomatic or > 70% asymptomatic.

  ***stroke** (30 days): **4.1% (stent) vs 2.3% (CEA)***
- ***ICSS** (International Carotid Stenting Study)* 1,713 patients

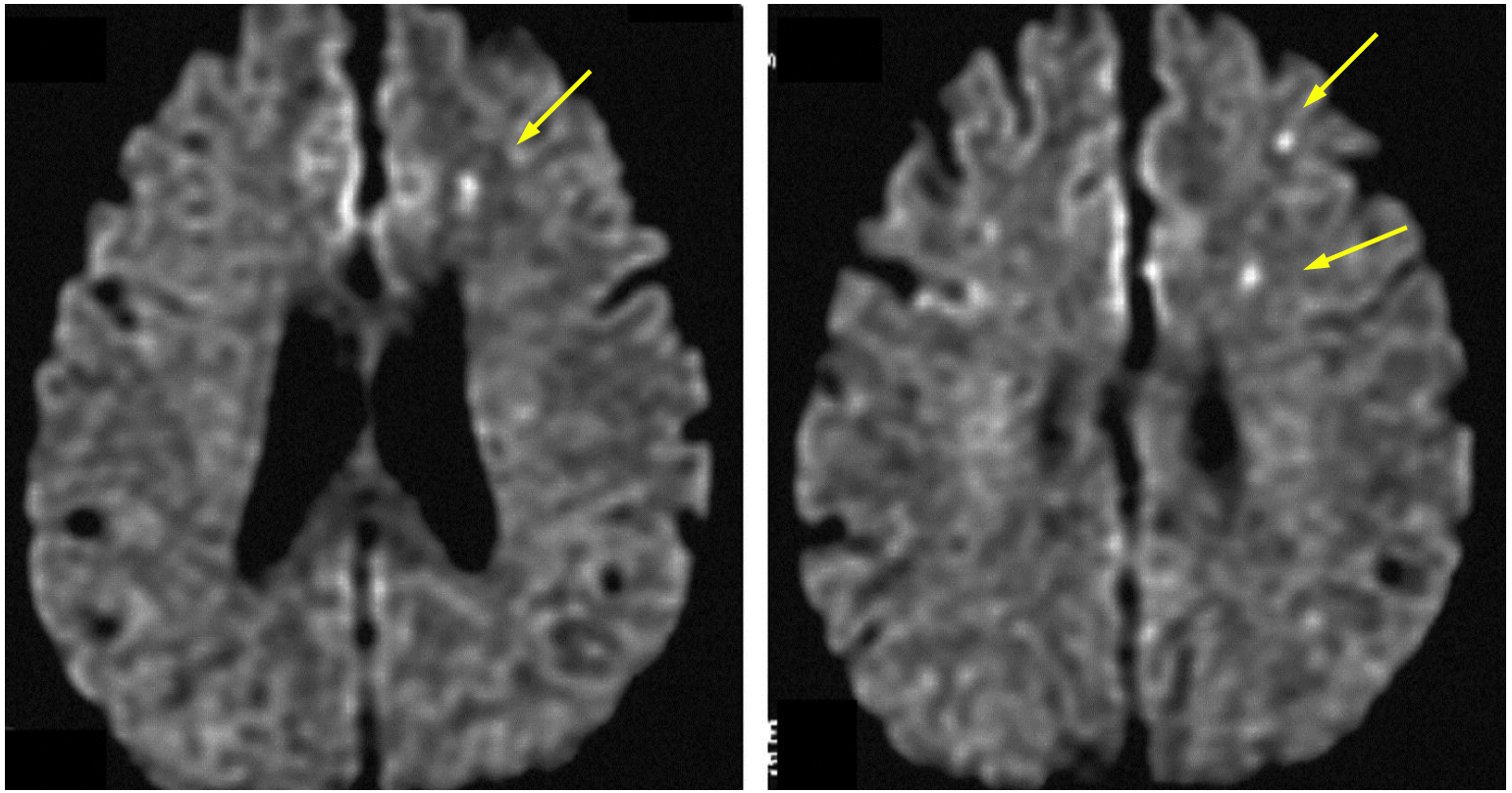
  ***stroke/MI/+** (30 days): **8.5% (stent) vs 5.2% (CEA)***

  subgroup analysis: 231 patients (new lesions in perfusion MR at 24 h): *stent* (50%) vs CEA (17%)

## *Carotid artery disease*

### Treatment (*stent vs* endarterectomy) ★

MR (diffusion-weighted)
post-*stent* ischemic lesions



*M. Rosenkranz et al. American Journal of Neuroradiology 2006;* 27:157-161

# Carotid artery disease

## Treatment (primary prevention)

### AHA/ACC Guidelines

- **prophylactic CEA can be useful in ICA stenosis > 60% (angiography) or > 70% (duplex scanning) if morbidity and mortality < 3%**

- ***carotid stenting: alternative treatment in selected patients with ICA stenosis > 60% (angiography), > 70% (duplex scanning), or > 80% (CT Angio or MRI)***

*Paraskevas KI, et al. J Vasc Surg 2012;55(5):1504-8*

# Carotid artery disease

## Treatment (secondary prevention)

### *ACC/AHA Guidelines*

- **CEA indicated 6 months after TIA/stroke if ICA stenosis 70-99% and surgical morbimortality < 6%.**

- CEA indicated (depending on risk factors) after recent TIA/stroke if ICA stenosis 70-99% and surgical morbimortality < 6%.

- Early CEA (< 15 days) recommended if there is no specific contraindication.

- **CEA is not indicated if IOCA stenosis < 50%.**

- ***Carotid stenting: alternative treatment in high-risk patients for surgery if ICA stenosis > 70% (duplex scanning/MRI) or > 50% (angiography) and morbimortality 4-6%.***

*Paraskevas KI, et al. J Vasc Surg 2012;55(5):1504-8*

# *Carotid artery disease*

## Clinical case

A 65-year-old man with a history of hypertension and dyslipidemia refers repeated episodes *of amaurosis fugax* in his right eye. Examination by duplex scanning and CT Angio shows stenosis > 70% in both internal carotid arteries.

# *Carotid artery disease*

## Clinical case

Based on the results of the main clinical trials on symptomatic (NASCET, ECST) and asymptomatic (ACAS, ACST) patients, what procedure would you indicate for this patient?

a) right carotid endarterectomy

b) left carotid endarterectomy

c) bilateral carotid endarterectomy

d) antiplatelet treatment

e) none of the above

# *Carotid artery disease*

## Clinical case

Based on the results of the main clinical trials on symptomatic (NASCET, ECST) and asymptomatic (ACAS, ACST) patients, what is the rate of morbidity and mortality that should have the surgical team?

a) < 7%
b) < 6%
c) < 5%
d) < 4%
e) none of the above

# *Carotid Artery Disease*