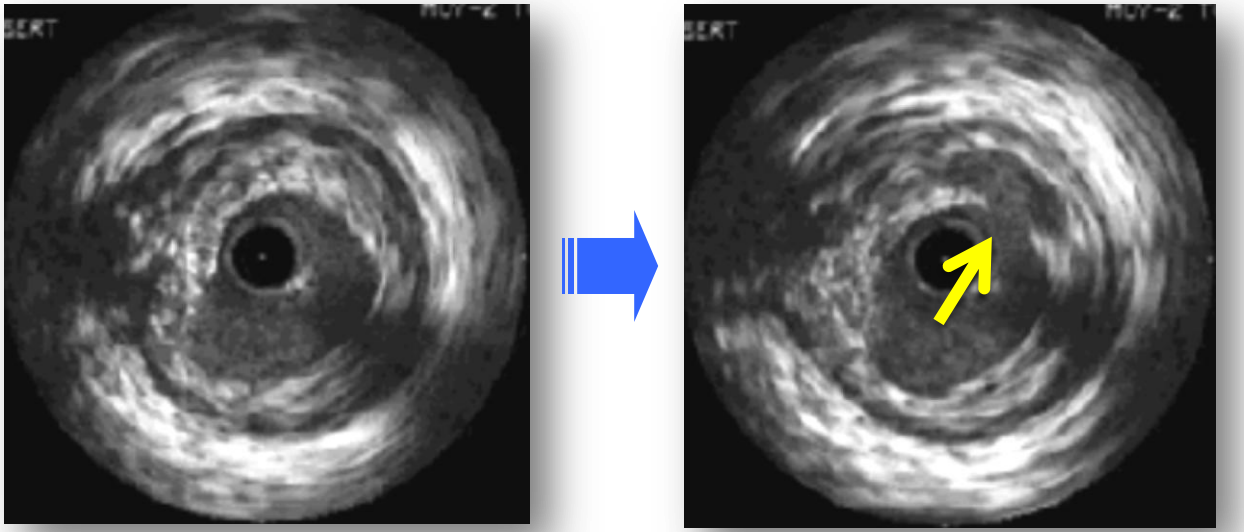
Rupture de plaque à l'effort : réalité ou fiction ?



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L'évolution de l'espèce Homo

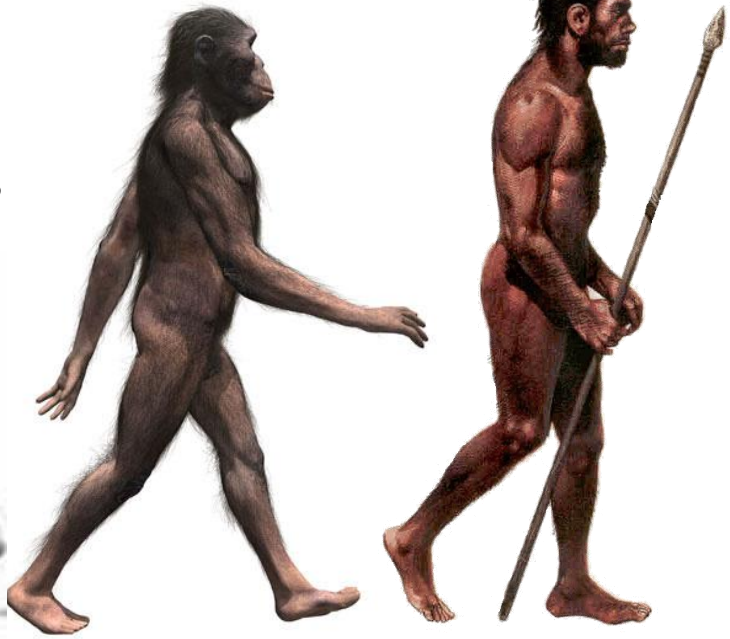
Homo sapiens

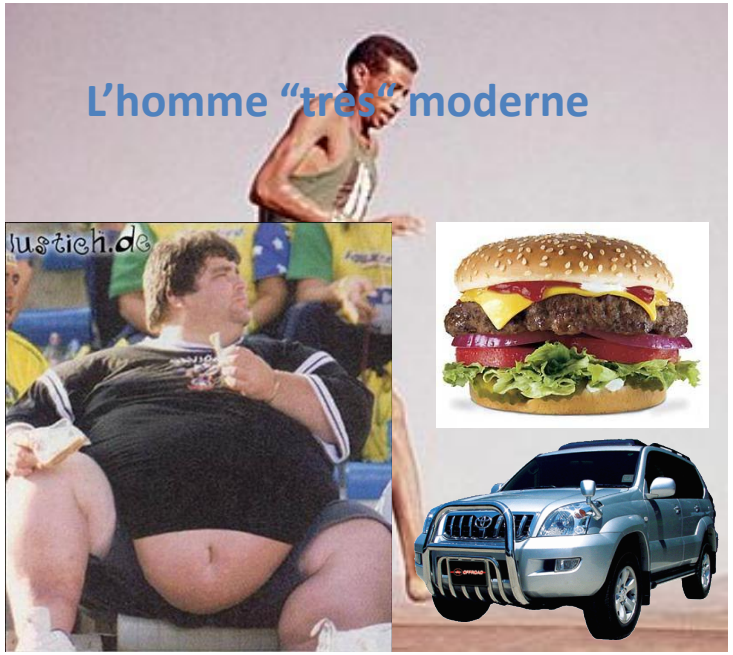
L'homme moderne "sportif"

Homo ergaster

L'homme "très" moderne

Ororrin Tugenensis





-6 millions d'années

-3.5 millions d'années

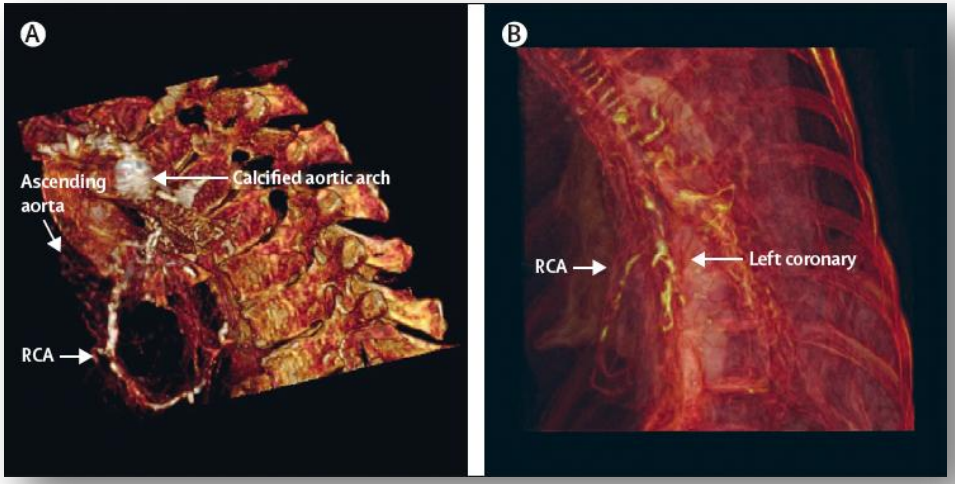
-75 000 ans

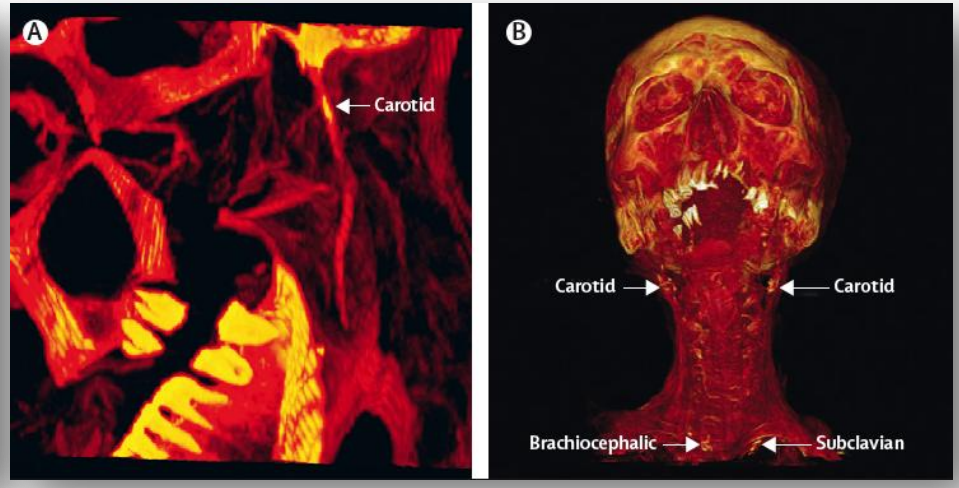
2013

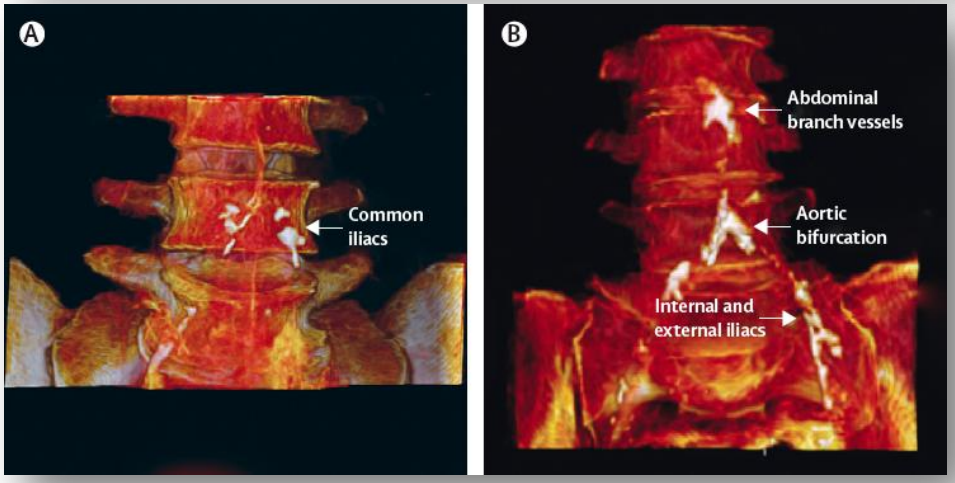
Thompson PD et al. Circulation 2003.
Mora S et al. Circualtion 2007.

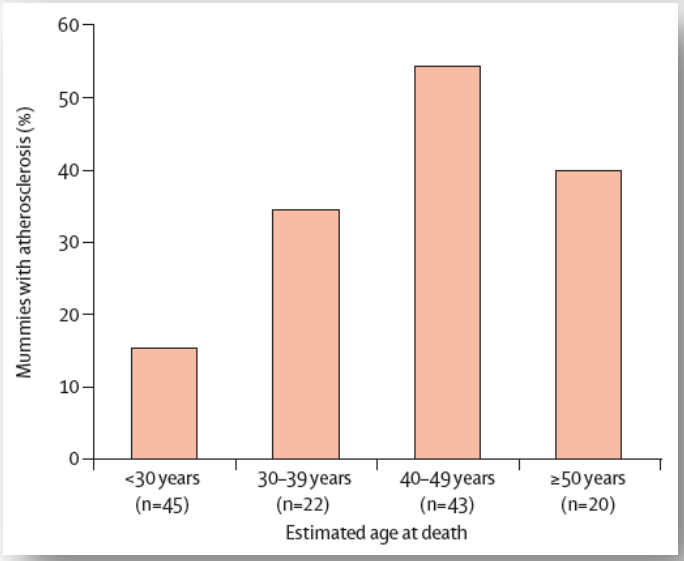
Atherosclerosis across 4000 years of human history: the Horus study of four ancient populations

Thompson RC. et al. Lancet 2013









whole body CT scans of 137 mummies from four different geographical regions or populations spanning more than 4000 years.

Le problème des calcifications artérielles

(sans trouble du métabolisme calcique)

Les lésions athéromateuses

Calcifications liées aux **tissus nécrosés**

Calcifications par cristallisation
des cristaux d'hydroxy-apatite
après **hémorragie intraplaque**

Sclérose de Mönckeberg

Calcifications de la media

peu liées à l'âge
mais à la ménopause

Liées aux fibres d'élastine
(lames élastiques)
surtout si altérées ou fragmentées
Ces fibres lésées agrègent les
phénomène de cristallisation des
cristaux d'apatite

sensible au métabolisme du fer

Yu SY and Blumenthal HT. The calcifications of elastic fiber. Various crystalline srtructures of apatite in human aorta. Lab invest. 1963; 12:154-1162.
Martin GR et al. Chemical and morphological studies on the in vitro calcification of the aorta. J Cell Biol. 1963;1:265-277.

Running: the risk of coronary events

Prevalence and prognostic relevance of coronary atherosclerosis in marathon runners

Table 2 Distribution of coronary artery calcification (CAC) measures in the three groups

	Participants of the Heinz Nixdorf Recall Study			*P*-value group I vs. group II	*P*-value group I vs. group III
	Marathon runners (group I)	Age-matched controls (8:1) (group II)	Controls matched for age and risk factors (2:1) (group III)		
$\log_2$(CAC + 1) (mean ± SD)	4.1 ± 3.6	4.9 ± 3.3	3.8 ± 3.4	0.28	0.02
CAC (Q1/median/Q3)	0/36/217	3/38/187	0/12/78	0.36	0.02
zero CAC (%)	28.7	18.4	31.5	0.01	0.50
CAC >75th percentile (%)	25.0	24.2	14.8	0.85	0.01
CAC 0 to <10	40.74	34.61	48.61	0.52	0.02
CAC 10 to <100	23.15	29.05	29.63		
CAC 100 to <400	23.15	22.80	13.43		
CAC ≥400	12.96	13.54	8.33		

Comparisons in continuous or binary measures adjusted for matching factors (age for group I/group II, age, body mass index, Framingham risk, smoking status for group I/group III).

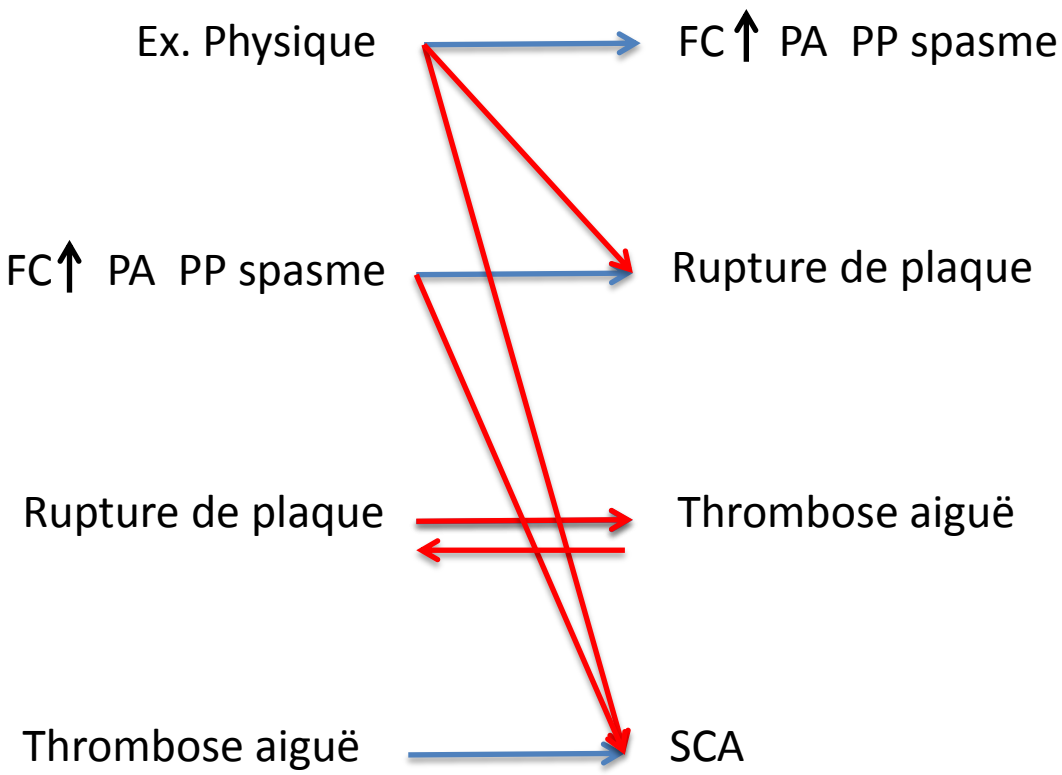
Möhlenkamp S et al. EHJ 2008;29:1903.

L'exercice physique

Induction hyperadrénergique

Augmentation de la fréquence cardiaque
Elévation des pressions artérielles
Augmentation de l'inotropisme

Maron BJ. NEJM 200
Shephard RJ, Balady GJ. Circulation 1999



Chevalier et al. Eur J Cardiovasc Rehabil 2009
Thompson et al. Circulation 2007
Siascovick et al. NEJM 1984
Albert et al. NEJM 2000
Corrado et al. Eur Heart J 2011

Ciampricotti et al. Am Heart J 1990

Davies et al. Eur Heart J 1989
Davies et Thomas NEJM 1984
Burke et al. NEJM 1987
Virmani et al. ATVB 2000

Kannel et al. Am Heart J 1987
Benetos et al. Hypertension 1999
Diaz et al. Eur Heart J 2005
Fox et al. Lancet 2008

Ex. Physique
Spectateurs foot
Heartquake
Missile scud
Stress mental

→ FC ↑ PA PP spasme

FC ↑ PA PP spasme → Rupture de plaque

Rupture de plaque → Thrombose aiguë

Thrombose aiguë → SCA

Exercice sportif

Chevalier et al. Eur J Cardiovasc Rehabil 2009
Thompson et al. Circulation 2007
Siascovick et al. NEJM 1984
Albert et al. NEJM 2000
Corrado et al. Eur Heart J 2011

Spectateurs "sportifs"

Witt et al BMJ 2002
Katz et al. Int J Cardiol 2006
Toubiana et al. BMJ 2001
Bauman et al. Med J Aust 2006
Klonner et al. Am J cardiol 2009

Séismes

Trichopoulos et al. Lancet 1983
Leor et al. NEJM 1996
Suzuki et al. Lancet 1995

Attaque missile

Meisel et al. Lancet 1991

Stress mental

Jiang et al. JAMA 1996

Ex. Physique → Rupture de plaque

Clinical characteristics and coronary angiographic findings of patients with unstable angina, acute myocardial infarction, and survivors of sudden ischemic death occurring during and after sport

Conclusions. This study constitutes the first acute coronary angiographic demonstration of a continuous spectrum of acute ischemic events related to sport. The predominant coronary feature of acute syndromes related to sport is an eccentric lesion that is often associated with thrombosis and less frequently with thrombosis and vasospasm. Physical exercise, probably through coronary spasm, may induce plaque rupture, which in turn can lead to coronary (sub)occlusion precipitating an acute coronary event. Such an event is in most instances unexpected and unpredictable. However, early recognition of risk factors for coronary artery disease and periodic evaluation can identify high-risk subjects. The mechanism proposed its hypothetical and needs to be validated by further studies.

Ciampricotti et al. Am Heart J 1990

Incidence des SCA au cours ou décours de l'effort

Ex. Physique → SCA

INSEE - 2005
63.4 millions d'habitants
Les + de 20 ans : 25.1%
Soit 47.5 millions

120 000 IDM/an

246 IDM/100 000 h/an

Table 2 Incidences (*n*) of sports-related ACVE deaths and nonlethal MI

Incidence *n*/100 000 participants/year	Global population	<35 years	35–59 years	>59 years
Total ACVE	6.5 (127)	3.4 (25)	9.8 (80)***	4.9 (20)
Women ACVE	2.2 (24)*	2.2 (8)*	2.9 (12)*	1.5 (4)*
Men ACVE	10.8 (103)	4.6 (17)	17.1 (68)***	8.7 (16)
Total deaths	2 (40)	1.4 (10)	3.0 (24)***	1.5 (6)
Women deaths	0.2 (2)**	0.0 (0)**	0.2 (1)**	0.4 (1)*
Men deaths	4 (38)	2.7 (10)	5.8 (23)†	2.7 (5)
Total MI	2.4 (47)	0.1 (1)	4.3 (35)†	2.7 (11)
Women MI	0.5 (5)**	0.0 (0)	1 (4)**	0.4 (1)**
Men MI	4.4 (42)	0.3 (1)	7.8 (31)†	5.4 (10)

Note that concerning ACVE, age was unknown for two men. ACVE, acute cardiovascular events; MI, myocardial infarction. *$P<0.01$ between men and women. **$P<0.001$ between men and women. ***$P<0.05$ between age groups. †$P \leq 0.01$ between age groups.

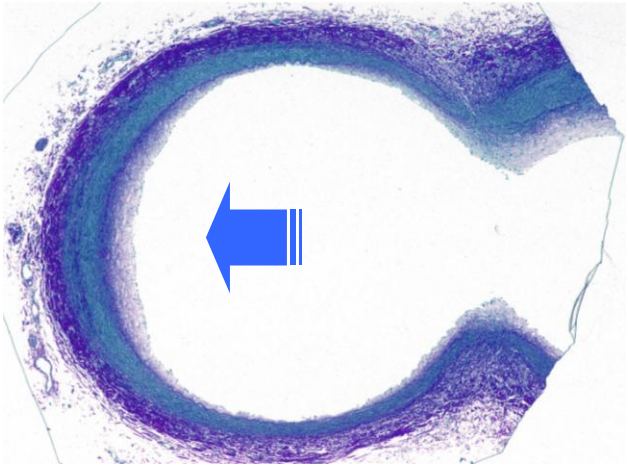
Soit 2.6%

Soit 0.9%

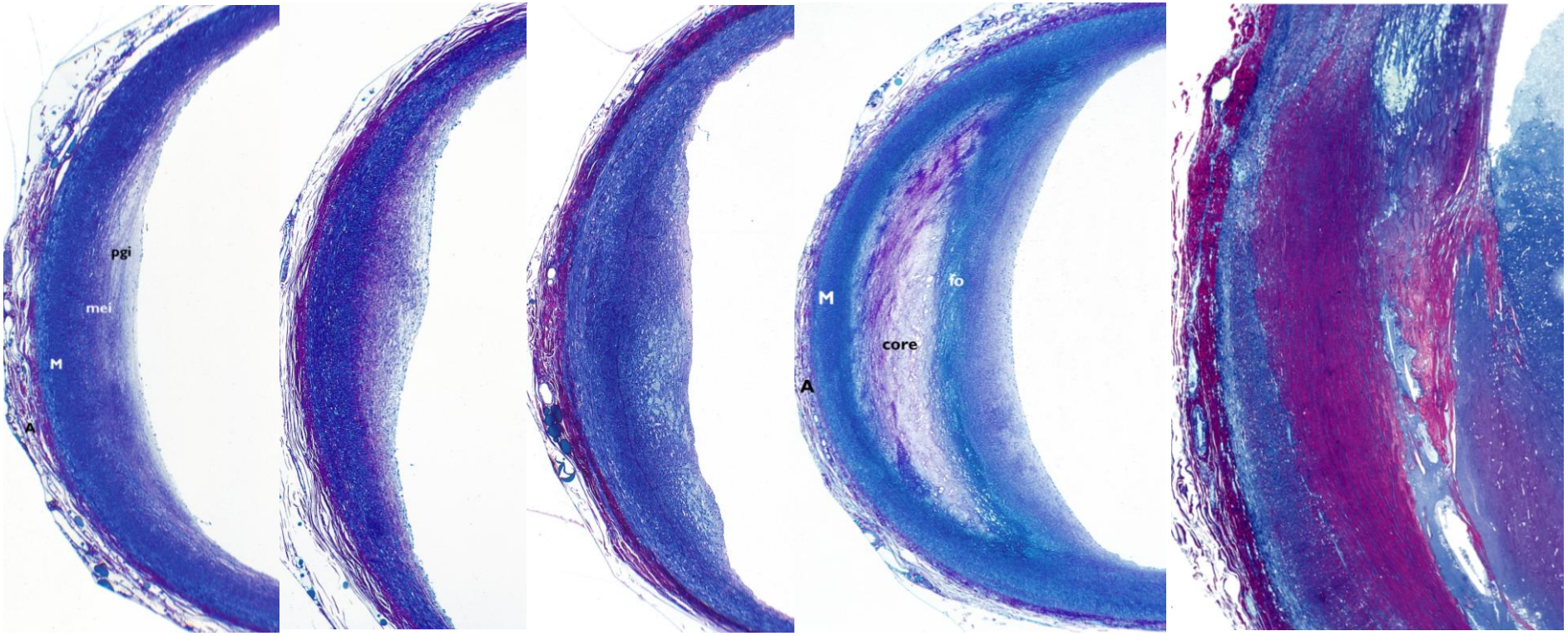
Chevalier et al. Eur J Cardiovasc Prev Rehabil 2009;16:365.

La biomécanique de la plaque vulnérable

Le processus de vulnérabilité



Rupture et thrombose

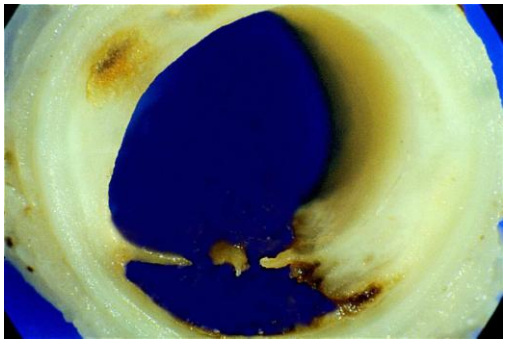


Atherosclerosis: progression et regression. HC Stary. Parthenon Publishing 2003.

Le processus de déstabilisation

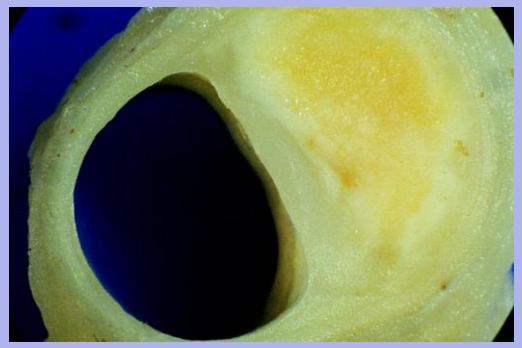
La rupture de plaque

≈ 70% des cas



± THROMBOSE

La plaque vulnérable



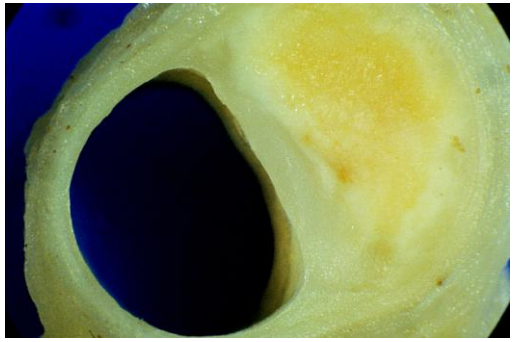
?

?

?

L'érosion

≈ 25% des cas

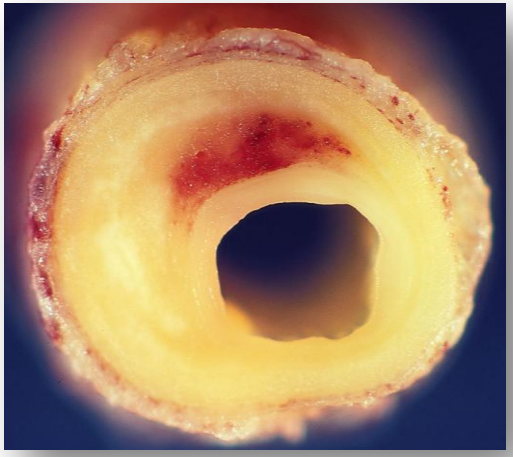


± THROMBOSE

≈ 20% des cas

L'hémorragie intraplaque

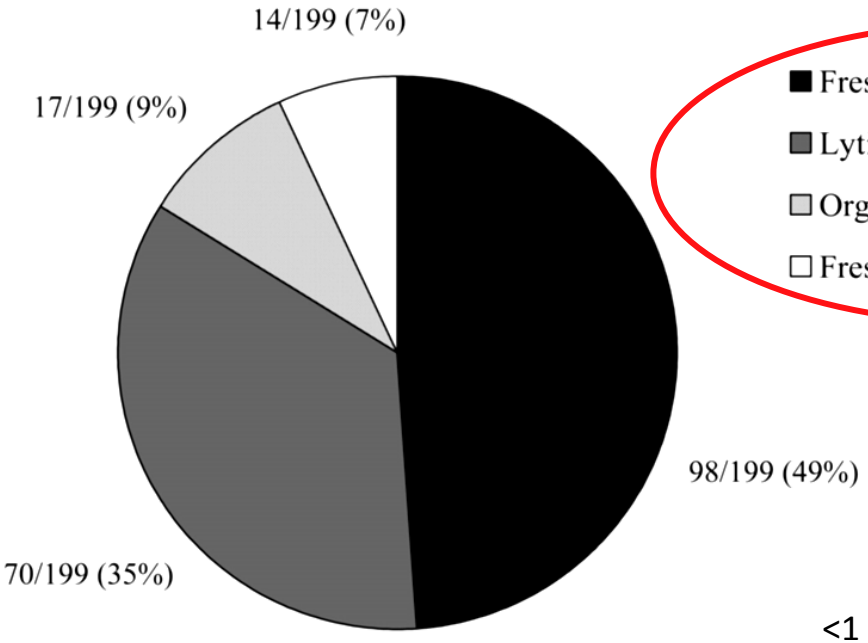
≈ 5% des cas



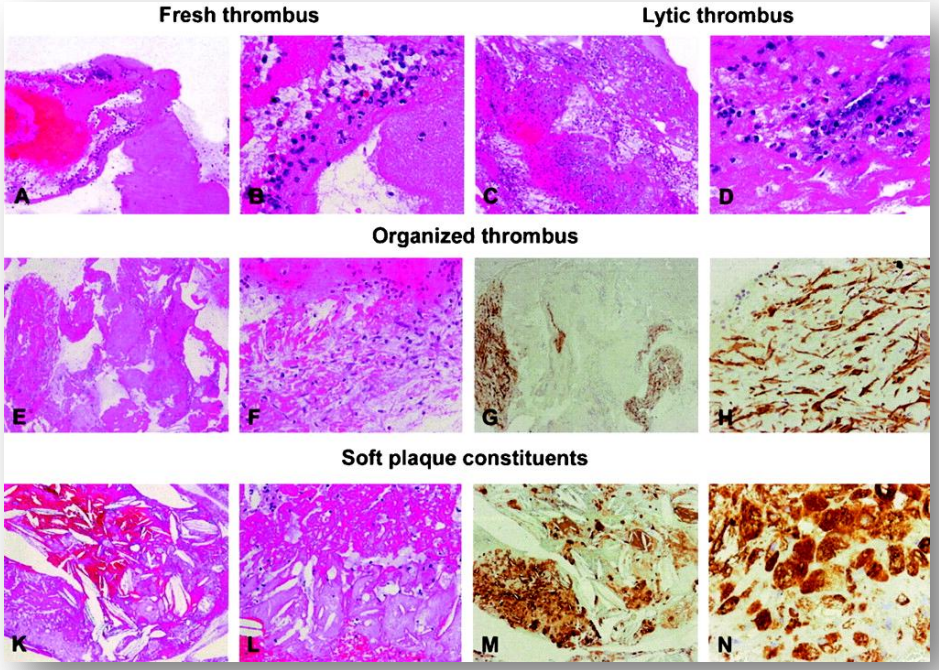
± disséquant

Davies et al. British Heart J 1988

Thrombus age after thrombosuction: proportions of treated patients (n 199)

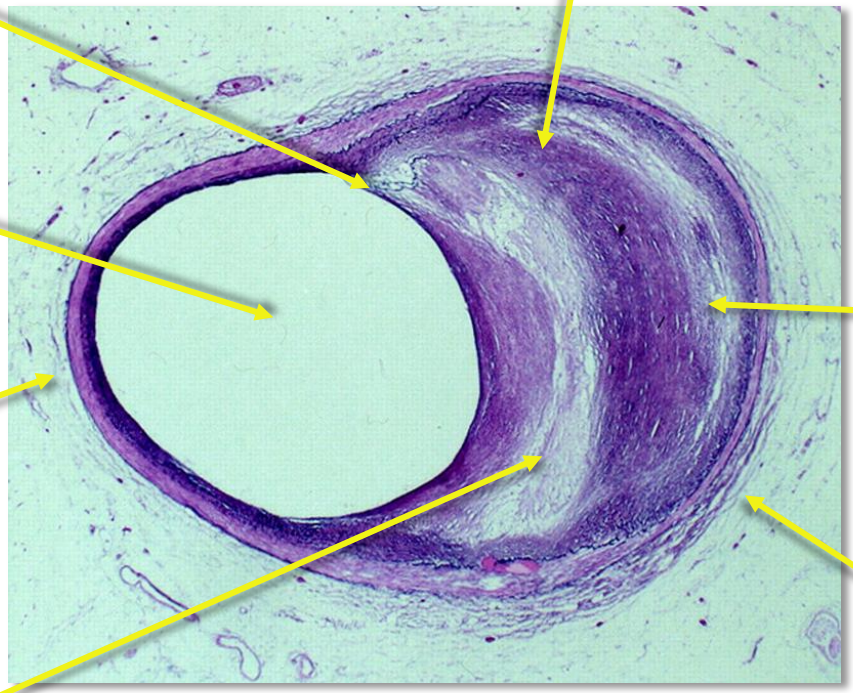


51%



Rittersman et al. Circulation 2005;111:1160.

La plaque vulnérable



Plaque excentrée

Fine capsule fibreuse (< 100 microns)

Non obstructive

Important PB% (>50%)

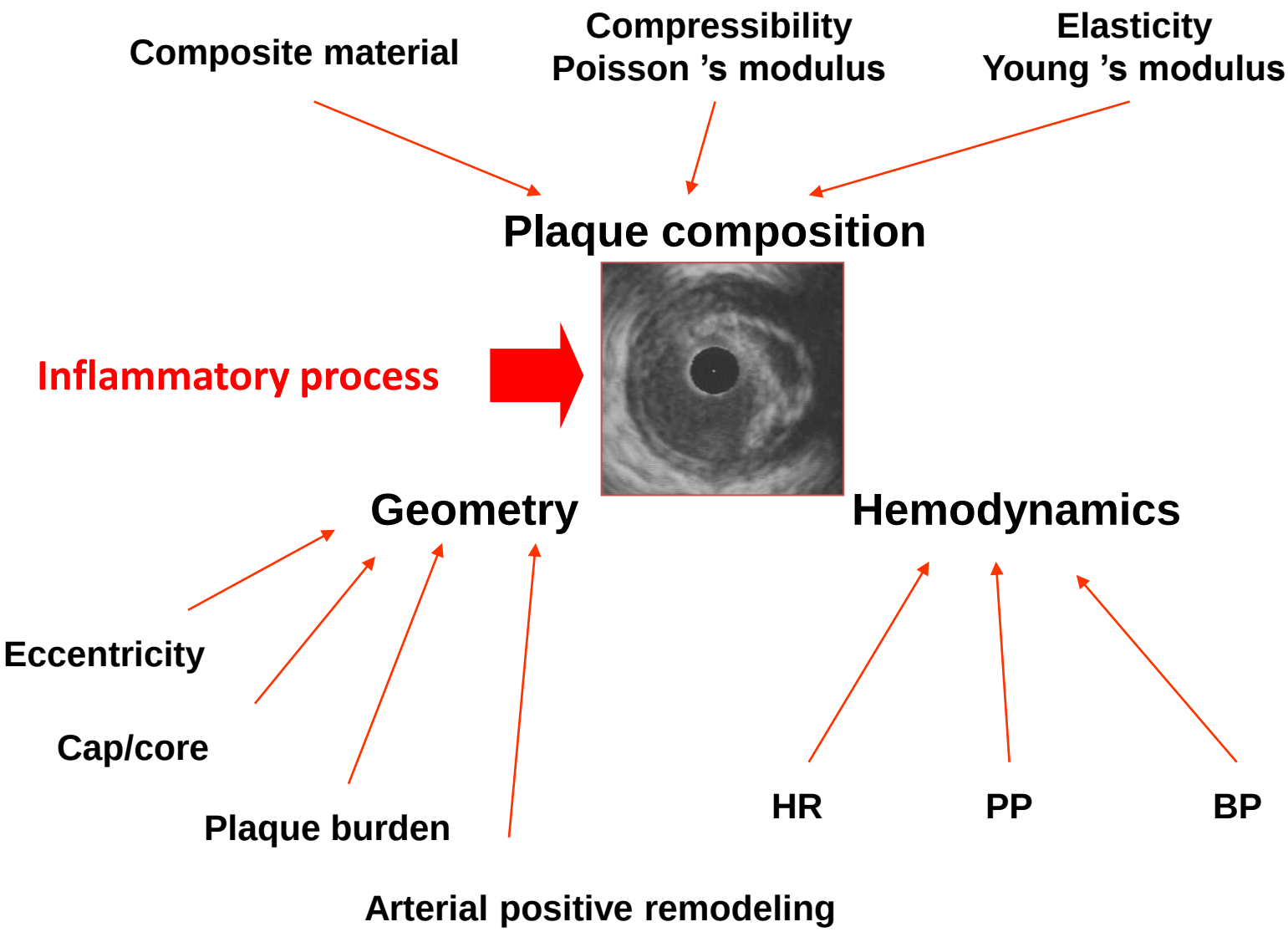
Arc sain

Important core lipido-nécrotique (>30-40% du PB%)

Remodelage positif (>1.0)

Yamagishi M. et al. JACC 2000;35:106-11.
Von Birgelen C. et al. JACC 2001;37:1864-70.
Rioufol G. et al. Circulation 2002;106 :804-808.

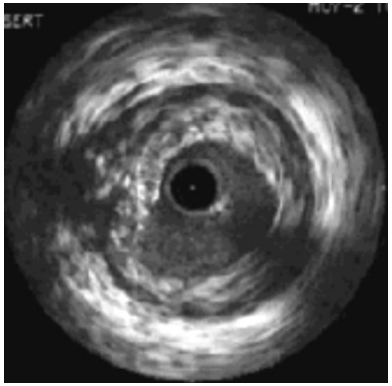
Complexe interaction

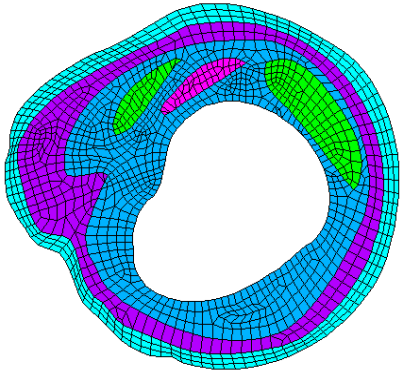


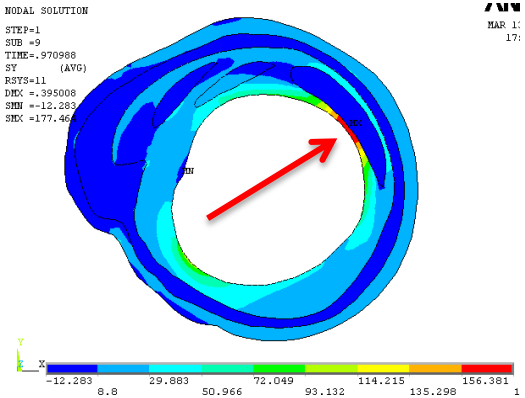
Plaque Vulnerability and Circumferential stress

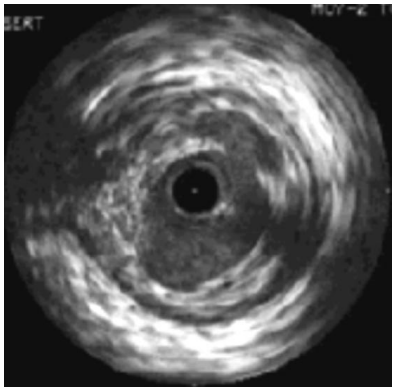
IVUS imaging *Finite element meshes* *Circumferential stress maps* *IVUS imaging*

CTH = 160 μm

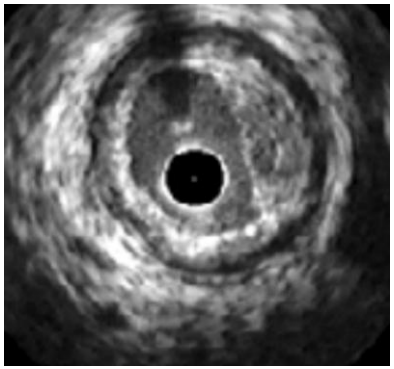


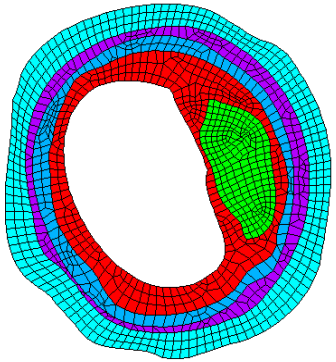


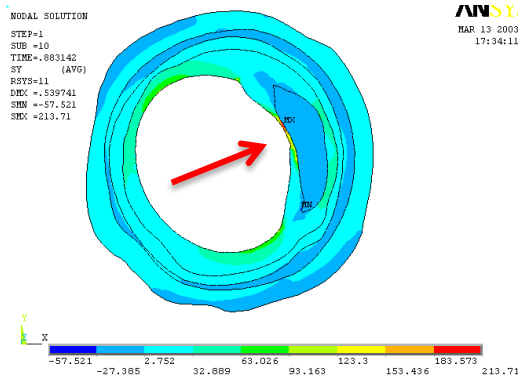


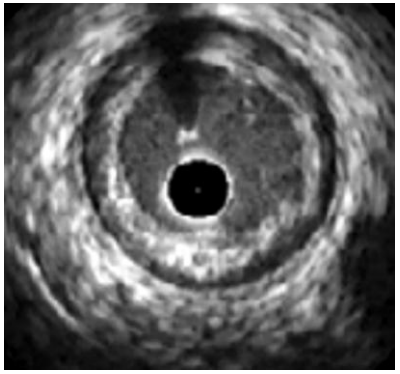


CTH = 56 μm







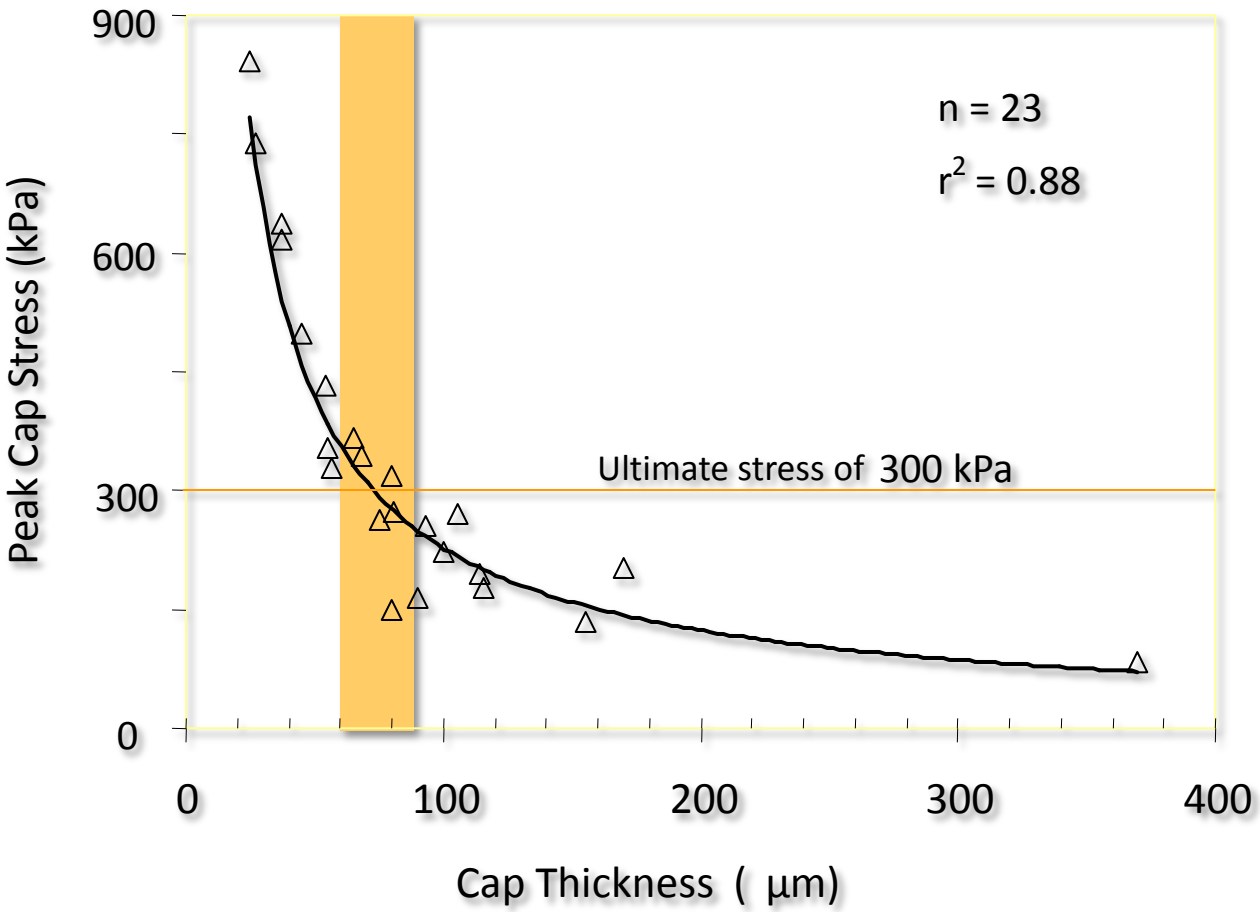


Adjacent non-ruptured plaque cross-sections

Ruptured plaque cross-sections

Finet et al. CAD 2004;15:13-20.

Plaque Vulnerability and Cap Thickness



Critical Cap Thickness:

65 – 100 µm

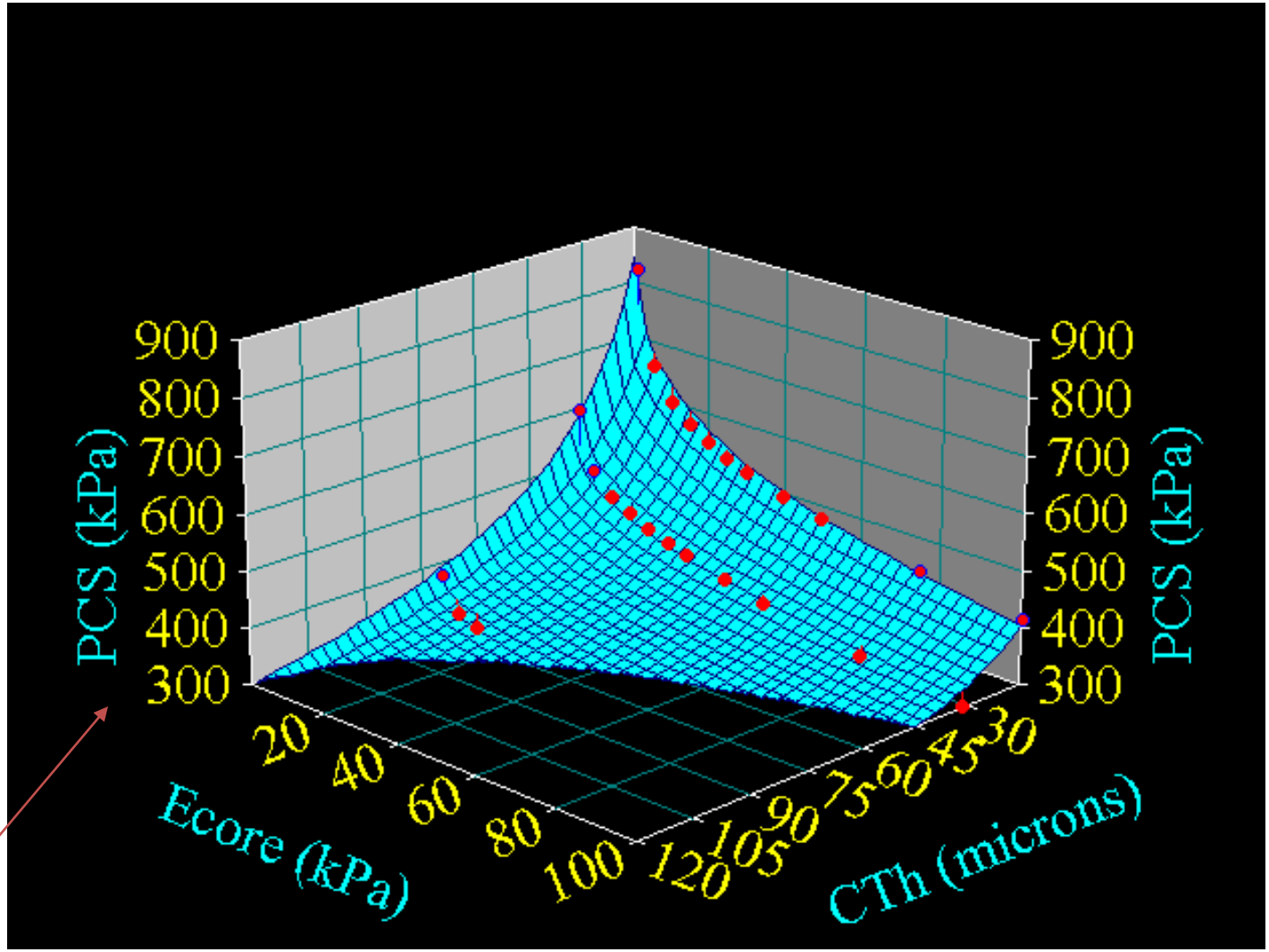
Richardson et al., Lancet 1989
Lee et al., Circulation 1991
Virmani et al., ATVB 2000

Finet et al. CAD 2004;15:13-20.

Effet “trigger“ de la pression artérielle

Surface 3D quantifiant les interactions complexes entre Cap thickness (CTh), le module de Young du core lipidique (Ecore), et le pic de contraintes circonférentielles (PCS)

P=10 kPa
(75 mm Hg)
P=14.6 kPa
(110 mm Hg)
P=20 kPa
(150 mm Hg)



Lendon et al. Atherosclerosis 1991
Cheng et al. Circulation 1993

Ohayon et al. CAD 2001;12:655-663. - Finet et al. CAD 2004;15:13-20.

Seventy-Four–Month Follow-Up of Coronary Vulnerable Plaques by Serial Gray-Scale Intravascular Ultrasound

Pascal Motreff, MD, PhD; Gilles Rioufol, MD, PhD; Gérard Finet, MD, PhD

A 56-year–old male nonsmoker with high blood pressure was referred for a first acute coronary syndrome in the lateral territory. Coronarography identified the culprit lesion on the circumflex artery. The left anterior descending artery (LAD) showed diffuse atherosclerosis and was further explored by 40-MHz intravascular ultrasound (IVUS; baseline). Ten months later, angina recurred, without circumflex artery restenosis; an LAD plaque (P4, among the 5 plaques ultimately detected) was detected and managed medically (Figure 1). Because the patient developed Canadian Cardiovascular Society (CCS) class 3 angina, this single stenosing LAD lesion was treated by bare-metal stenting at 22 months of follow-up. Symptoms resolved, but 1 year later (at 33-month follow-up) there was recurrence of CCS-3 angina without

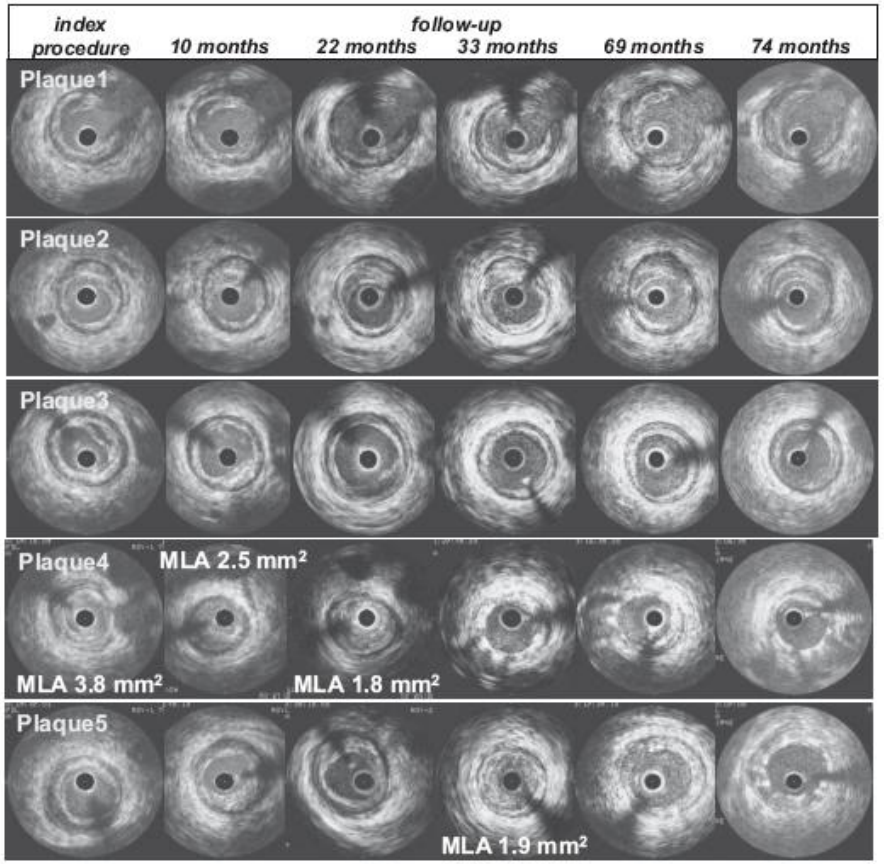


Figure 1. Six-year serial examination of 5 distinct atheromatous coronary plaques by intracoronary ultrasound in the same patient. MLA indicates minimal lumen diameter.

Circulation. 2012;126:2878-2879

Conclusions

Les relations entre l'exercice physique et la vulnérabilité des plaques d'athérosclérose coronaires s'avèrent contradictoires.

L'exercice physique, par l'augmentation des pressions artérielles plus que la fréquence cardiaque, peut être un trigger de la rupture de plaque en acutisant brutalement les pics de contraintes circonférentielles au delà des seuils de rupture du matériau clé : le collagène (capsule fibreuse).

Les interactions entre composition et géométrie de la plaque, biologie, et biomécanique sont tellement multiples et complexes que toute tentative d'explication déductive globale de ces mécanismes semble illusoire.

Un test d'effort négatif, des coronaires angiographiquement normales ou subnormales, et/ou l'absence de calcifications coronaires ne permettent pas d'éliminer la possibilité d'une rupture de plaque ou plus généralement un ACS.

La présence angographique d'une ATS coronaire non obstructive, ou de calcifications coronaires, et même la détection d'une plaque "morphologiquement" vulnérable par IVUS ou OCT ne permettent pas la prédiction d'une rupture de plaque ou plus généralement un SCA

En conséquence, toute velléité de prévision des évènements coronariens aigus, patient par patient, apparaît utopique.

Qu’est-ce qu’une plaque réellement vulnérable dans le milieu sportif?