

Les lésions calcifiées

Actualités sur la plaque d'athérosclérose

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Trahis par le Calcium!



La plaque d'athérosclérose ?



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

Thompson RC. et al. *Lancet* 2013

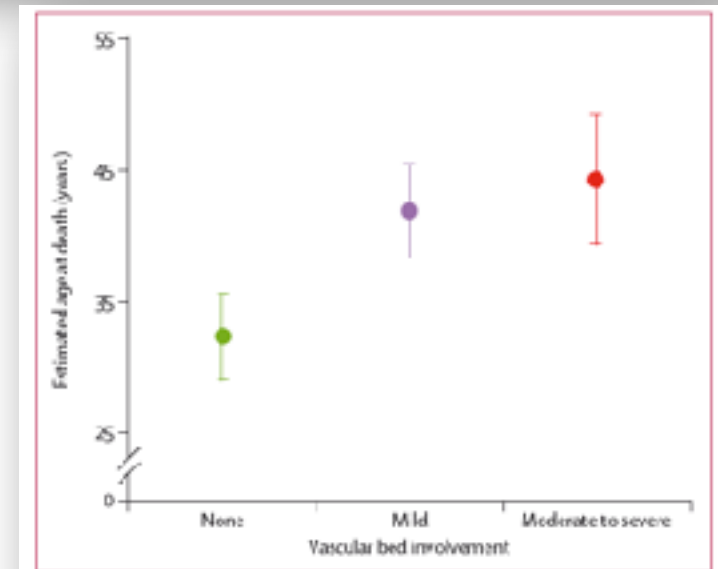
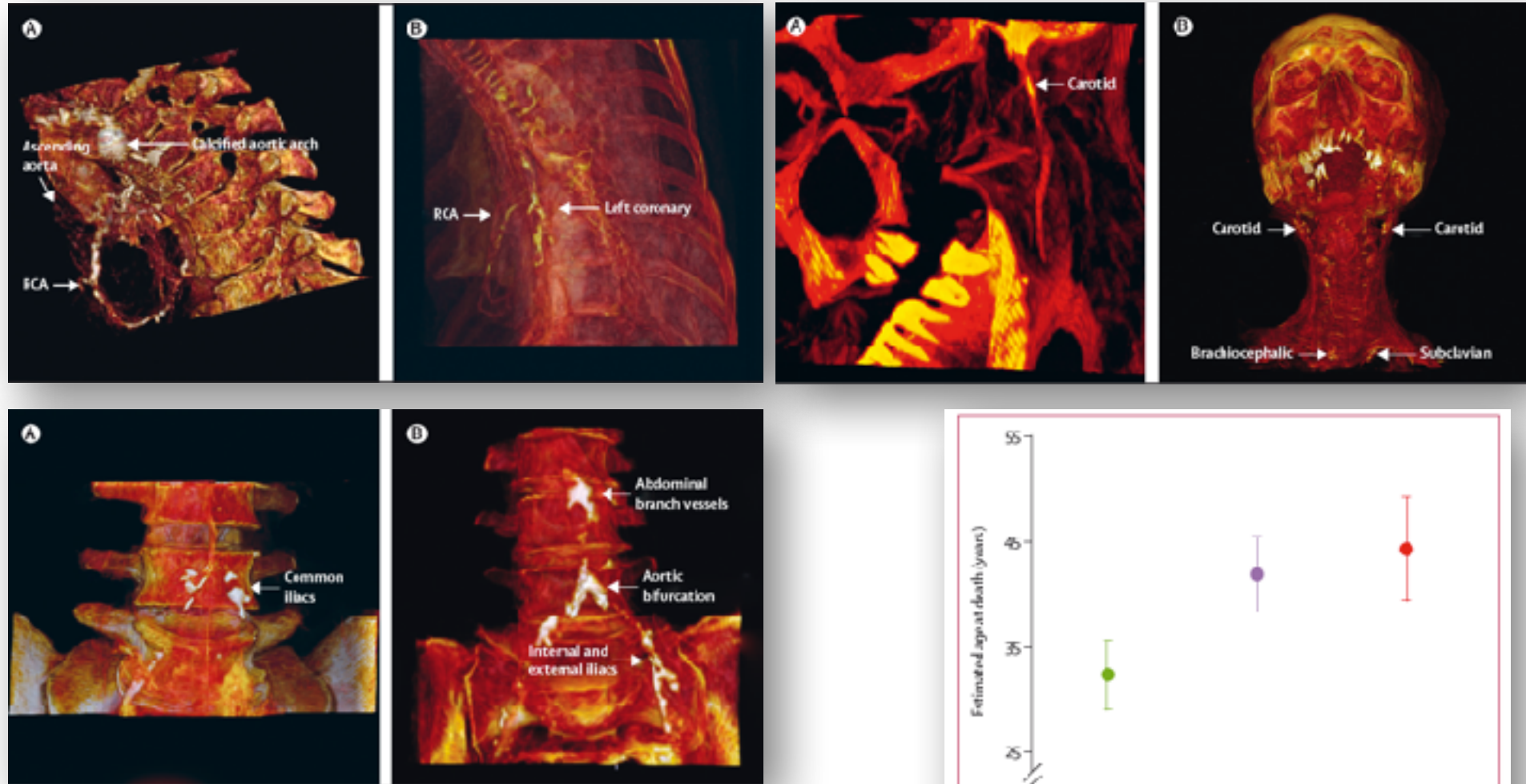


Figure 1: Mean estimated age at death of the mummies in the three categories of atherosclerosis. Error bars show 95% CI.

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
phénomènes de cristallisation des
cristaux d'apatite

sensible au métabolisme du fer

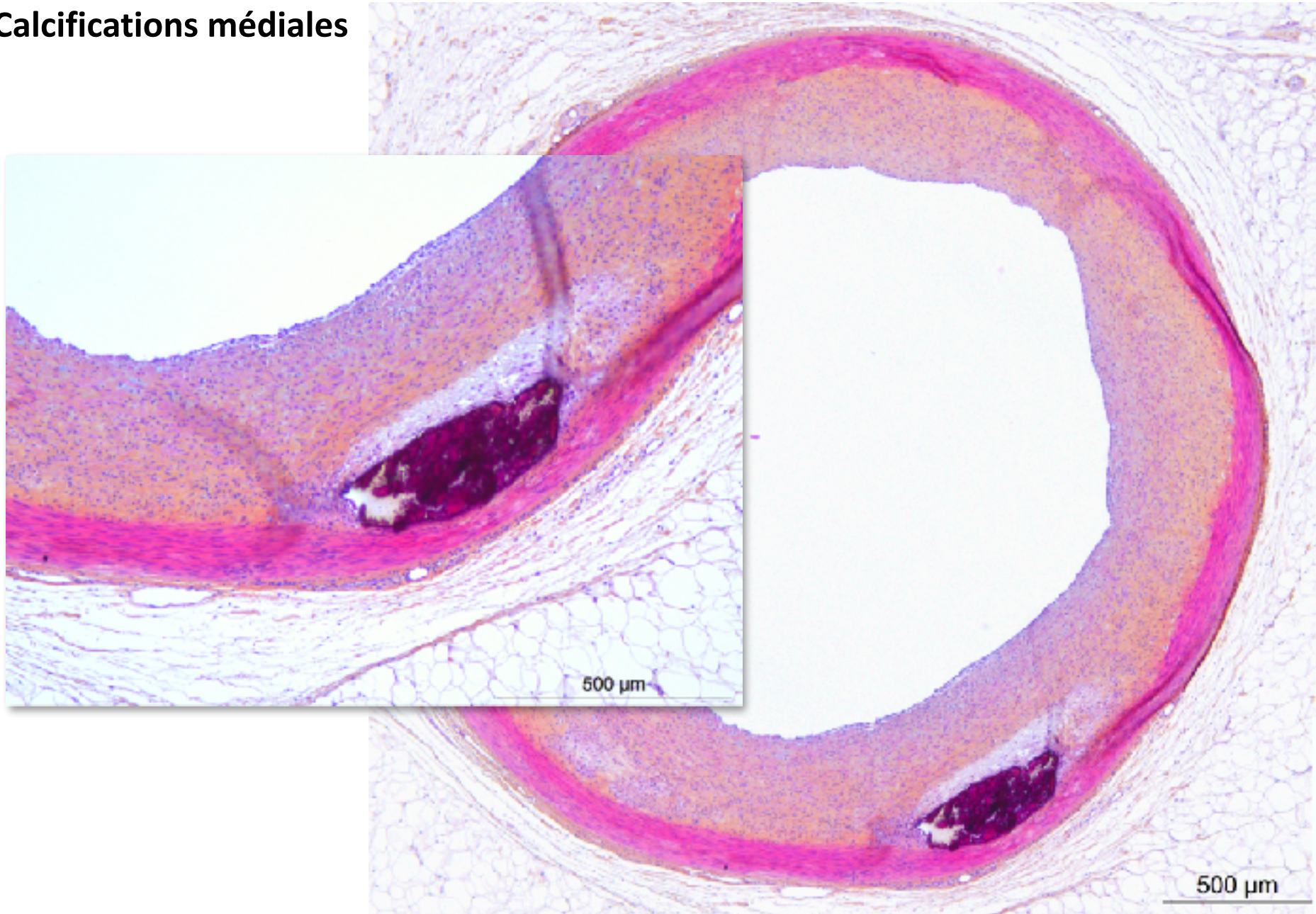
Yu SY and Blumenthal HT. The calcifications of elastic fiber. Various crystalline structures of apatite in human aorta. Lab invest. 1963; 12:154-1162.

Martin GR et al. Chemical and morphological studies on the in vitro calcification of the aorta. J Cell Biol. 1963;1:265-277.

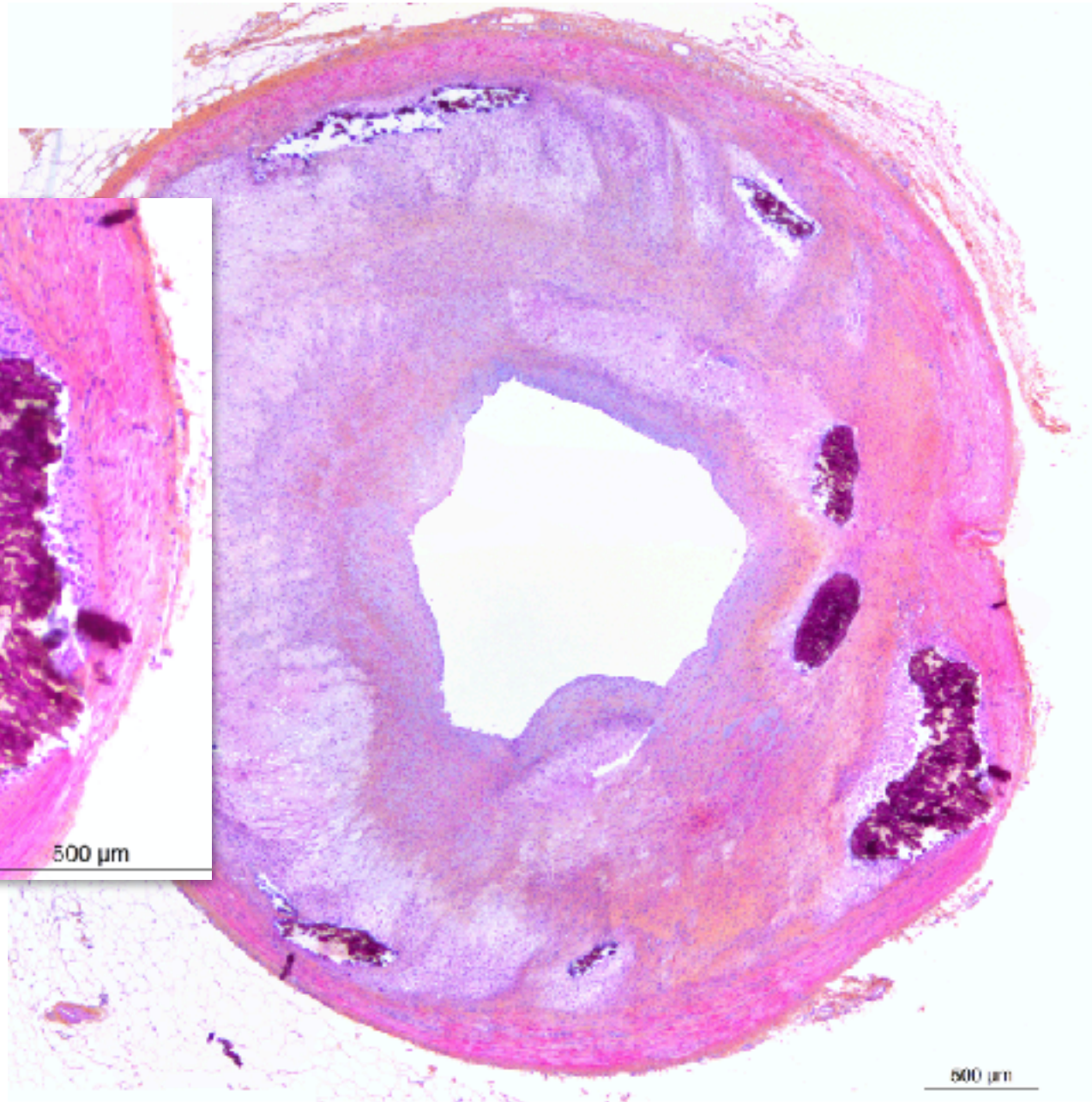
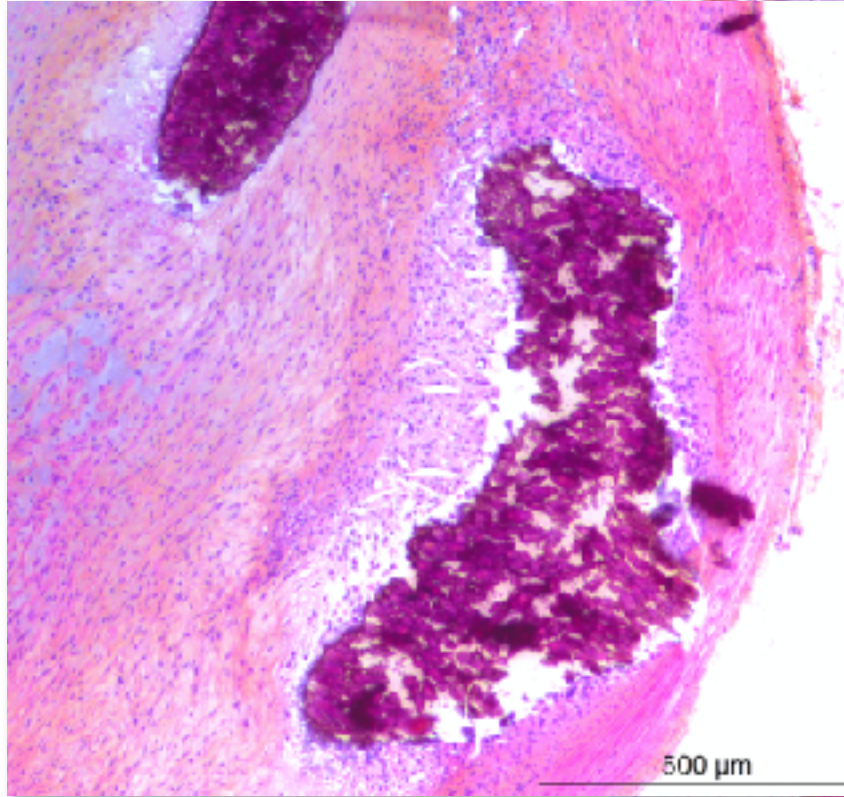


Porcin model of accelerated coronary atherosclerosis. G. Finet, J. Ohayon, F. Dérimay, A. Tacheau. Unpublished data

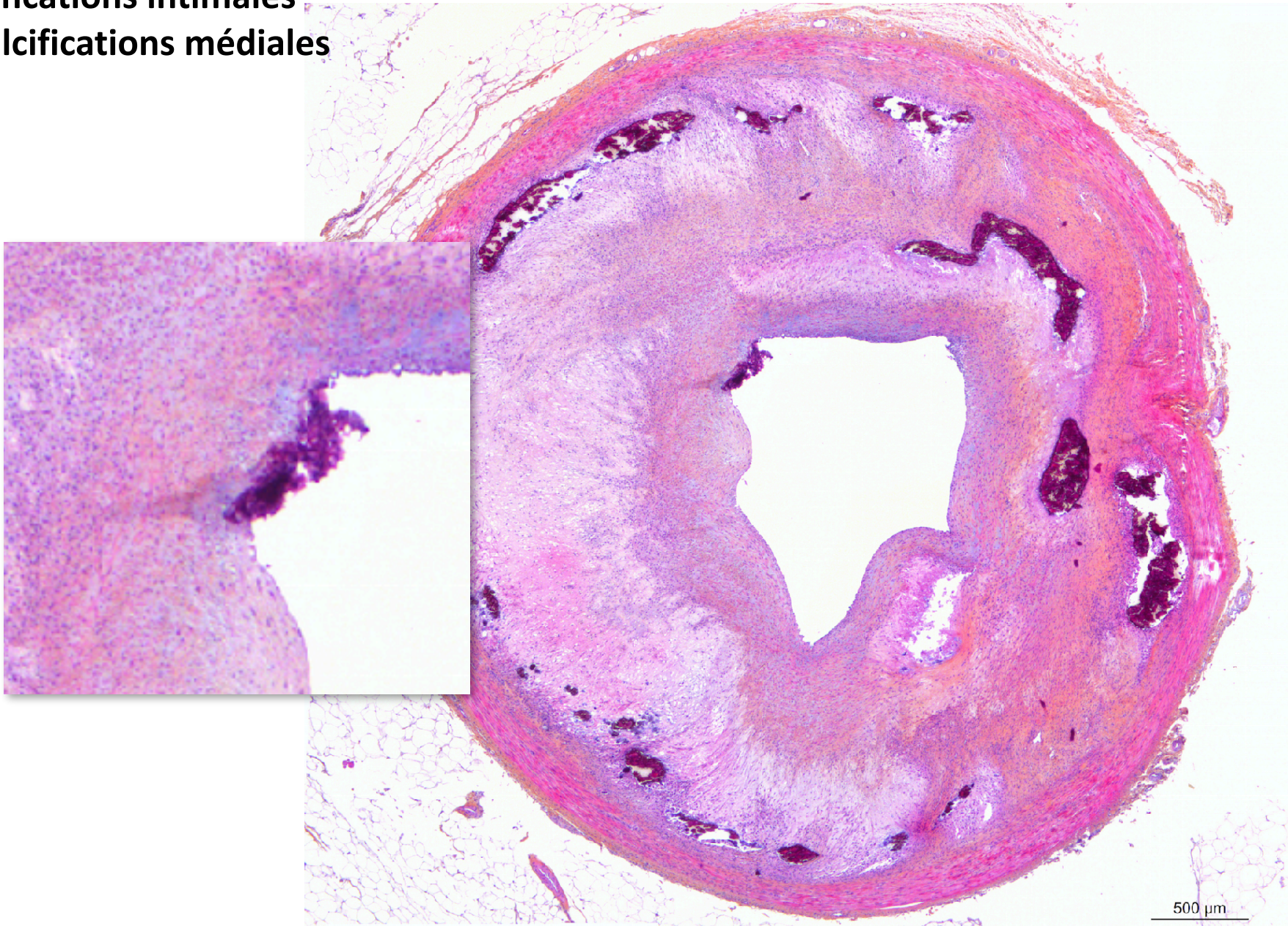
Calcifications médiales



Calcifications médiales



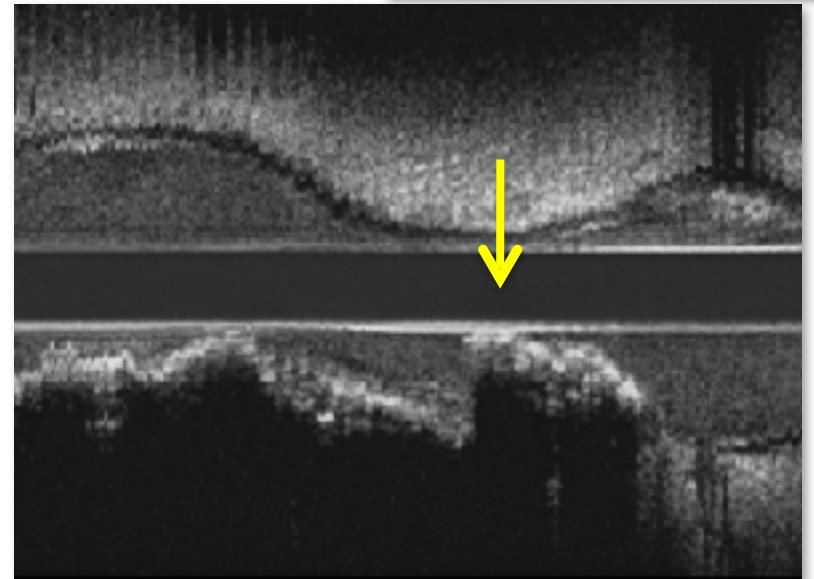
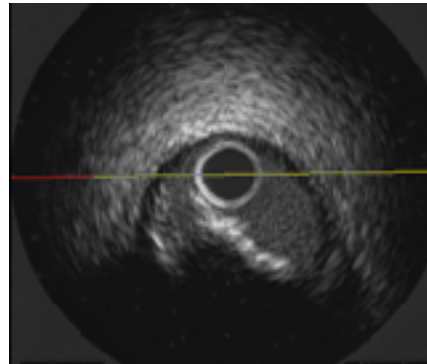
**Calcifications intimaes
et calcifications médiaies**



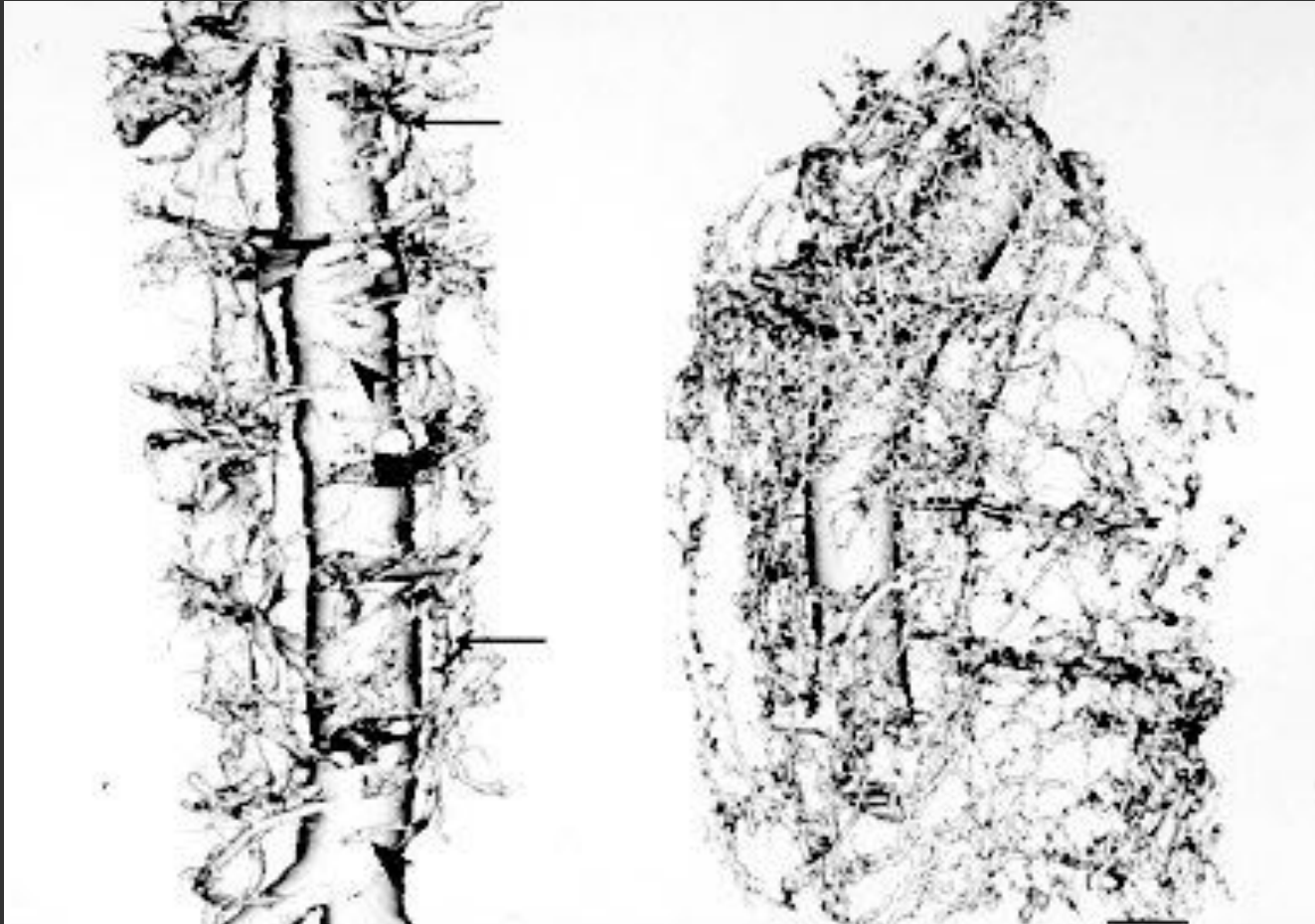
500 μm

Etiologie des obstructions coronaires endoluminales

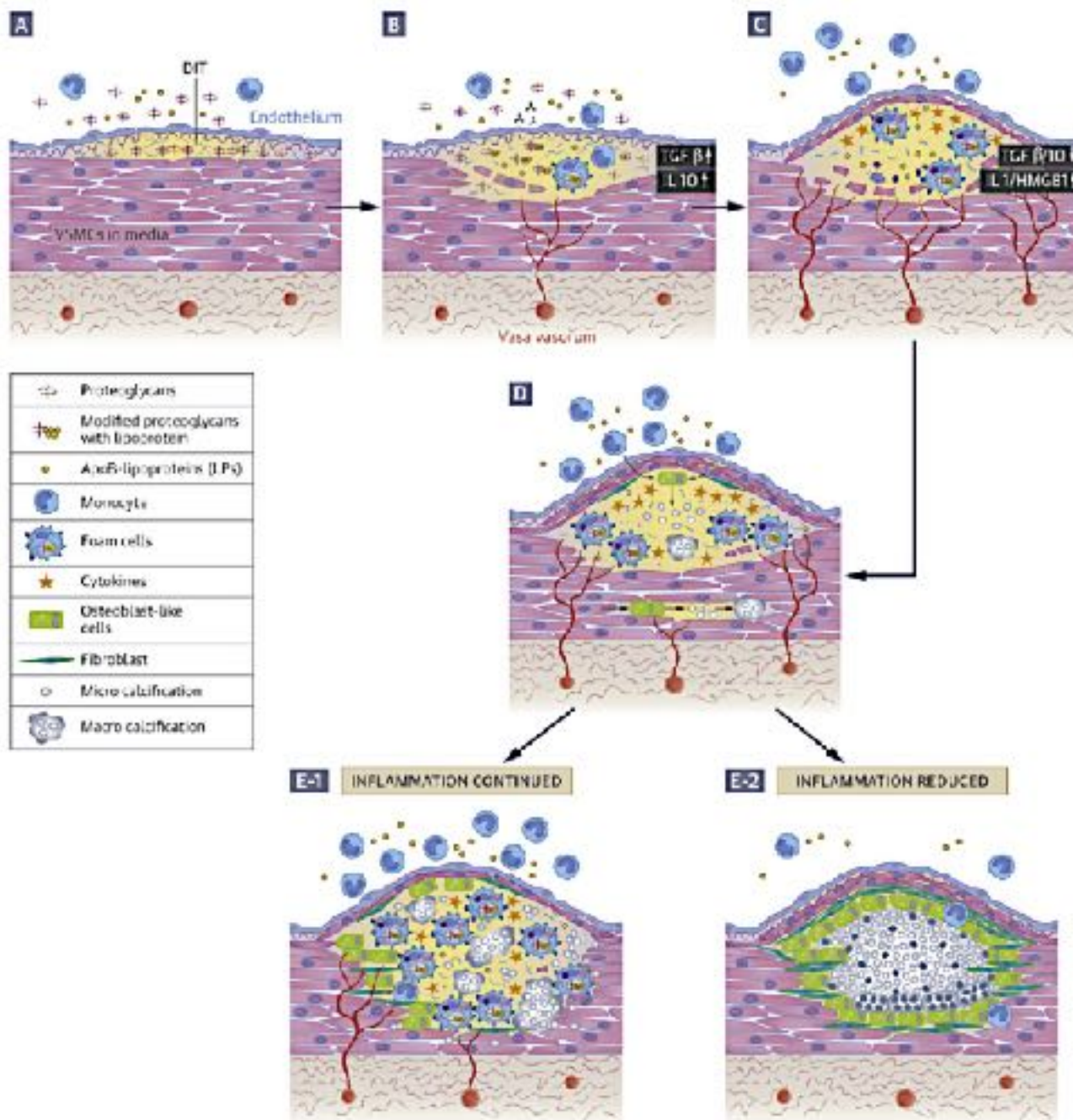
La macrocalcification protrusive



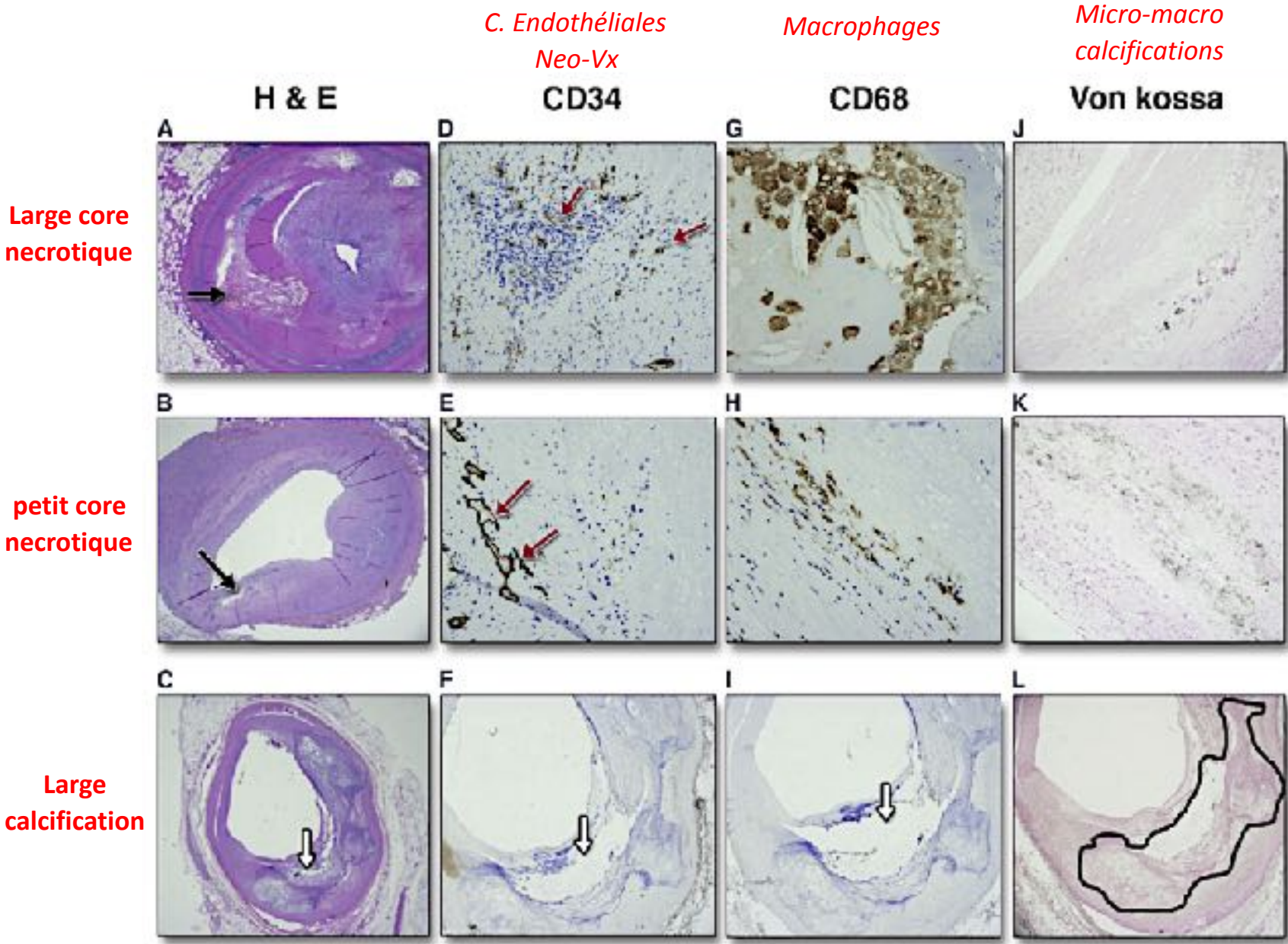
**Adventitial vasa vasorum in balloon-injured coronary arteries:
Visualization and quantitation
by a microscopic three-dimensional computed tomography technique**



Kwon et al. JACC 1998



Coronary Artery Calcification From Mechanism to Molecular Imaging



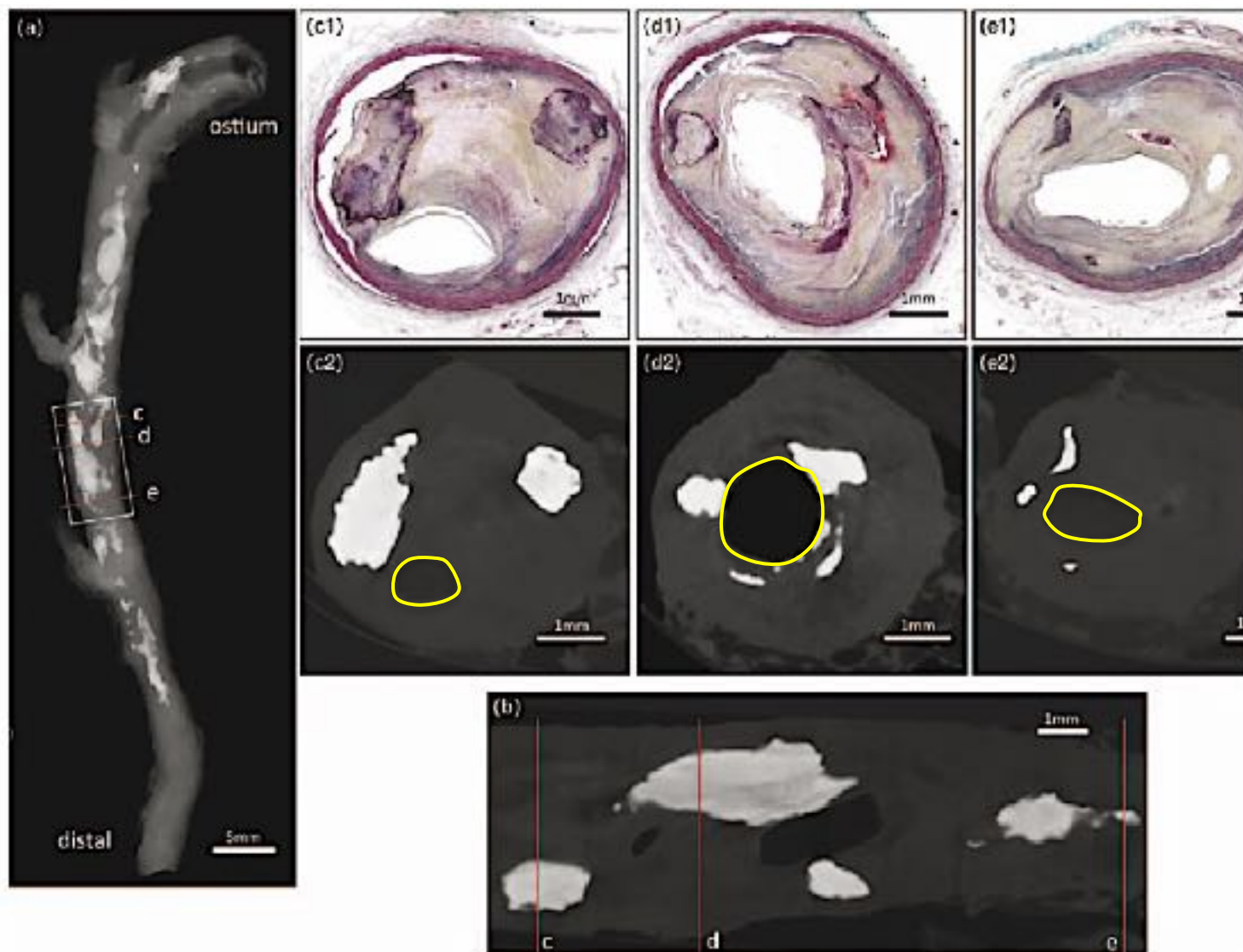
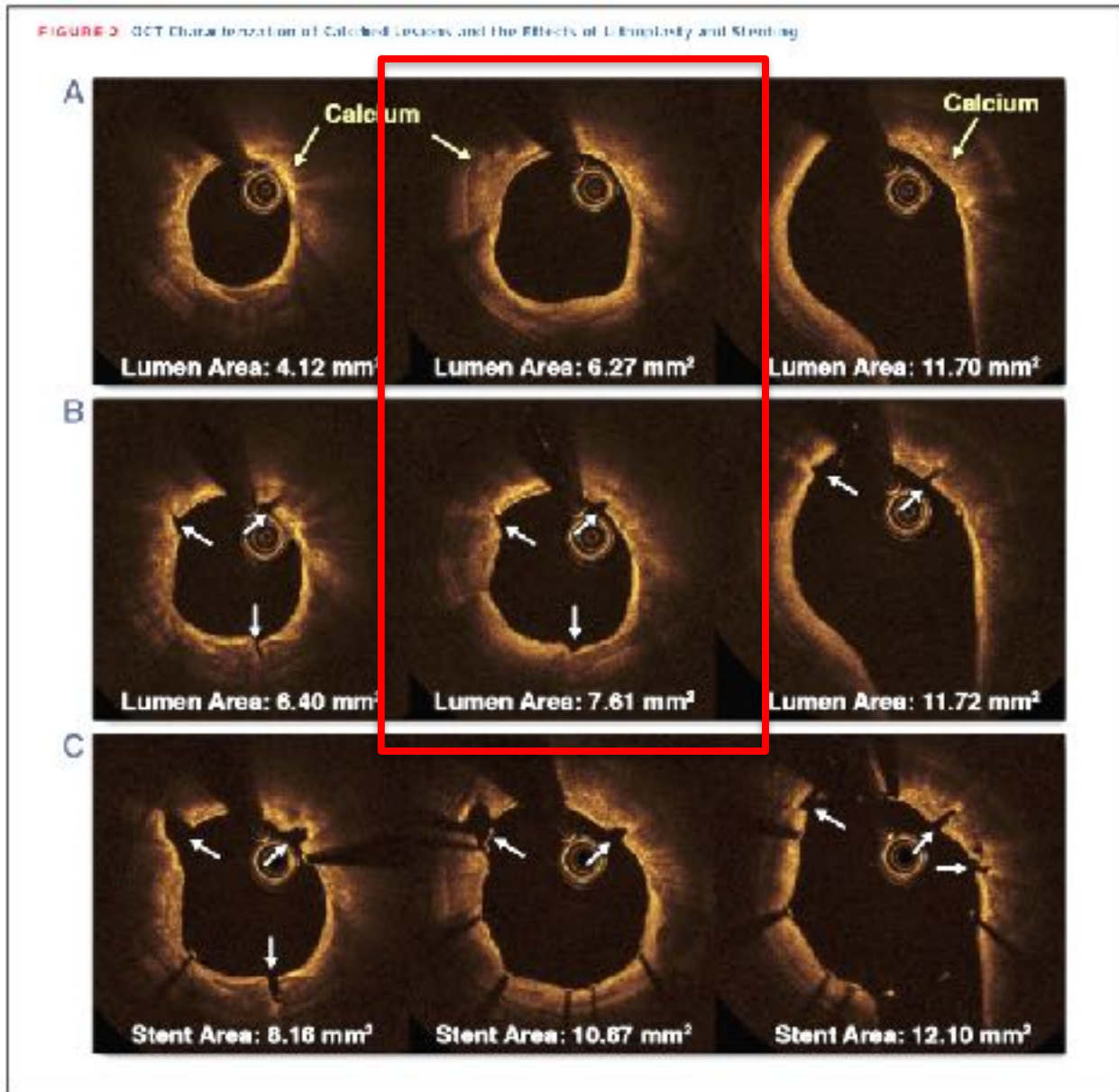


FIGURE 2. Detection of calcific morphologies of human coronary artery via high-resolution micro computed tomography. An 81-year old men autopsy case. (a) Radiography showed diffuse calcification in middle portion of right coronary artery. (b) Longitudinal image of high-resolution micro computed tomography (micro CT) image that corresponds to white rectangular area in radiograph. (c–e) Corresponding images of histology (1) (Movat staining) and transverse micro CT images (2) taken from the areas shown in radiograph and longitudinal micro CT image as red lines.

Optical Coherence Tomography Characterization of Coronary Lithoplasty for Treatment of Calcified Lesions



Optical Coherence Tomography Characterization of Coronary Lithoplasty for Treatment of Calcified Lesions

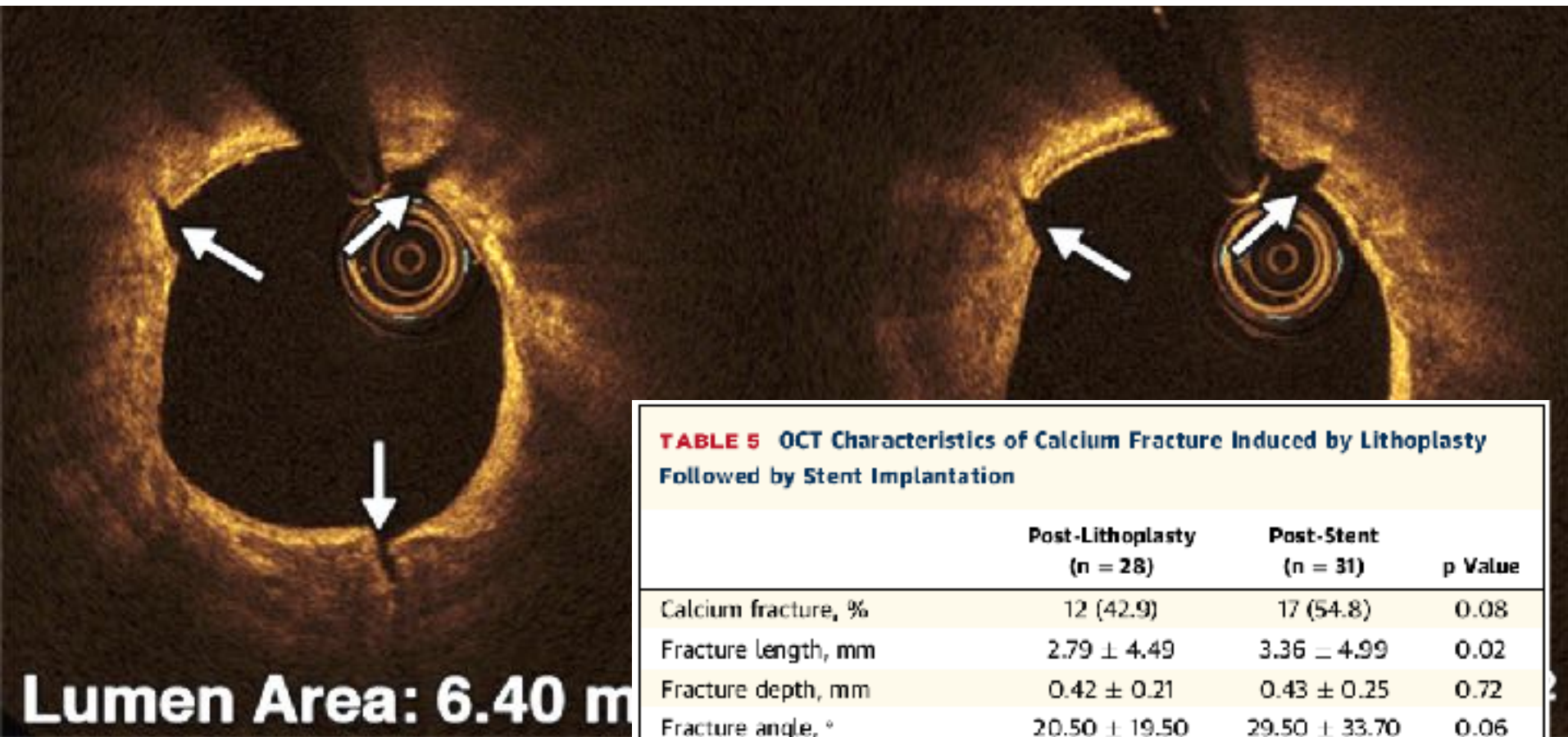


TABLE 5 OCT Characteristics of Calcium Fracture Induced by Lithoplasty Followed by Stent Implantation

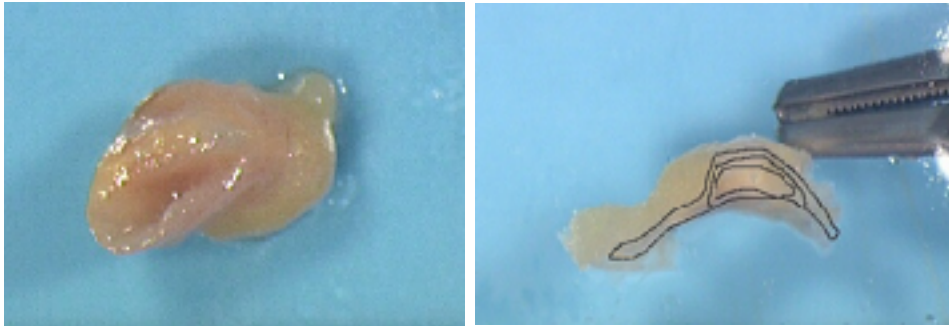
	Post-Lithoplasty (n = 28)	Post-Stent (n = 31)	p Value
Calcium fracture, %	12 (42.9)	17 (54.8)	0.08
Fracture length, mm	2.79 ± 4.49	3.36 ± 4.99	0.02
Fracture depth, mm	0.42 ± 0.21	0.43 ± 0.25	0.72
Fracture angle, °	20.50 ± 19.50	29.50 ± 33.70	0.06
Calcium fractures per lesion	0.00 (0.00–1.50)	1.00 (0.00–2.00)	0.03
Multiple calcium fracture/frame	7 (26.2)	9 (29)	0.34

Values are n (%), mean ± SD, or median (interquartile range).

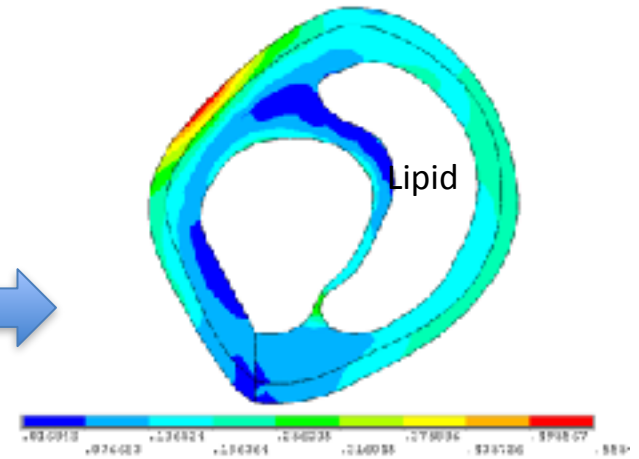
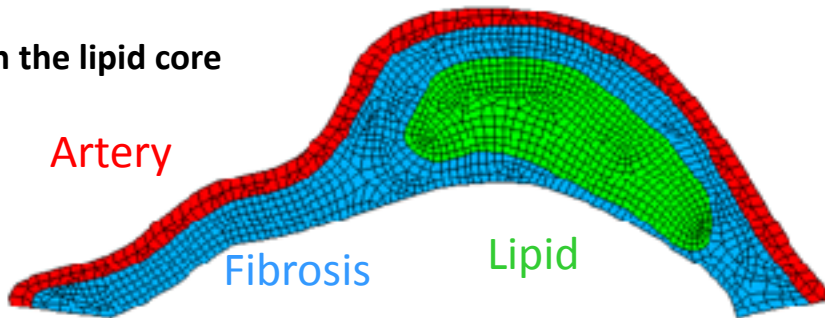
OCT = optical coherence tomography.

Contraintes résiduelles d'une artère coronaire

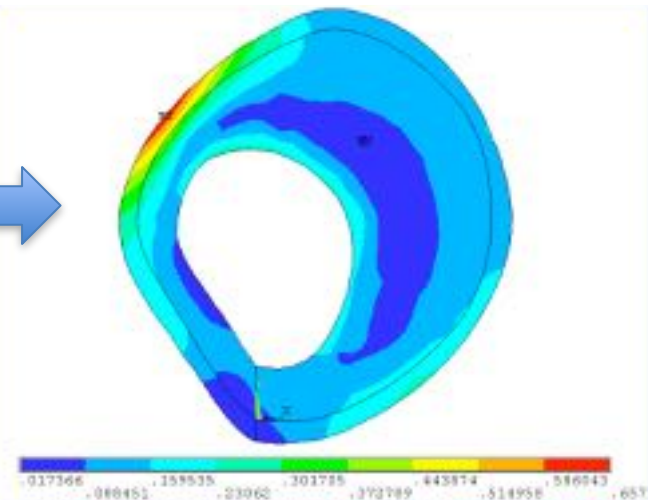
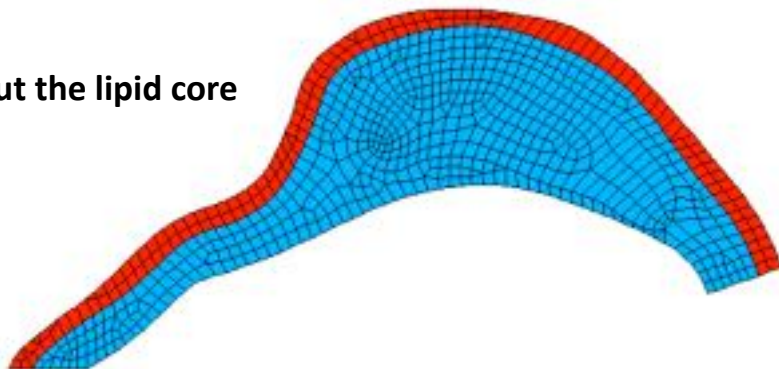
Explications biomécaniques (I)



with the lipid core

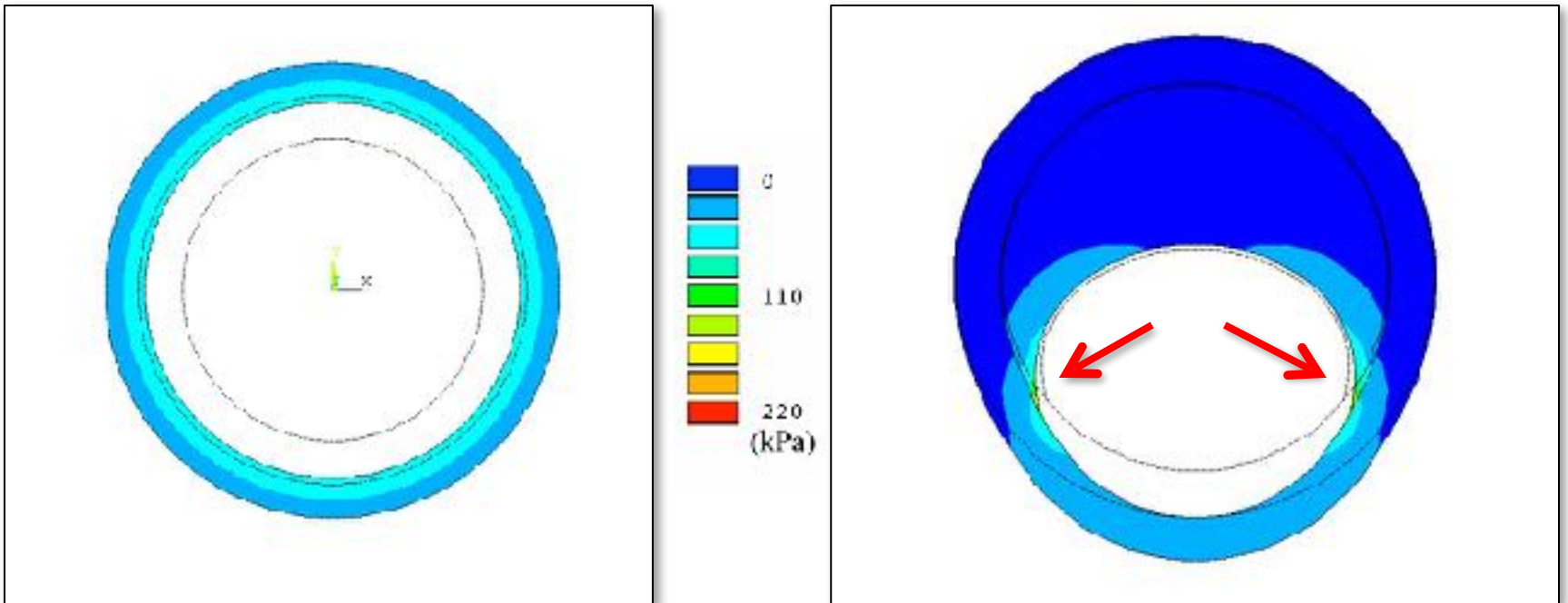


without the lipid core



Excentricité et contraintes circonférentielles

Explications biomécaniques (II)

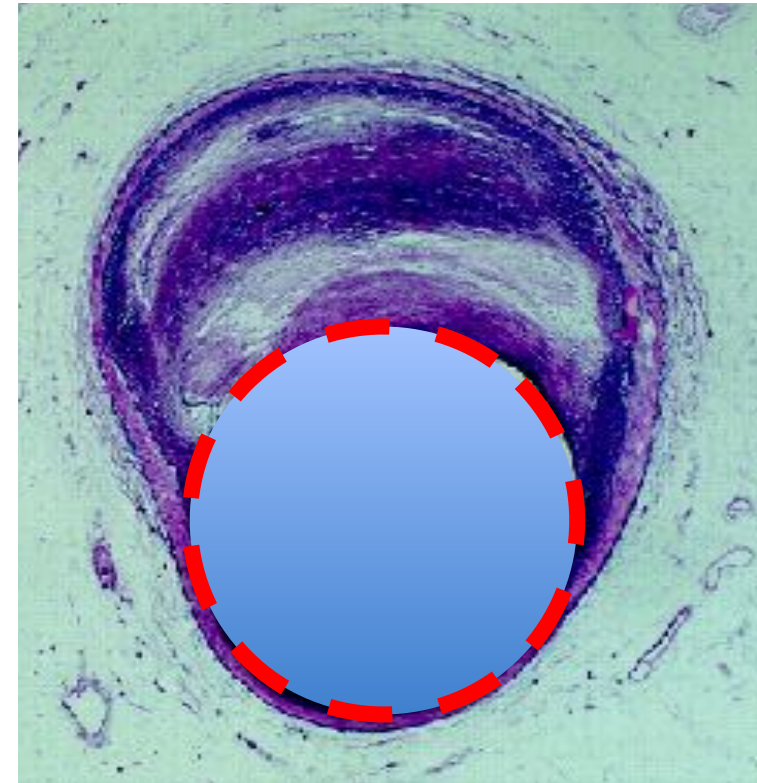
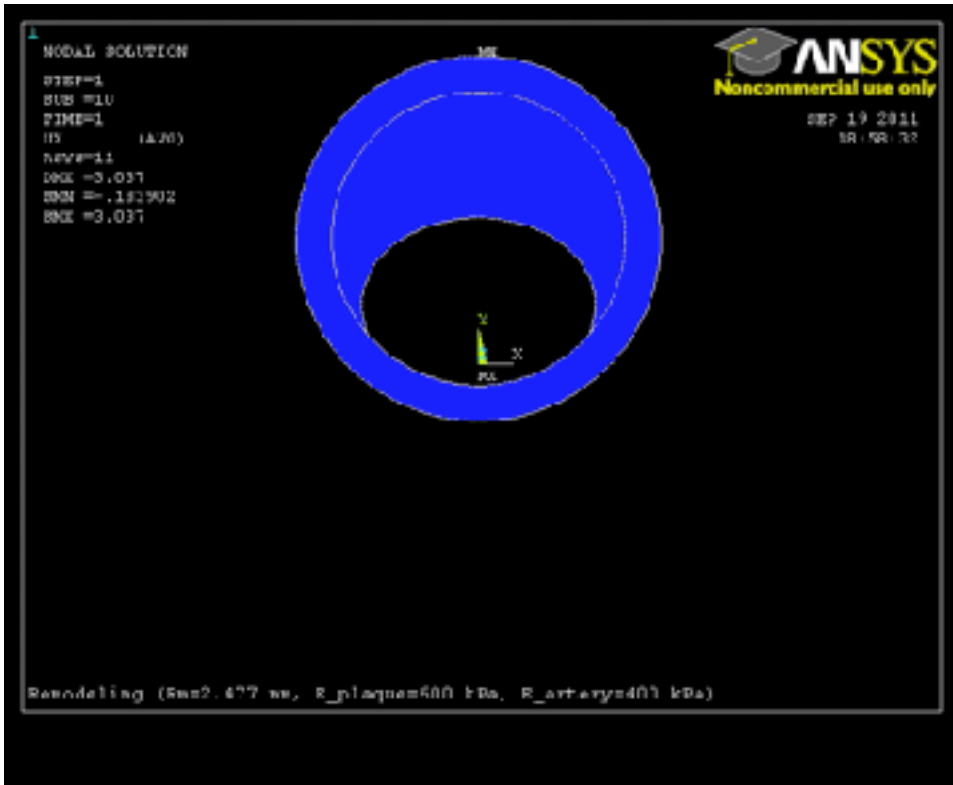


Impact de la rigidité des matériaux d'une plaque athéroscléreuse

Explications biomécaniques (III)

Déformations radiales au cours d'un stenting

Stent implanté



Les plaques et les artères sont:

Incompressibles (Poisson's modulus - ν)

Anisotropes

Hyperélastiques (Young's modulus - E)

Hétérogènes

$E_{media} = 150 \text{ kPa}$

$E_{core} = 1 \text{ to } 20 \text{ kPa}$

$E_{hypocellular \text{ fibrosis}} = 500 \text{ kPa}$

$E_{dense \text{ fibrosis}} = 1000 - 3000 \text{ kPa}$

$E_{calcification} \geq 5000 - 10\,000 \text{ kPa}$

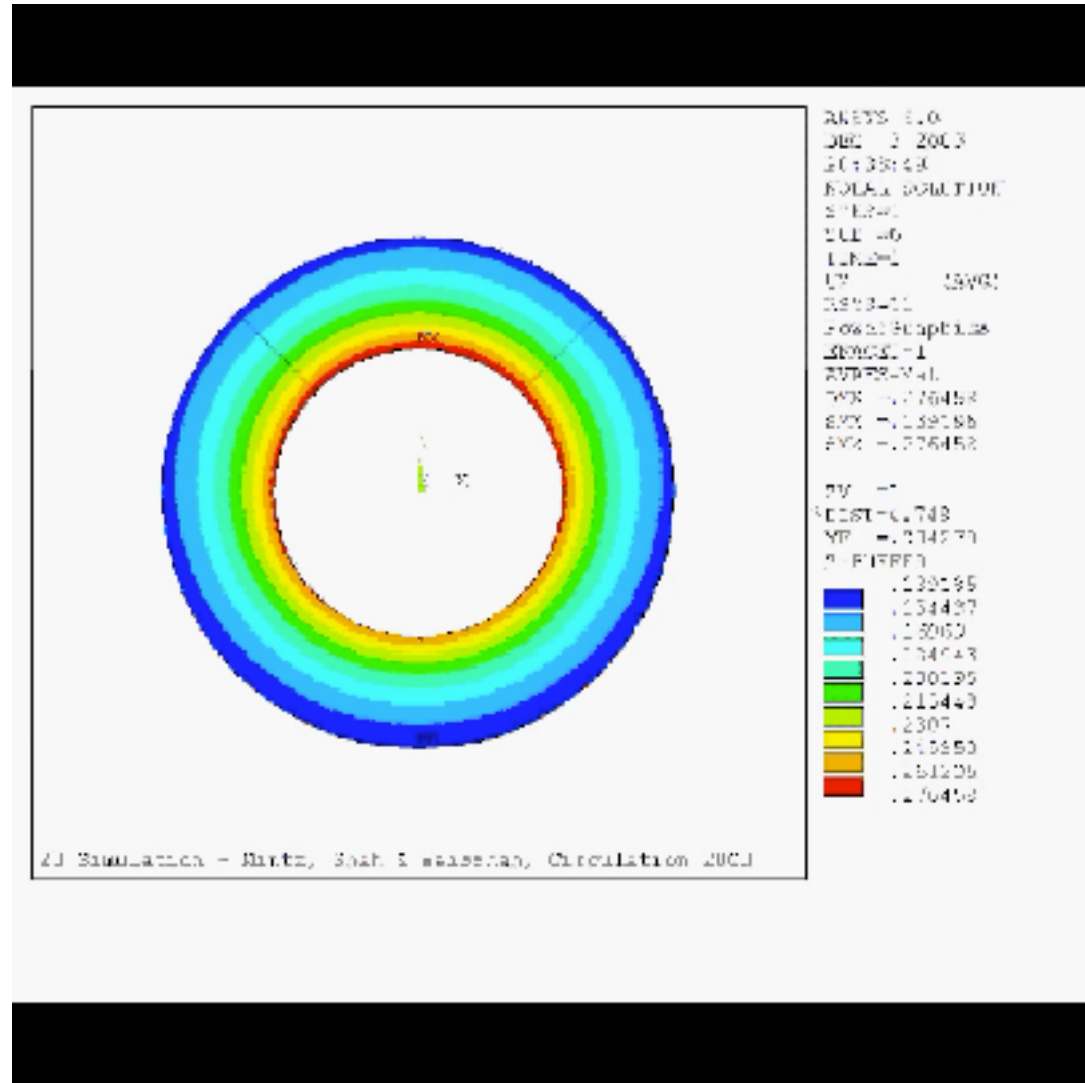
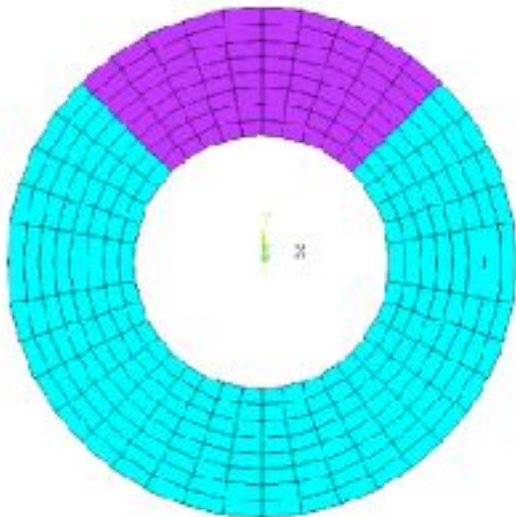
NB : 1 atm = 100 kPa = 750 mmHg

Remodelage focal d'une artère coronaire

Explications biomécaniques (IV)

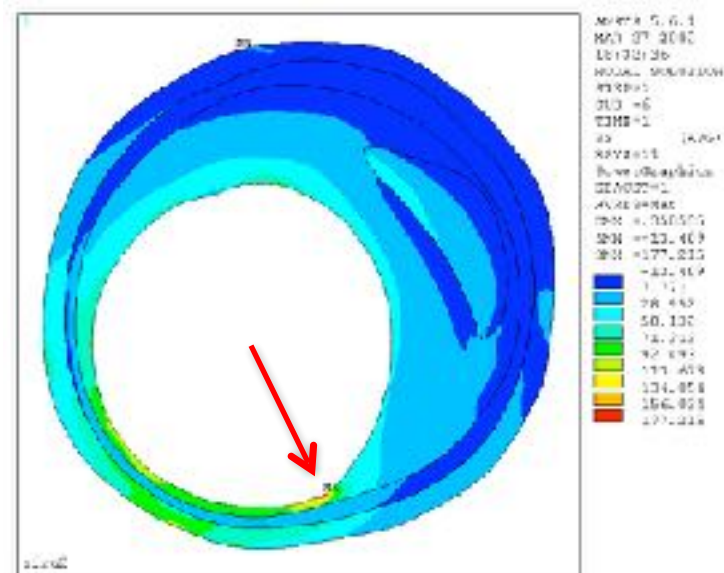
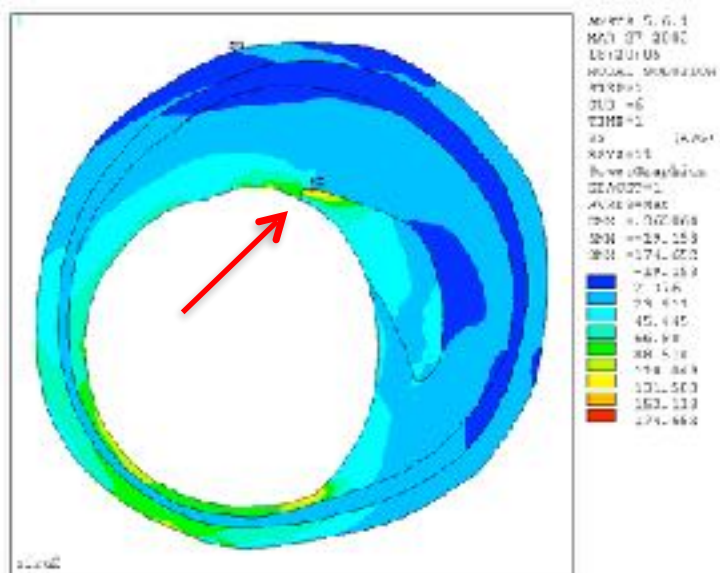
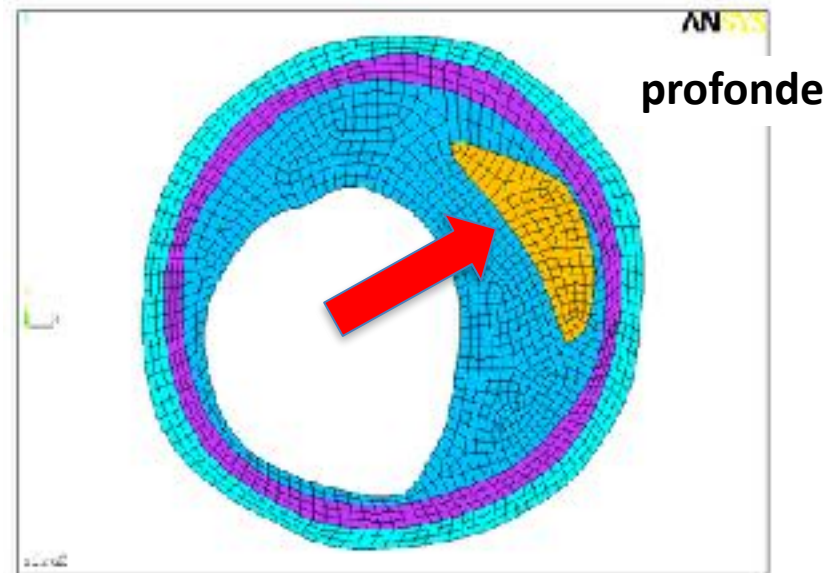
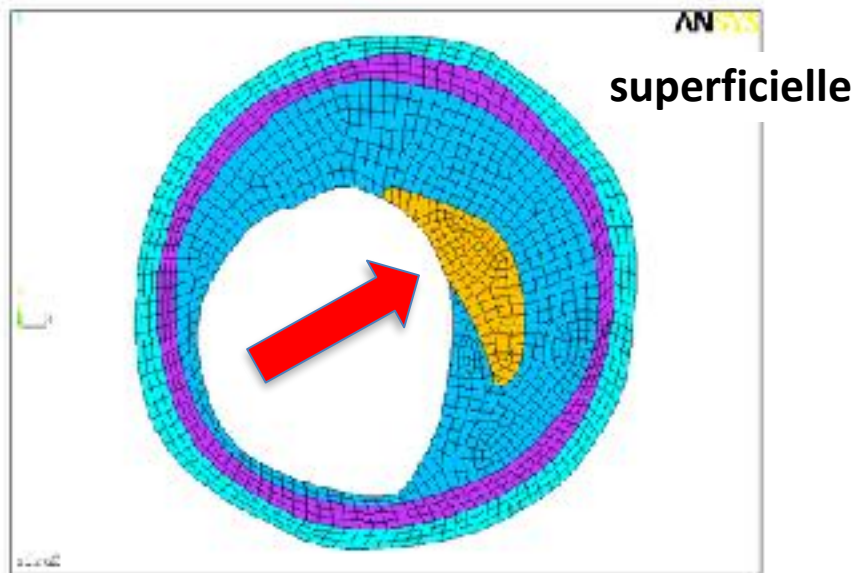
Constant pressure = 100 mmHg

Young's modulus
 E : 400 kPa to 100 kPa



Impact de la localisation d'une calcification massive

Explications biomécaniques (V)



Expansion lumineuse par réduction des contraintes superficielles

Augmentation de la compliance de la paroi coronaire

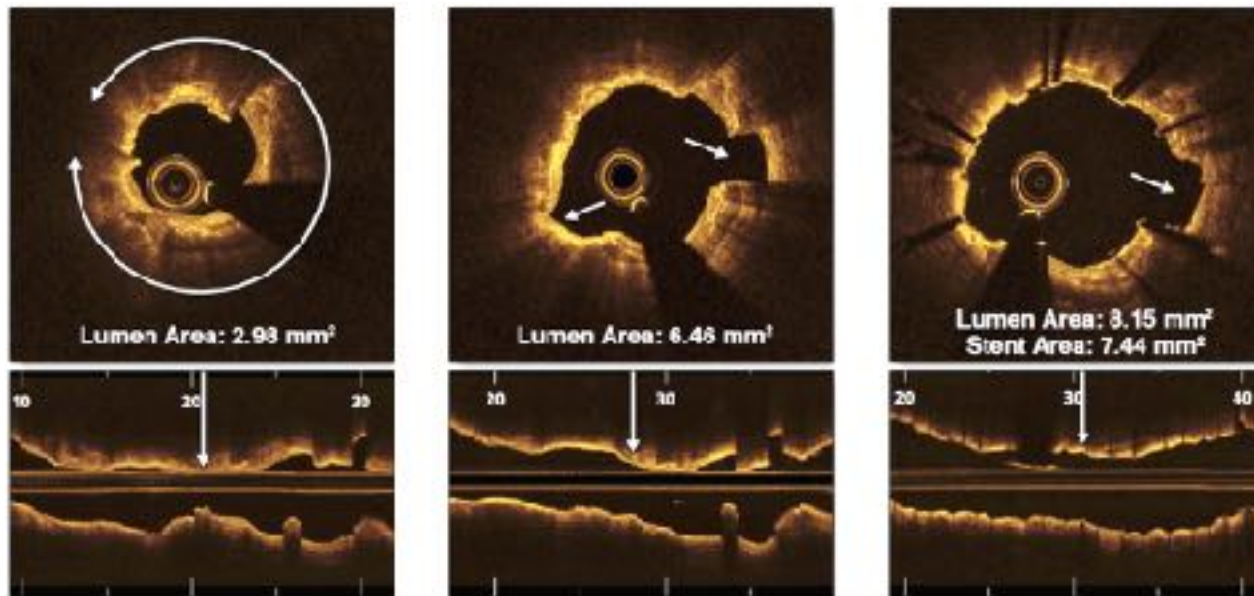


TABLE 4 Serial Measurements of Calcified Coronary Lesions on OCT

	Pre-Lithoplasty	Post-Lithoplasty	Post-Stent	p Value		
				Pre- vs. Post-Lithoplasty	Post-Lithoplasty vs. Post-Stent	Pre-Lithoplasty vs. Post-Stent
Pre-lithoplasty at maximum calcium site	26	24	25	-	-	-
Lumen area, mm ²	4.04 ± 2.02	5.71 ± 1.94	8.30 ± 3.00	<0.001	<0.001	<0.001
Calcium angle, °	229.00 ± 93.00	217.00 ± 81.40	198.00 ± 100.00	0.057	<0.001	0.085
Max calcium thickness, mm	0.97 ± 0.25	0.94 ± 0.23	0.94 ± 0.24	0.400	0.071	0.358
Stent area, mm ²	-	-	7.98 ± 2.85	-	-	-
Stent expansion, %	-	-	112.00 ± 32.50	-	-	-
Acute area gain, mm ²	-	1.69 ± 1.63	4.18 ± 1.93	-	-	<0.001

Résumé

- ✓ Les processus inflammatoires de l'ATS génèrent des calcifications coronaires médiales (profondes) ou intimaux (\pm superficielles)
- ✓ Les calcifications profondes de la média ont un effet plutôt « stabilisant » de la plaque
- ✓ Les calcifications superficielles intimaux (microcalcifications) sont reconnues pour avoir un effet plutôt « déstabilisant » de la plaque
- ✓ L'impact des calcifications intimaux juxta-luminales est prédominant en biomécanique vasculaire
- ✓ Les couches artérielles juxta-luminales sont le siège de contraintes circonférentielles maximales imposées à la paroi coronaire
- ✓ Toute fracturation ou fragmentation dans ces couches est biomécaniquement compatible avec une modification de leur rigidité (réduction du module de Young) et donc avec une augmentation de la compliance artérielle ($\Delta S/\Delta P$).