Revascularization Strategies for Calcified Vessels

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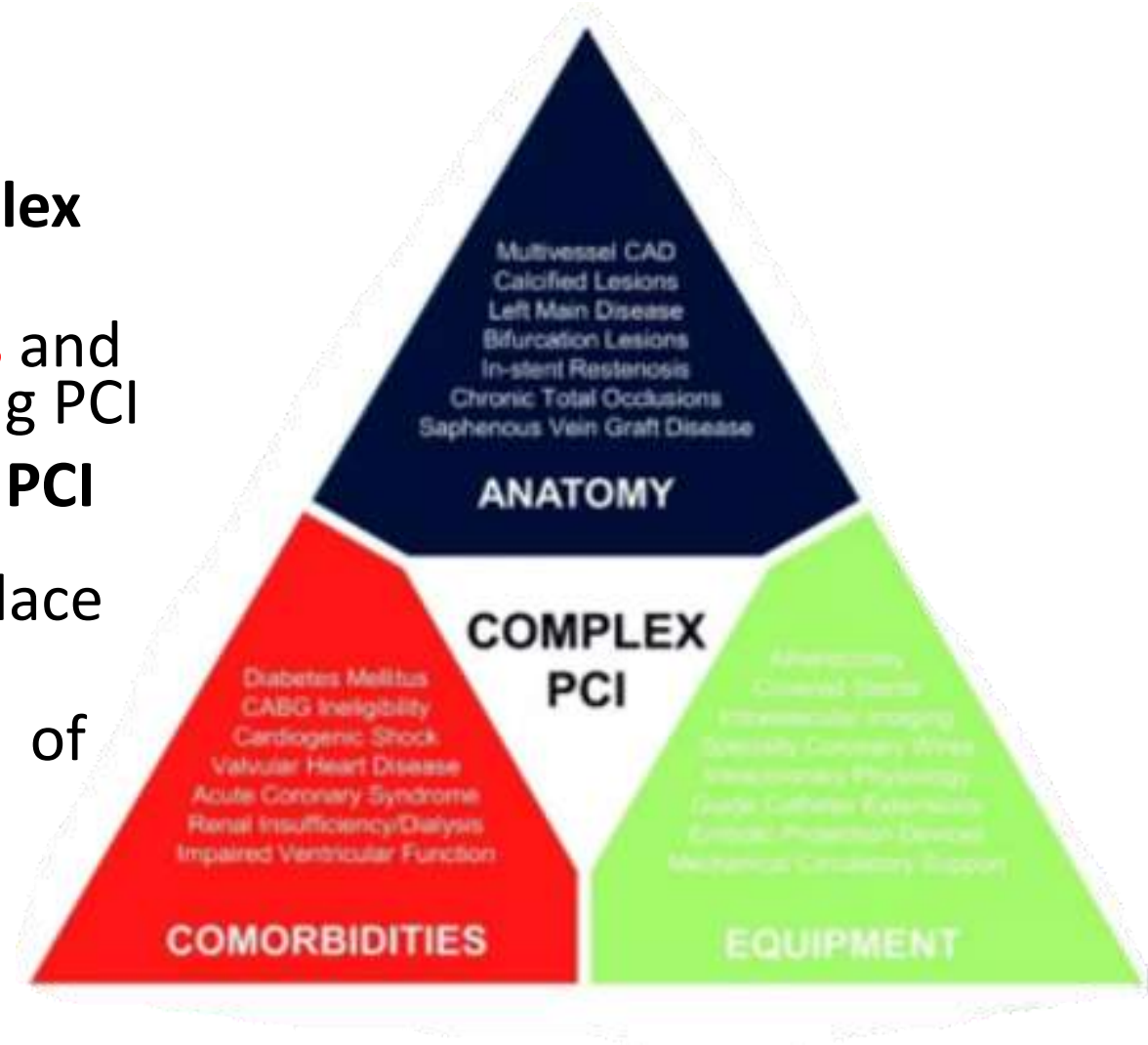
Potential conflicts of interest

✓I do not have any potential conflict of interest to report

CORONARY ARTERY CALCIFICATION

- Coronary lesions with severe calcification are classified as **complex lesions**
- Known to carry **lower succes rates** and **higher complication** rates following PCI
- Poses **technical challenges during PCI** are stent underexpansion, malapposition or the inability to place stent
- May **damage the polymer coating** of DES



CLASSIFICATION OF CORONARY ARTERY CALSIFICATION

TYPE A

- Length< 10mm
- Discrete
- Consentric readily accessible
- <45 degree angle
- Smooth contour
- Little or no calcification
- Less than totally ocluded
- Not osteal
- No major side branch involvement
- Absence of thrombus

TYPE B

- Length 10-20 mm
- Eccentric
- Moderate tortuousity of proximal segment
- 45-90 degree angle
- Irregular contour
- Precence of any thrombous grade
- Moderate or heavily calcification
- Total occlusion < 3months old
- Osteal lesion
- Bifurcation lesion requiring 2 guidewire

TYPE C

- Length > 20mm
- Difuse
- Excessive tortuosity of prox segment
- 90 degree angle
- Total occlusion > 3 months old
- Degenerative ven greft

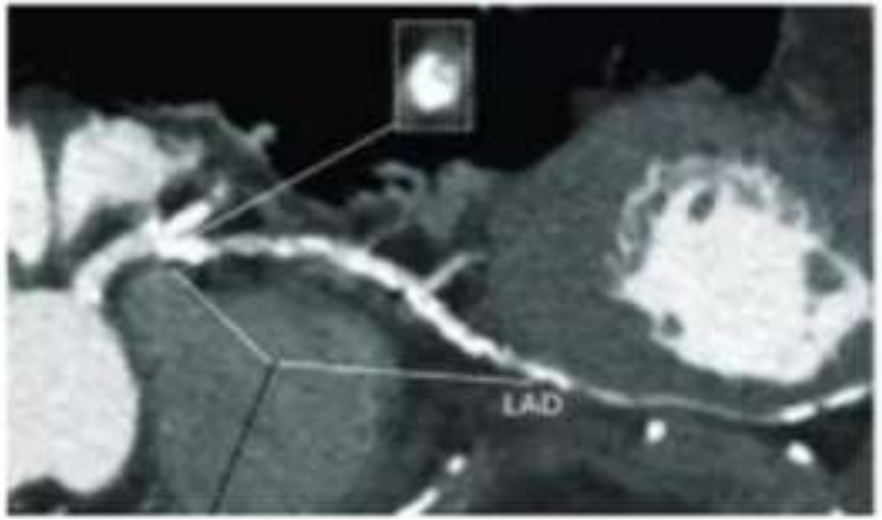
IMAGING MODALITIES

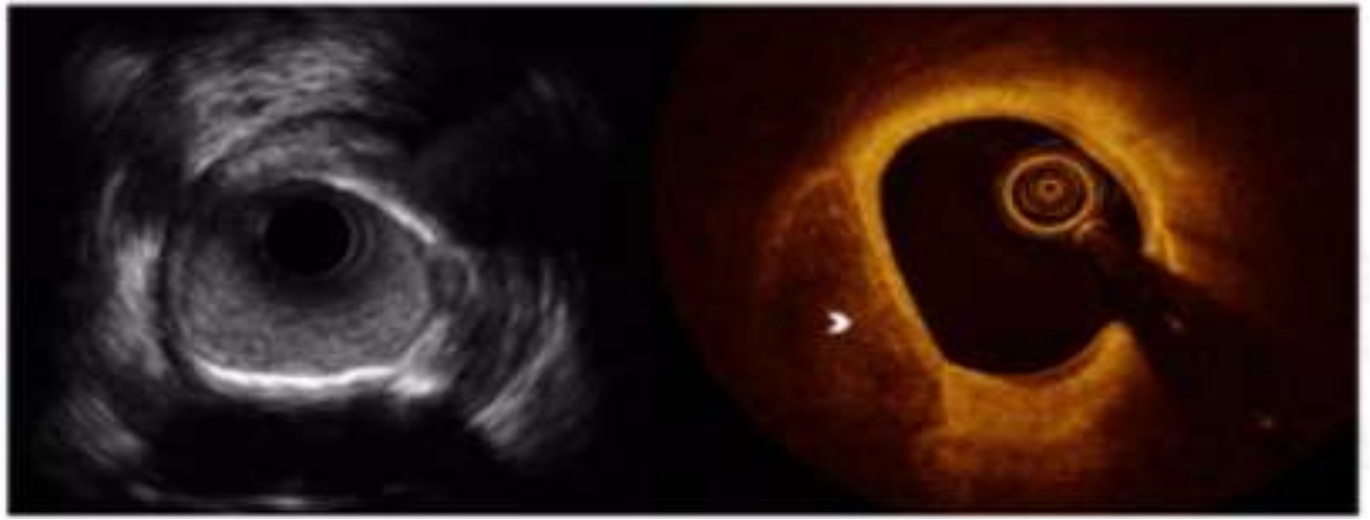
Imaging modalities for identifying and characterizing calcified coronary lesions:

- **Coronary Angiography**
- **Coronary CT Angiography**
- **Intravascular Imaging :**

  Intravascular ultrosound (IVUS)

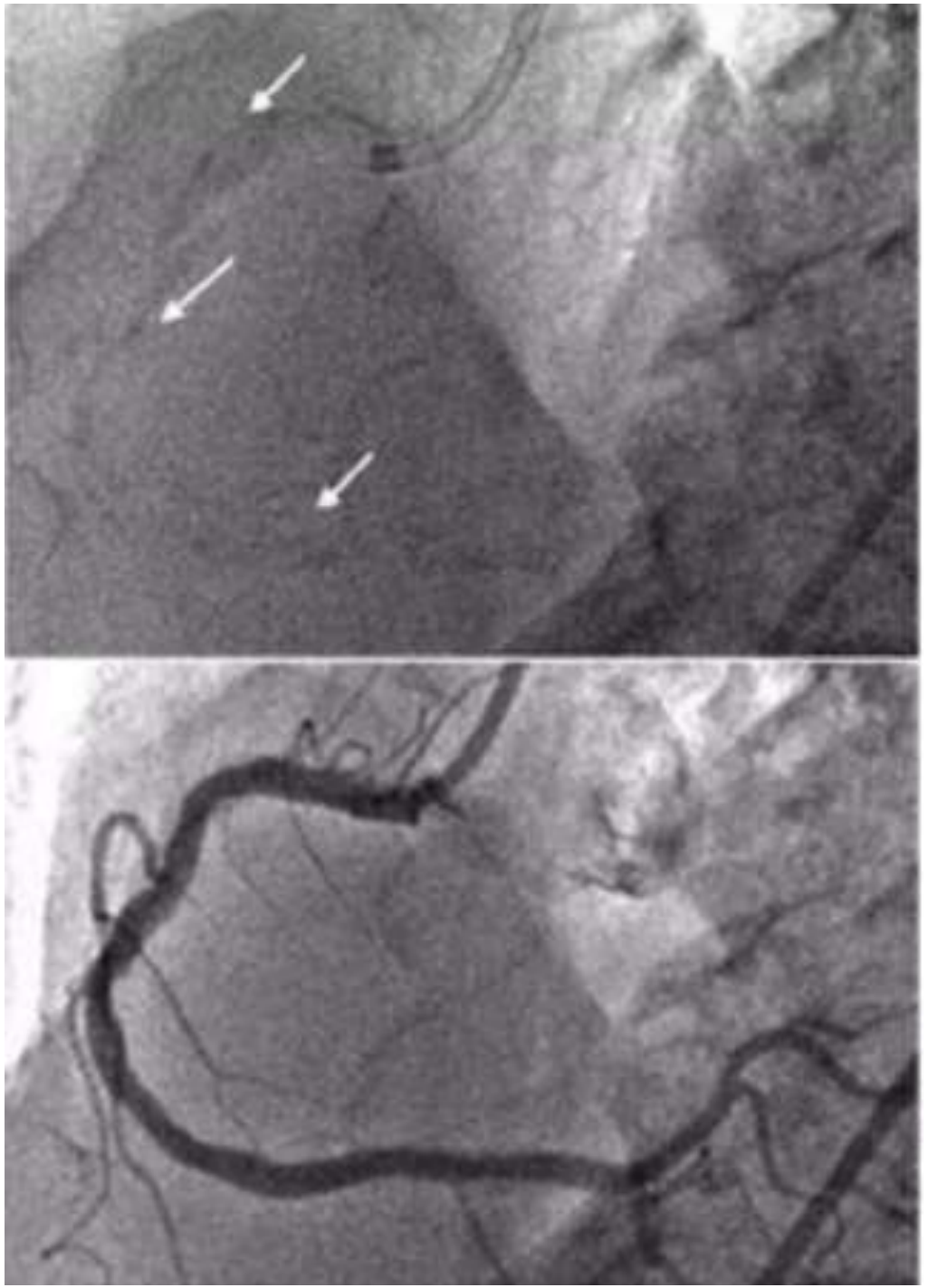
  Optical coherence tomography (OCT)



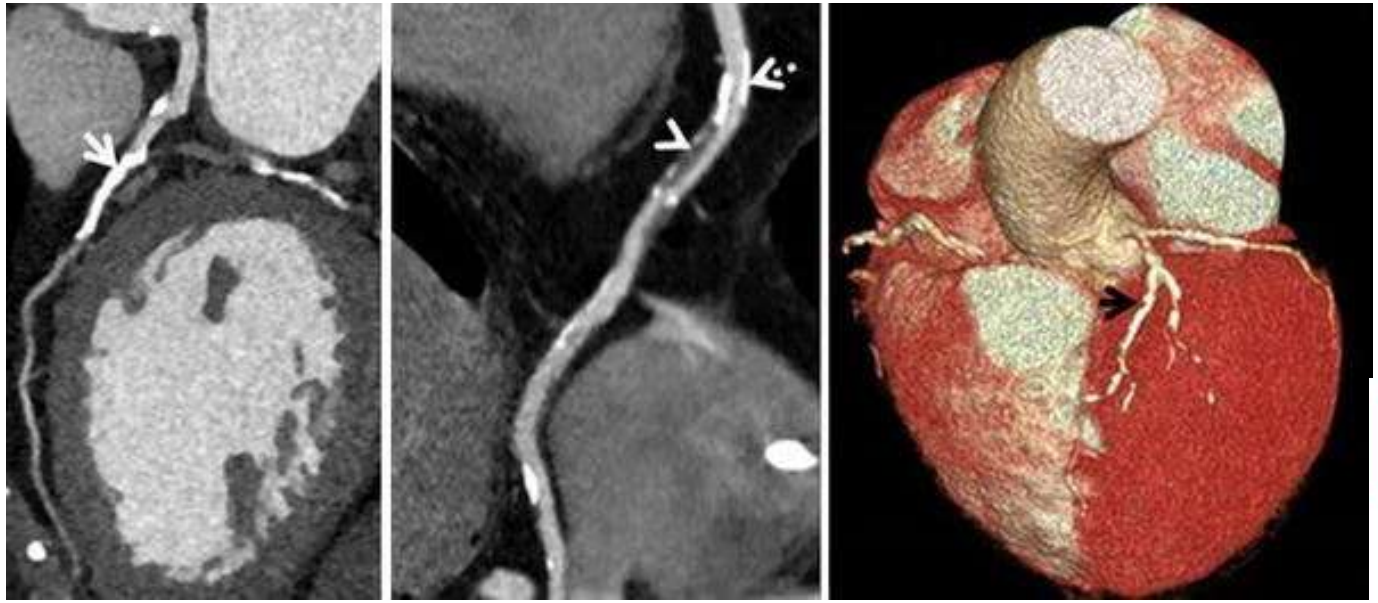


CORONARY ANGIOGRAPHY

- **Calcified lesions** will appear as an area of attenuation of the X-rays:
  - Visible already before the contrast injection
  - Arranged along the contour of the vessel
  - Moves with heart movement
- Angiography alone has been shown to have **low sensitivity** in identifying calcified lesions→necessary to combine with intravascular imaging



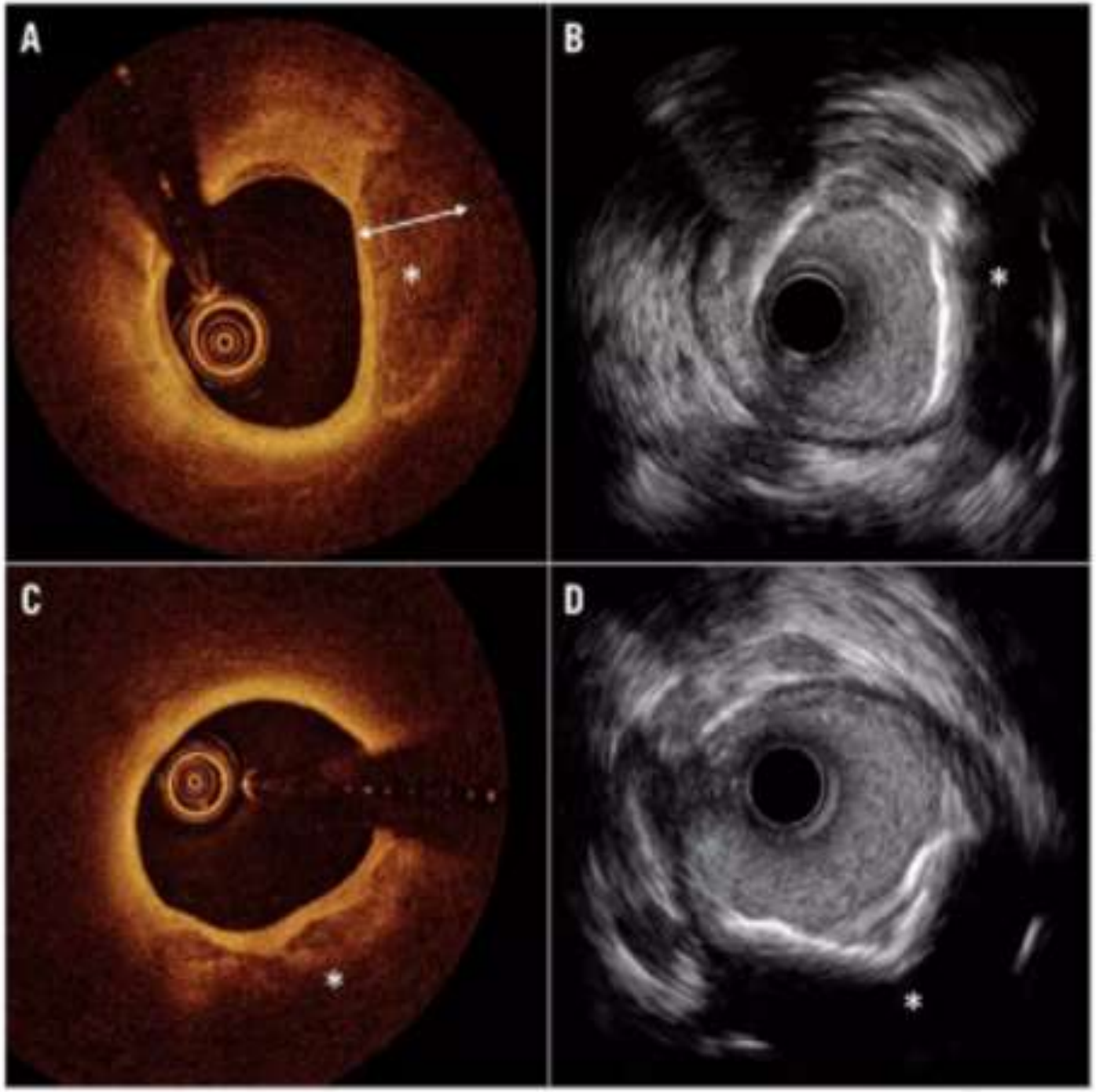
Coronary CT Angiography (CCTA)



CCS (Agaston)	Risk	Description
0	Non-identified	Negative test. Findings are consistent with a low risk of having a cardiovascular event in the next 5 years.
1-10	Minimal	Minimal atherosclerosis is present. Findings are consistent with a low risk of having a cardiovascular event in the next 5 years.
11-100	Mild	Mild coronary atherosclerosis is present. There is likely mild or minimal coronary stenosis. A mild risk of having CAD exists.
101-400	Moderate	Moderate calcium is detected in the coronary arteries and confirms the presence of atherosclerotic plaque. A moderate risk of having a cardiovascular event exists.
>400	High	A high calcium score may be consistent with significant risk of having a cardiovascular event within the next 5 years

IVUS/OCT

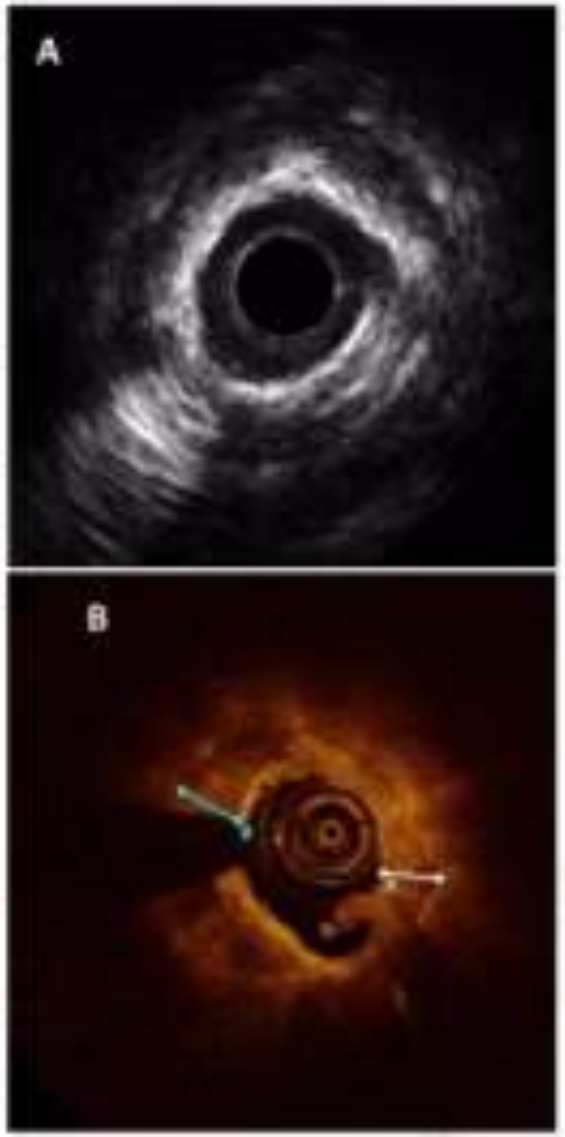
- The use of intracoronary imaging to guide PCI **improves procedural and long-term clinical outcomes**
- Provide important insights into coronary lesion morphology →**detecting,localizing and quantifying** coronary calcification
- Assist with assessing the need for lesion preparation,stent sizing, minimizing geographic miss, verifying stent expansion,evaluating complicatons and identifying causes of stent failure



Severity Classification

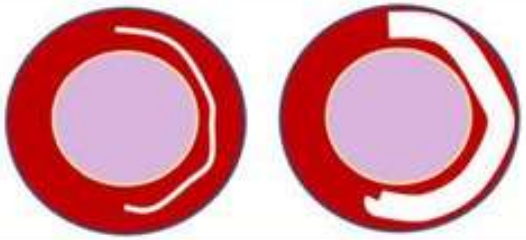
Severity	IVUS-Based Calcium Score 1. Length of Calcium (>270°) of >5 mm (1 Point) 2. Presence of 360° Circumferential Calcium (1 Point) 3. Vessel Diameter of ≤3.5 mm (1 Point) 4. Presence of a Calcified Nodule (1 Point)
Mild to moderate	0–1
Severe	≥2

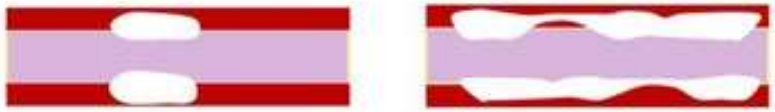
Severity	OCT-Based Calcium Score 1. Calcium Arc of >180° (2 Points), 90–180° (1 Point) 2. Calcium Length of >5 mm (1 Point) 3. Calcium Thickness of >0.5 mm (1 Point)
Mild to moderate	0–3
Severe	≥4



Calcium distribution

Eccentricity	Calcific Arc (degrees or quadrants)	Eccentric Calcium Concentric Calcium Calcium Ring (360°)
Depth	Distance from Lumen Profile	Protruding *("nodule")* Superficial Deep
Thickness	Max Calcium Thickness	Thin Thick
Length	Longitudinal Extension	Focal Long





Comparison of Imaging techniques of CAC

FIGURE 1 Comparison of Imaging Techniques for Coronary Calcium Detection, Characterization, and Quantification

Diagnostic Accuracy	Angiography	IVUS	OCT
Severe LHCC	●●●	●●●	●●●
Mild/Moderate LHCC	●	●●	●●●
Deep calcium	●	●●●	●●
Calcium arch	X	●●●	●●●
Calcium thickness	X	X	●●●
Longitudinal calcium length	X	●	●●●
Non-homogeneous plaque / Necrotic core	X	●●●	●

●●● Optimal ●● Moderate ● Modest

Comparison of imaging techniques (angiography, intravascular ultrasound, and optical coherence tomography) for coronary calcium detection, characterization, and quantification. IVUS = intravascular ultrasound; LHCC = lesion with high calcium content; OCT = optical coherence tomography.

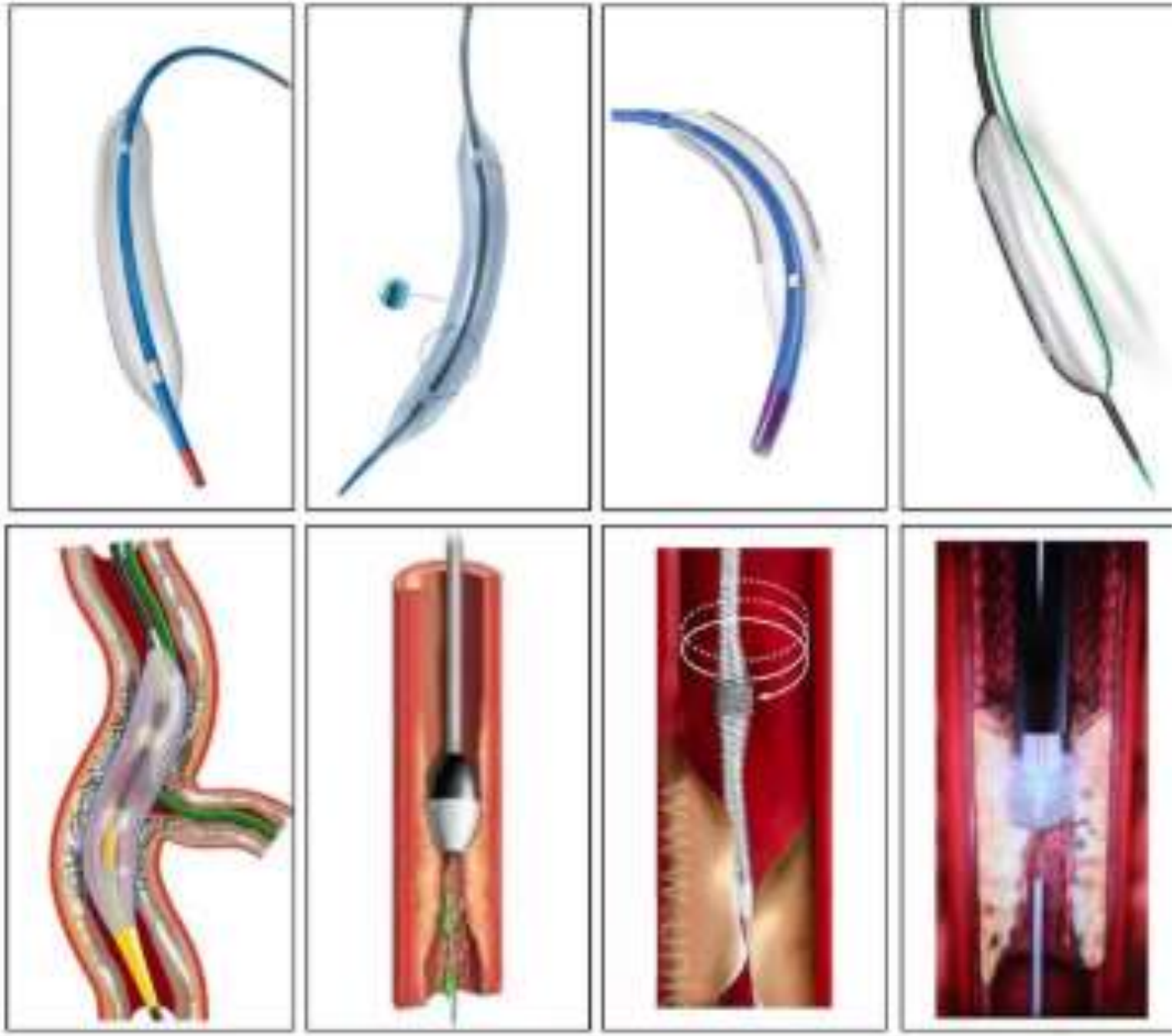
TECHNIQUES

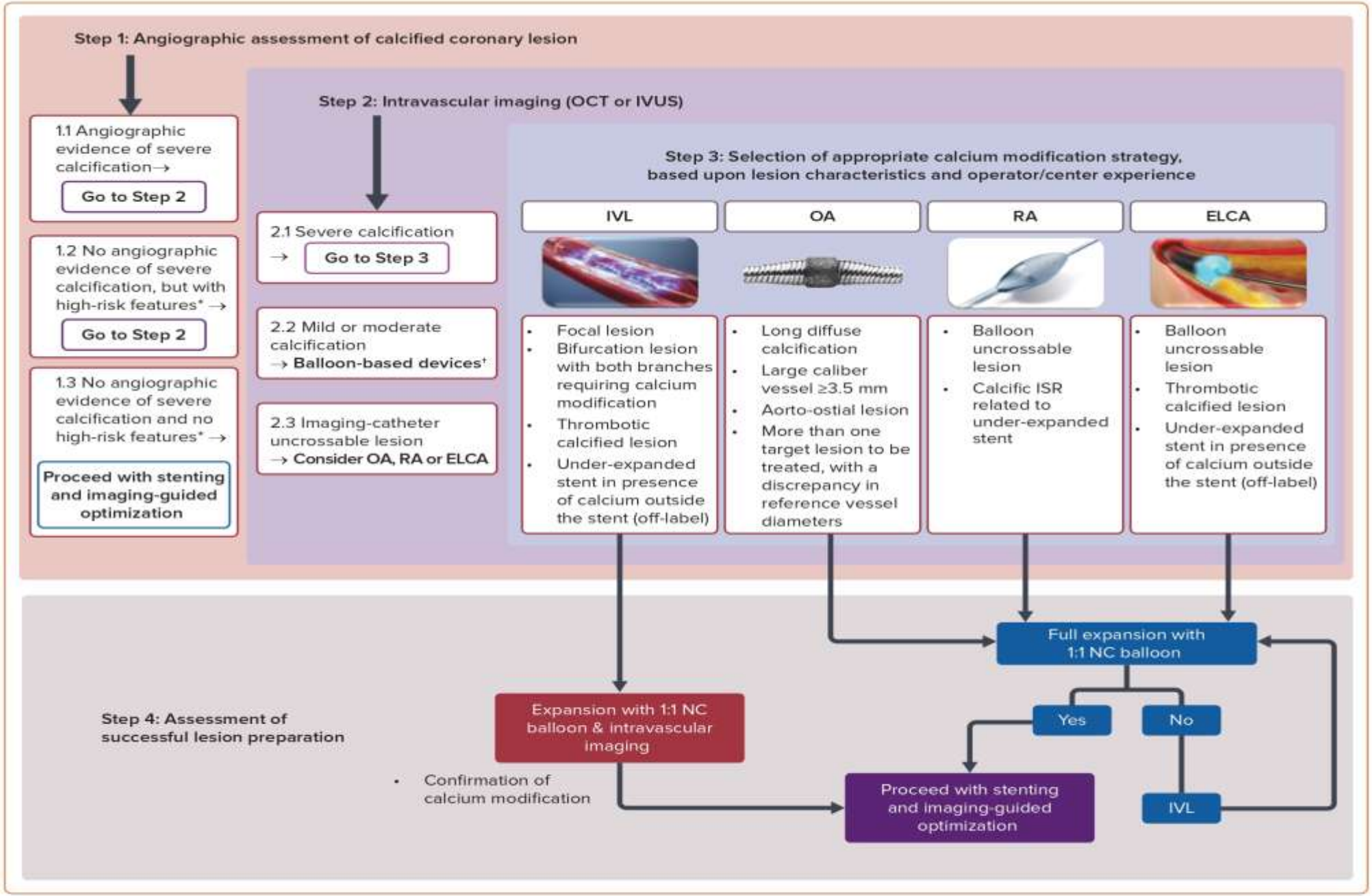
Balloon-Based Devices:

- Non-Compliant Balloons
- High-Pressure (Dual-Layer) Non-Compliant Balloons
- Cutting Balloons
- Scoring Balloons
- Intravascular Lithotripsy

Coronary Atherectomy:

- Rotational Atherectomy
- Orbital Atherectomy
- Laser Atherectomy



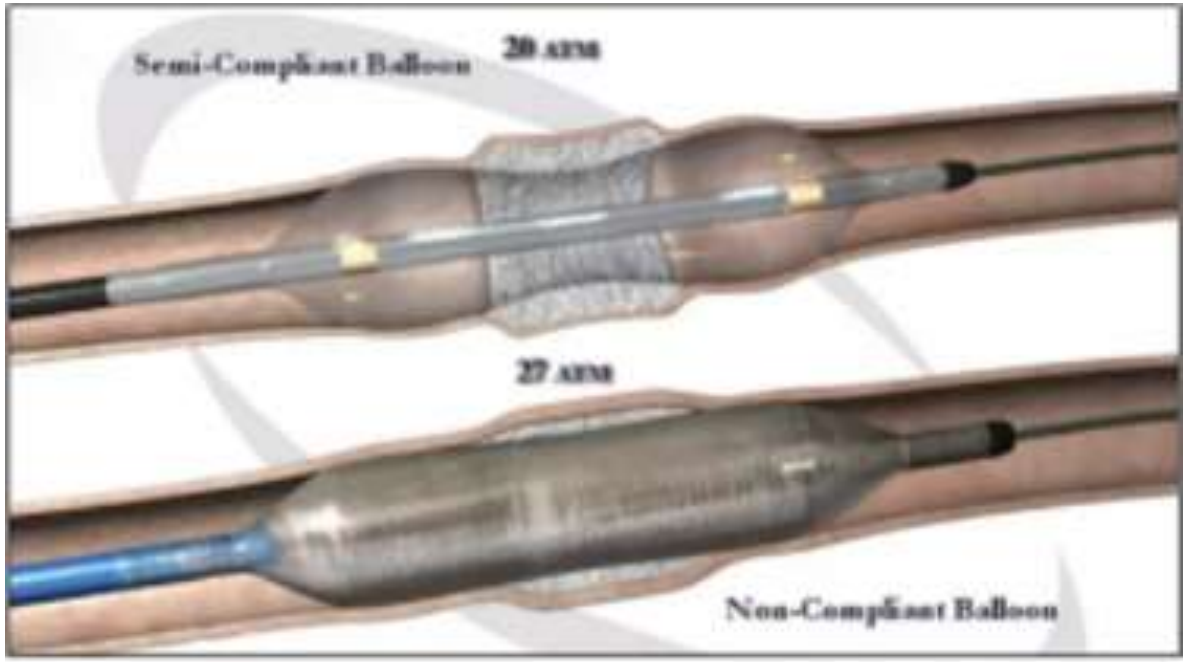


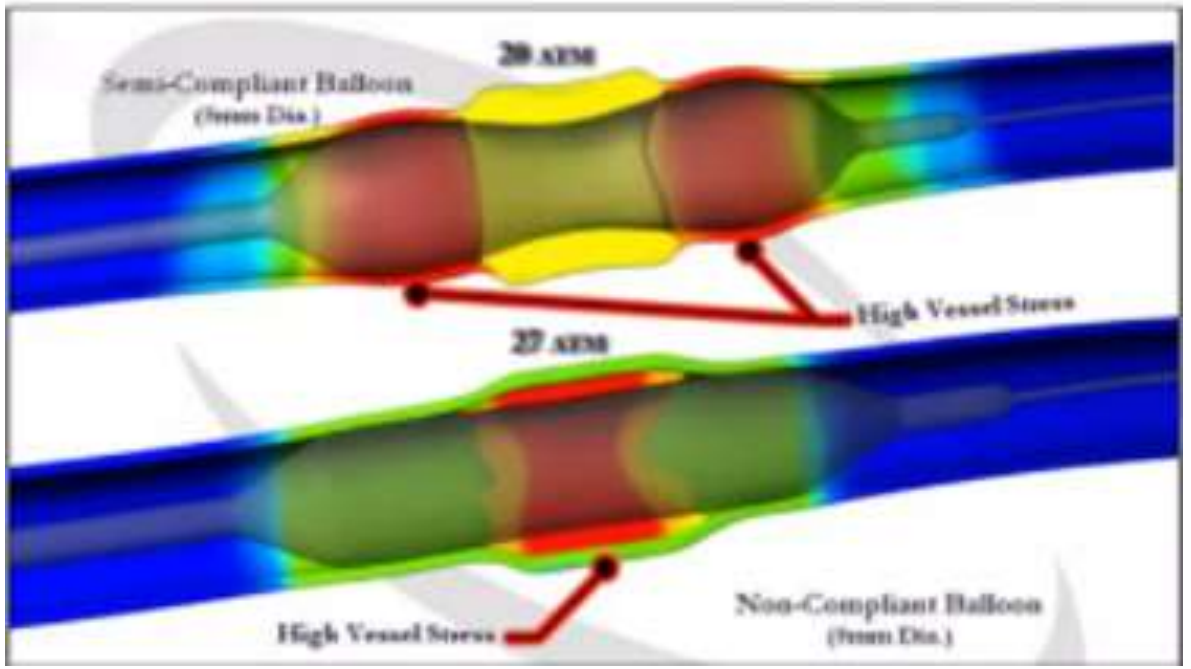
**High-risk features include end-stage renal disease, elderly age, smoking, hypertension, and diabetes. †Balloon-based devices include standard NC balloon angioplasty, high-pressure balloon angioplasty, scoring balloon angioplasty, and cutting balloon angioplasty. ELCA = excimer laser coronary angioplasty; ISR = in-stent restenosis; IVL = intravascular lithotripsy; IVUS = intravascular ultrasound; NC = non-compliant; OA = orbital atherectomy; OCT = optical coherence tomography; RA = rotational atherectomy. Source: Angsubhakorn et al. 2022.[59] Reproduced from MDPI under a Creative Commons CC BY-4.0 license.*

NON-COMPLIANT BALLON (NCB)

- **Single layer**
- Can be expanded to **high pressures** (20-24 atm)
- **Failure:**
  - **Eccentric calcium** → guidewire bias may direct force toward the non-calcified segments of the artery
  - **Concentric calcium**→insufficient force fails to induce calcium fracture

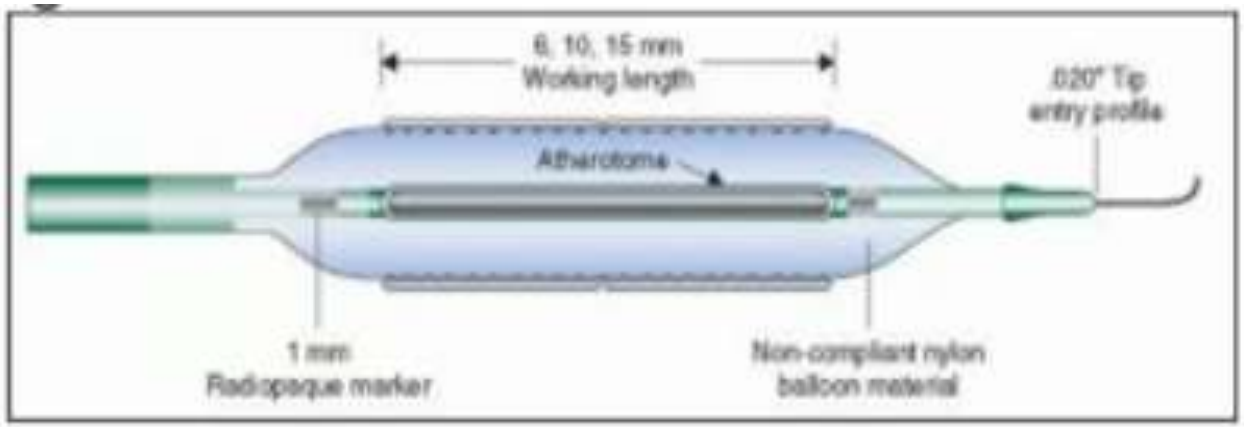
Possible complications: balloons rupture, vessel dissection or perforation

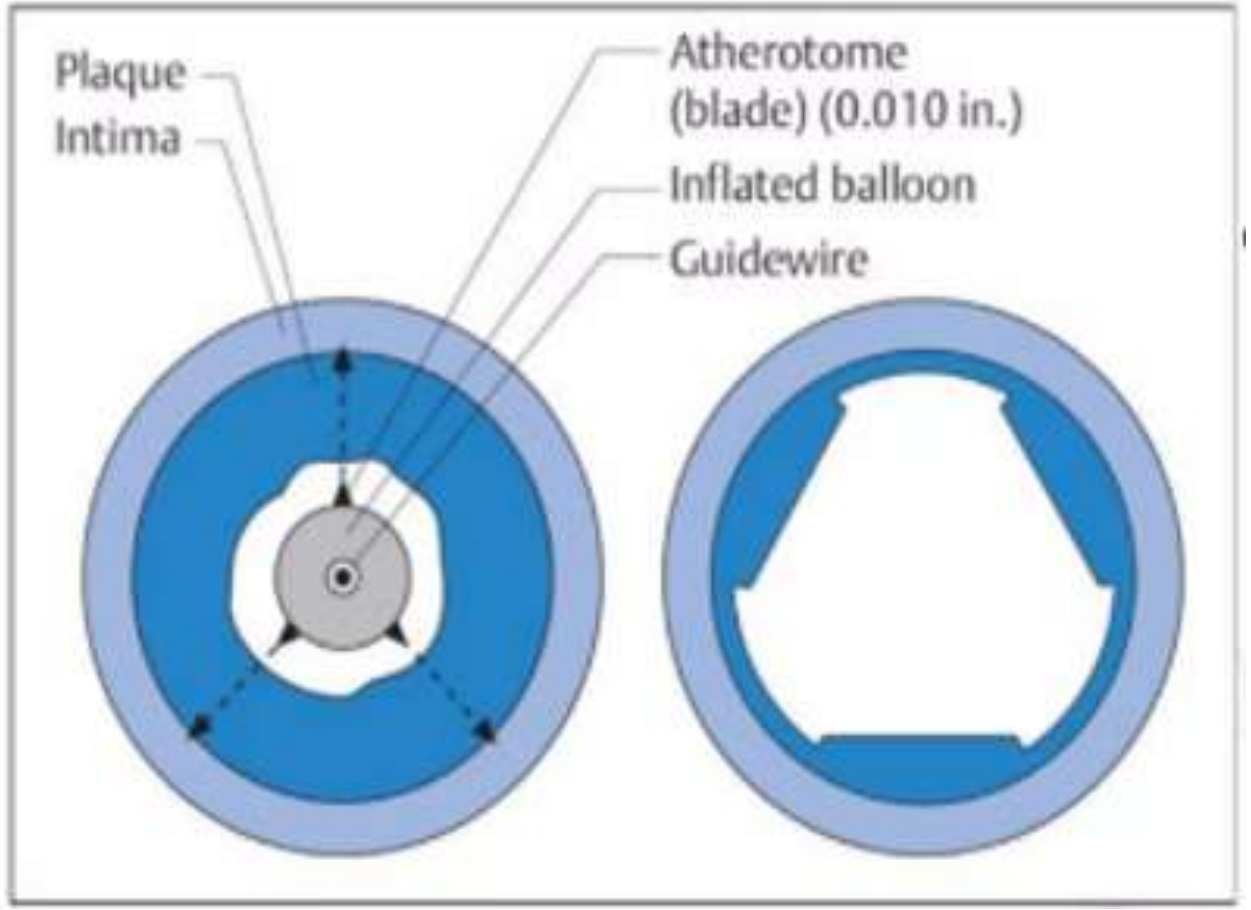




CUTTING BALLOON

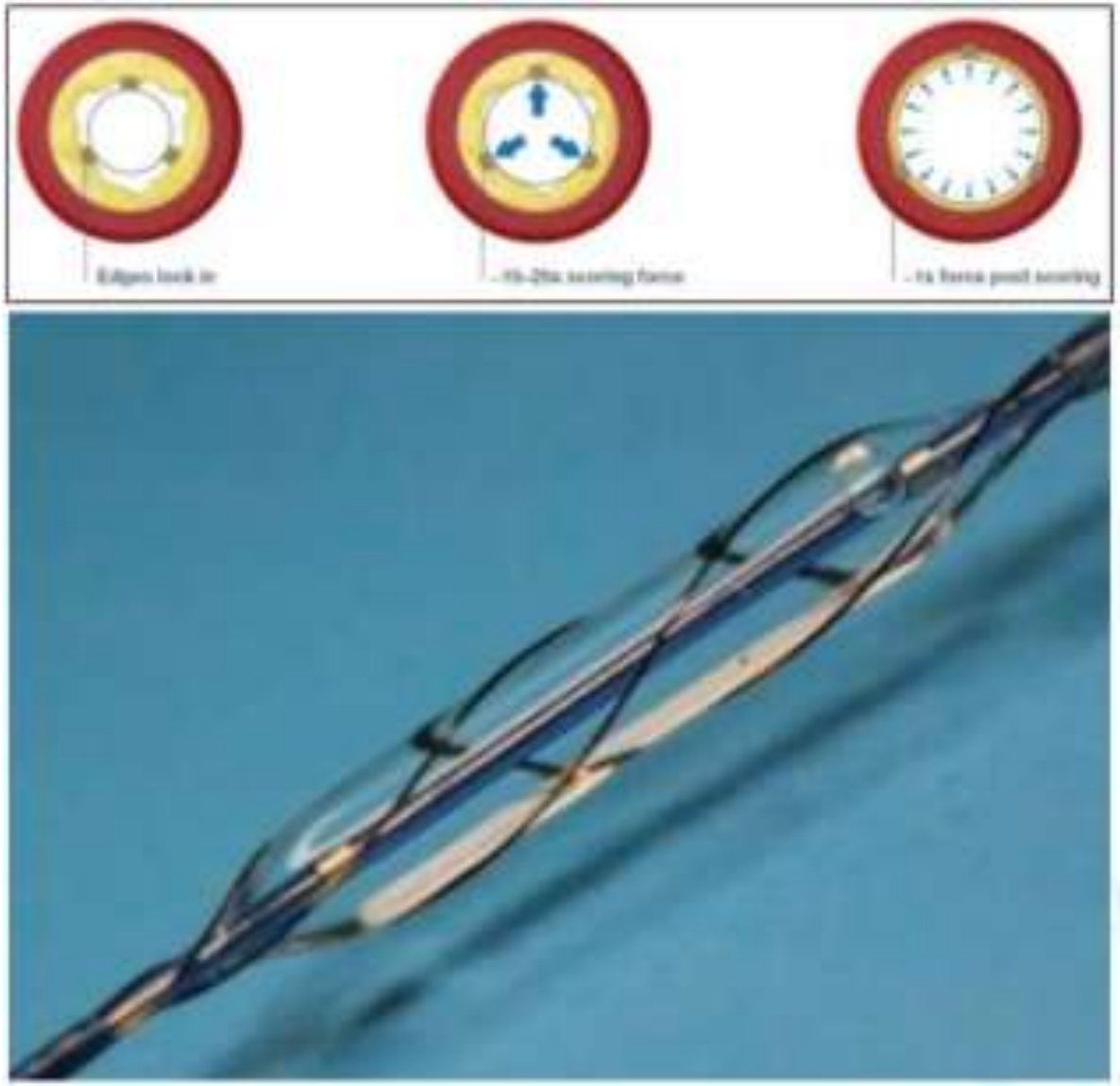
- Composed of a conventional balloon with **three or four atherotomes**(microsurgical blades) that are mounted **longitudinally** along the balloon surface
- Provides a focused force at low pressure → **controlled incisions** along the lesion length → create greater vessel compliance + improved stent expansion

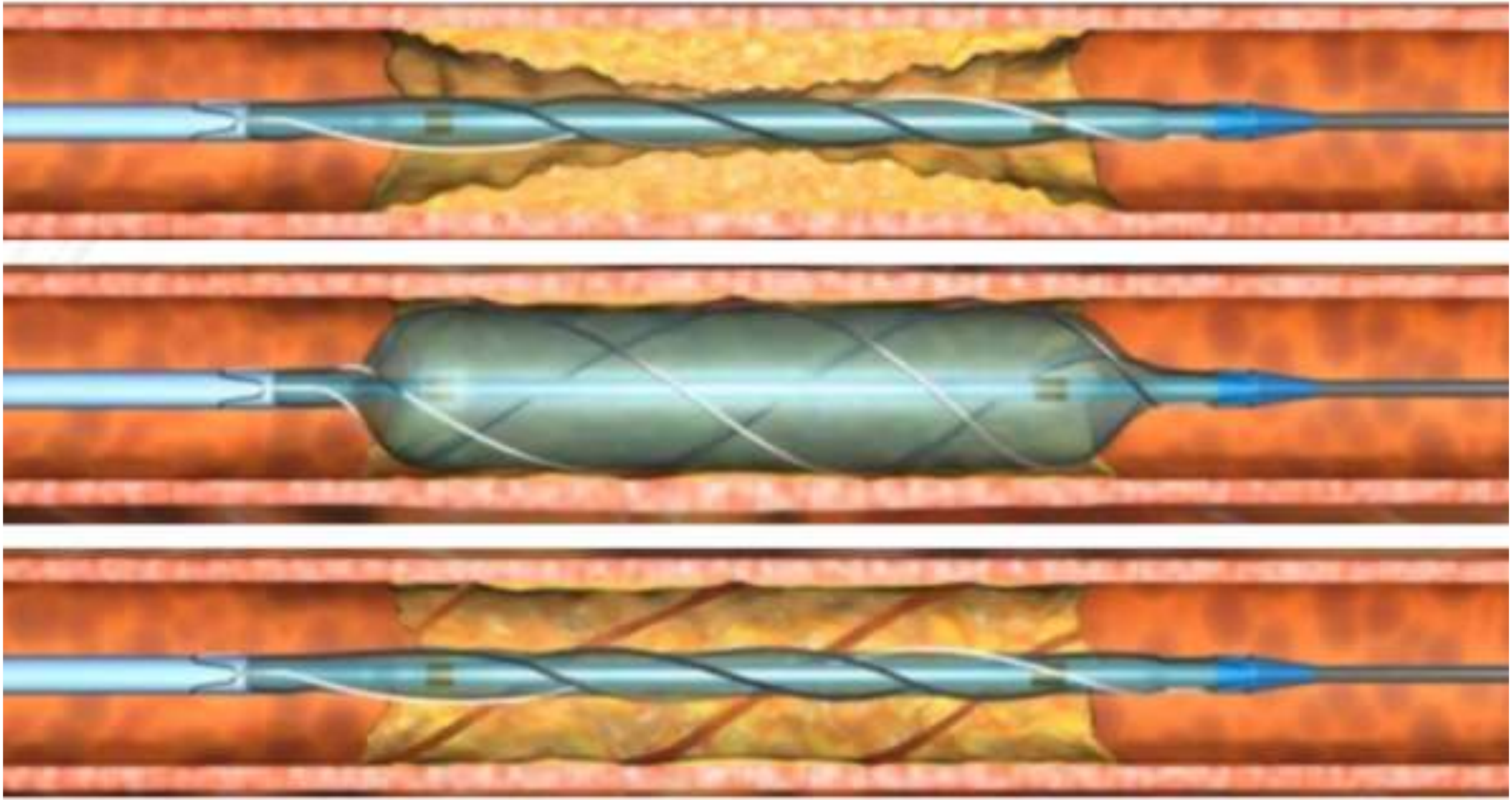




SCORING BALLOON

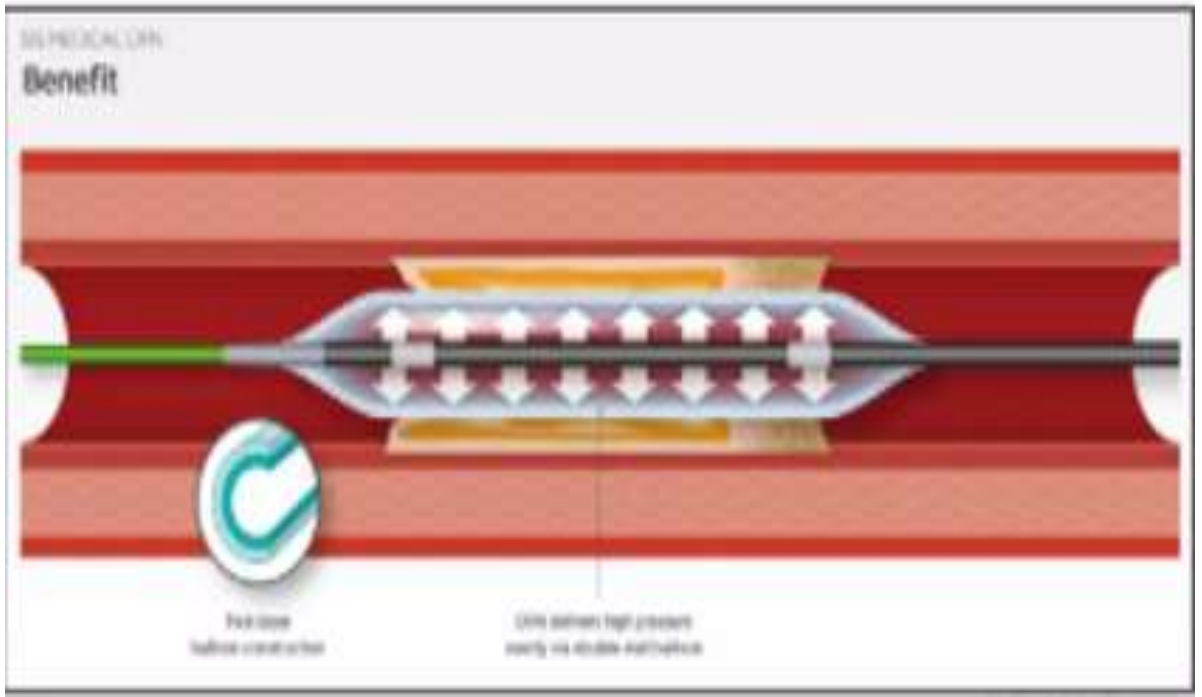
- Consist of a **semi-complian balloon** with **3-4 rectangular nitinol-based struts** that encircle the balloon in a **helical pattern**
- Mechanistic evolution of the CB:
  - Reducing the mechanical trauma exerted on the vessel wall → **lower risk of dissection**
  - More deliverable





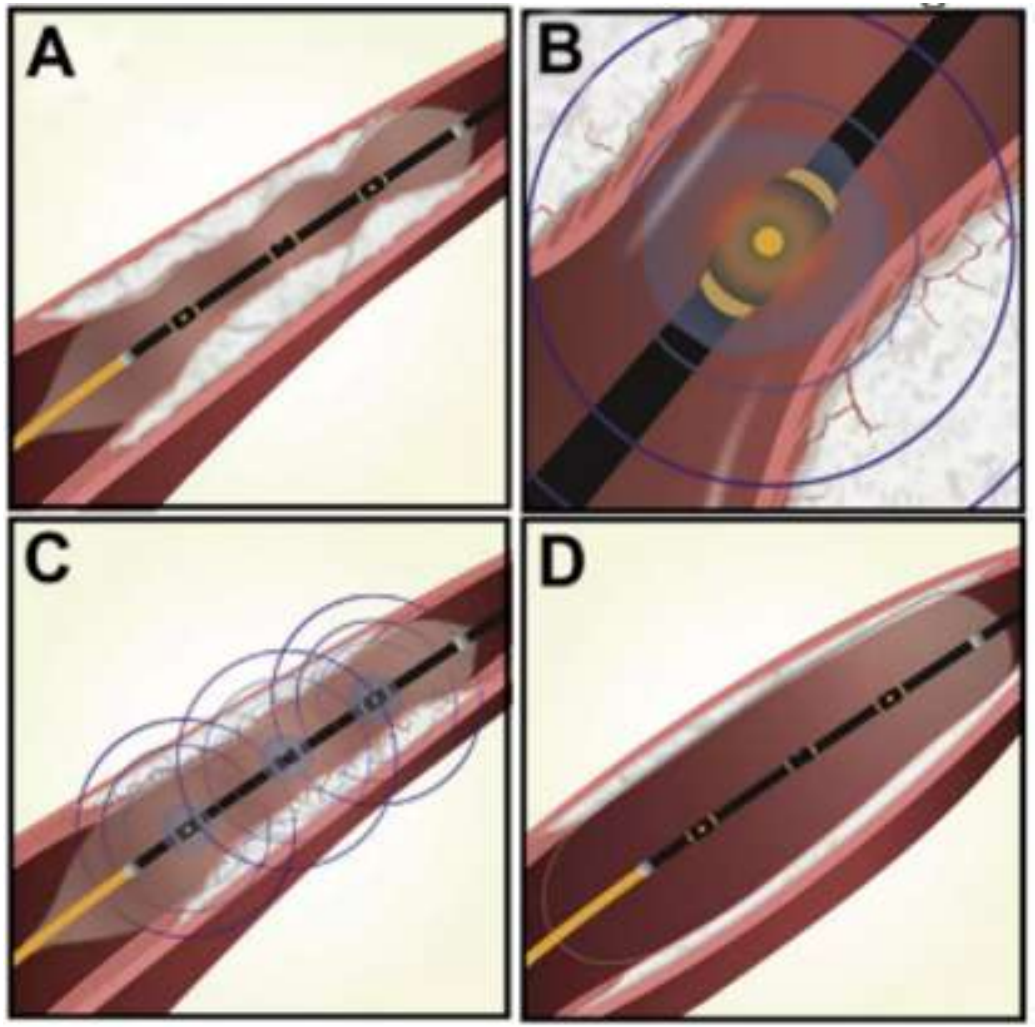
HIGH-PRESSURE NC BALLOONS

- **Dual layer**
- **Low profile**
- Can exert **super high pressures** on the lesion (**35 atm** rated pressure)
- **When conventional NCBs fall**→high pressure NC balloons provide an effective strategy
- **Potential risk:** coronary dissection, perforation,localized wall injury



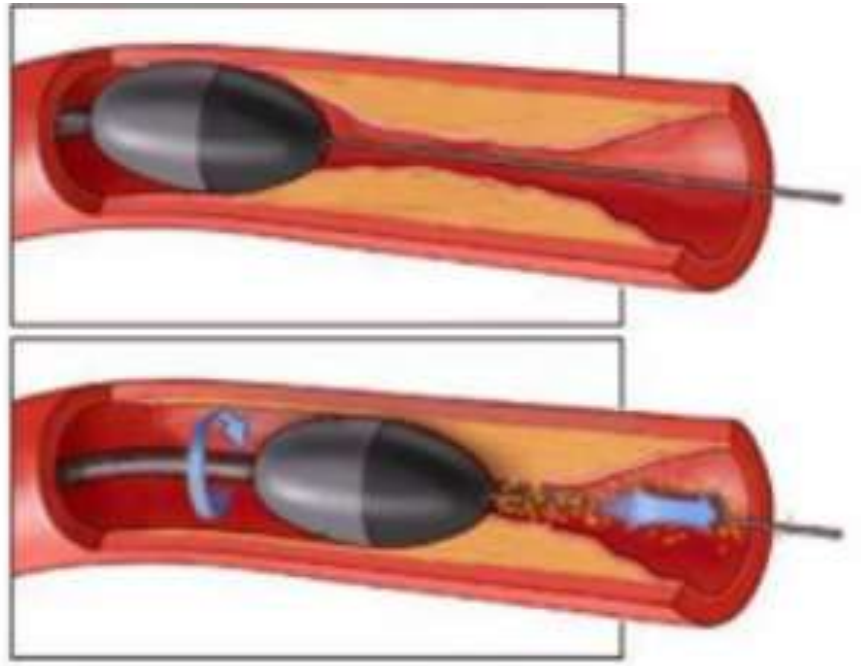
INTRAVASCULAR LITHOTRIPSY (IVL)

- IVL is best for modifying **circumferential calcium** in balloon crossable lesions
- IVL can be used with **multiple guidewires** in place (eg,bifurcation lesions).
- IVL Shokwaves affect superficial and deep calcium
- The balloon is placed within the target lesion (size 1:1) and inflated to **4 atm to deliver 10 shockwaves**.



ROTATHIONAL ATHERECTOMY

- RA system is composed of **high speed rotating diamond coated burr** that acts as an abrasive rotatory surface against calcific plaque
- The **ellipyic shaped** metallic burr is available in different sizes (from 1.25 to 2.5 mm)
- Burr size/ artery ratio is 0.4 to 0.6

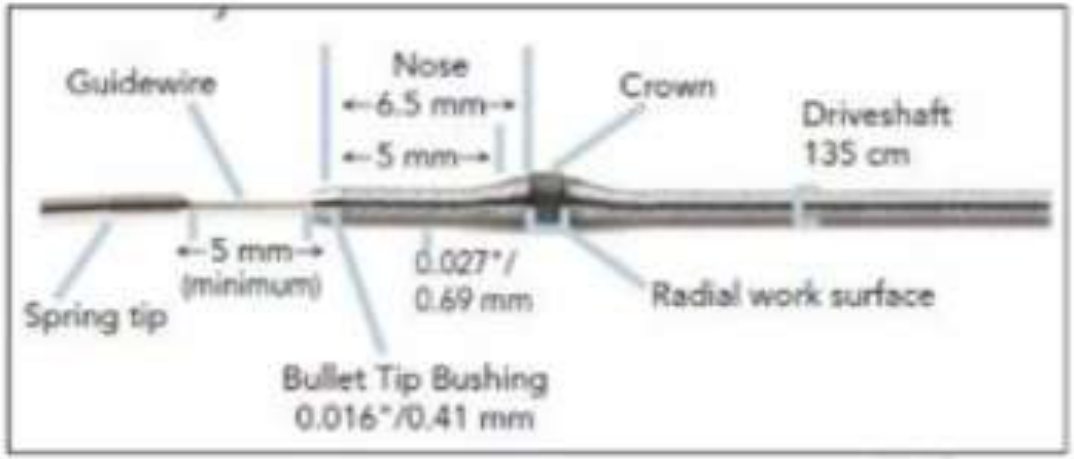


Box 1: Fundamental Elements of Optimal Rotational Atherectomy Technique

Single burr with burr-to-artery ratio of 0.5:0.6
Rotational speed of 140,000–180,000 rpm
Gradual burr advancement using a pecking motion
Short ablation runs of 15–20 sec
Avoidance of decelerations >5,000 rpm
Final polishing run

ORBITAL ATHERECTOMY

- OA is consists of an **eccentrically mounted diamond coated** 1.25 mm crown, allowing for bidirectional atherectomy
- Compared with rotaburr, witch only allows calcium ablation during forward advancement, the crown of OA presents diamond chips **both on front and back**, allowing ablation during **antegrade and retrograde**



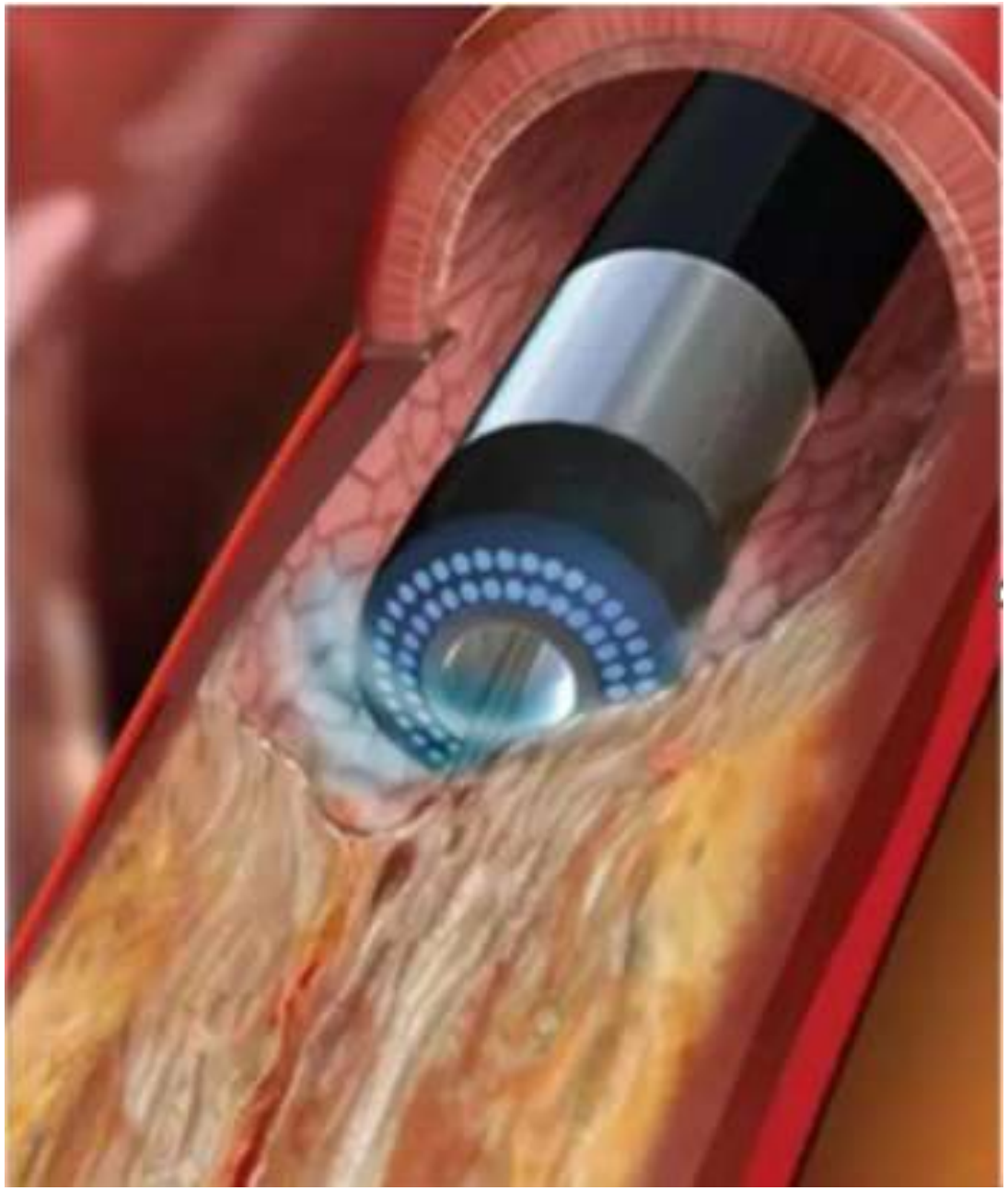
LASER ATHERECTOMY

- EL is based on the principle of photo ablation of atherosclerotic plaque, uses a **pulse waved,ultraviolet** laser catheter
- Laser produces ablation of atherosclerotic material via 3 main mechanisms :

  1)**Photochemical**

  2) **Photothermal**

  3)**Photomechanical**



CONCLUSION

- Coronary artery calcification represents a major challenge associated with adverse outcomes after PCI
- To avoid stent failure, optimal plaque preparation of calcified coronary lesions is required
- Intracoronary imaging and determination of coronary calcification severity and characteristics are the keys to guiding further treatment decisions
- The decision relating to which modification technique to use is based on numerous anatomic factors and technical factors, including the location of the lesion, the concentricity of the calcium pool and local device availability

Thank you for attention!