Percutaneus coronary intervention for chronic total occlusion

- Chronic total occlusion (CTO) of a coronary artery is typically defined as a completely occluded artery without any antegrade flow and a duration of at least 3 months

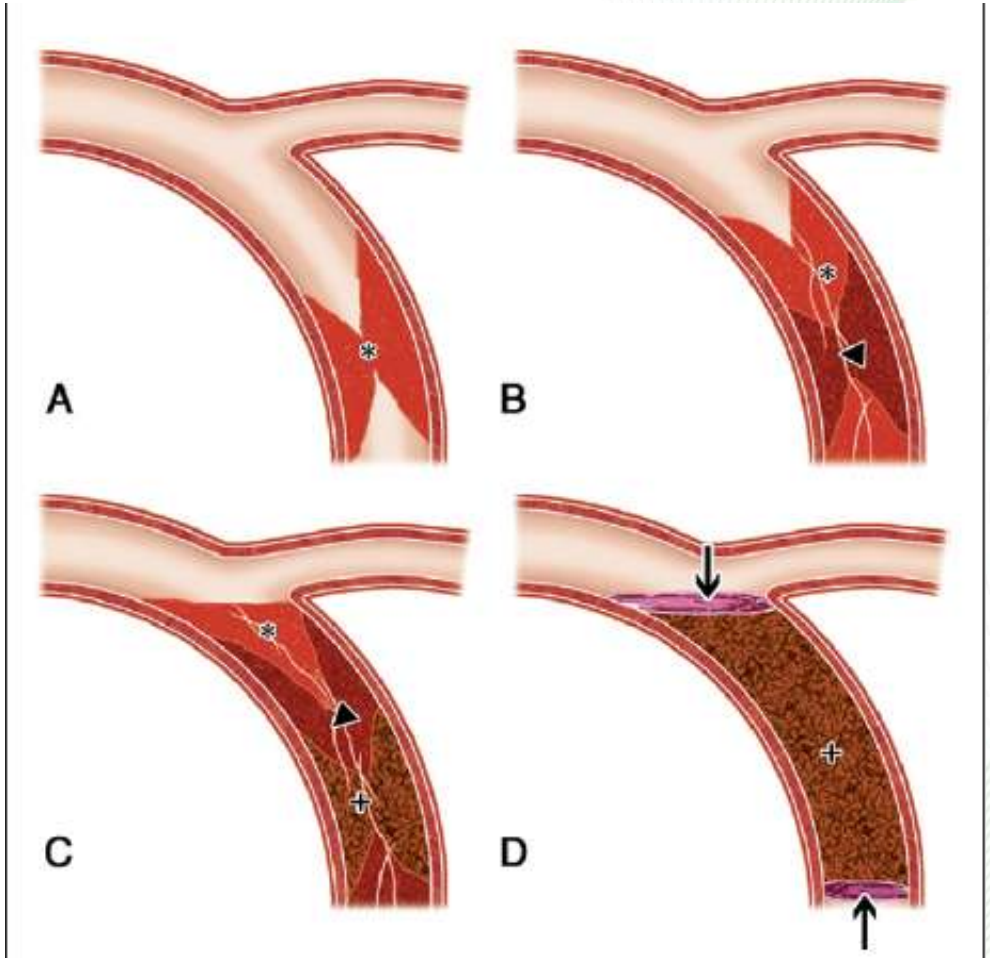


Figure 1. Progression of Chronic Total Occlusion: Extending and Organizing Thrombus

What we know about CTO

- The prevalence of CTO's is approximately 25% among patients undergoing PCI .
- PCI of CTO can be a technically complex procedure with relatively lower success rates compared with non-CTO PCI
- associated with a higher complication rate especially at nonspecialized centers.
- successful CTO-PCI is associated with symptomatic improvement but does not appear to improve mortality, myocardial infarction, stroke, and repeat revascularization rates

- Based on contemporary data, PCI of CTO lesions may be considered in patients with incapacitating angina despite treatment with OMT and in whom based on coronary anatomy there is a reasonable chance of technical success with an acceptable risk.

Non-invasive cardiac imaging modalities for CTO evaluation

TTE

Readily available

Assessment of wall motion abnormalities and wall thickness reduction; LV ejection fraction

LV strain by speckle tracking increases accuracy for viability detection

Can confirm viable myocardium if no wall motion abnormalities are present

Low dose dobutamine stress to assess contractile reserve in hypokinetic/akinetic regions

More specific than SPECT for viability

SPECT

Modality of choice in randomized trials as it is readily available

Assessment of perfusion (Tc tracer preferred) and viability (Tl tracer preferred)

Robust semi-quantification

Global and regional function by gated SPECT

New CZT cameras provide high resolution, less radiation, dynamic imaging with MPR calculation in progress

More sensitive than dobutamine Echocardiography for viability

Hybrid techniques available

CMR

Less available

Gold standard to detect myocardial scar

Gold standard for LV volumes and ejection fraction

Provides anatomical information

Assessment of perfusion and regional wall motion for ischemia and viability detection

Higher spatial resolution as compared to other modalities

High sensitivity and specificity

No radiation exposure

Hybrid techniques available

PET

Less available

Gold standard to assess myocardial perfusion

Absolute blood flow quantification by dynamic imaging

Assessment of metabolism for viability

Higher spatial resolution and sensitivity + specificity than SPECT

Hybrid techniques available

Limitations: Non-invasive cardiac imaging modalities for CTO evaluation

TTE

- Low sensitivity in differentiation of viable and non-viable myocardium
- Resting echocardiography provides no perfusion or metabolic assessment
- Stress-TTE has lower sensitivity than other methods in assessing myocardial perfusion
- Lower image quality as compared to CMR
- Less feasible in patients with difficult acoustic windows
- High interpreter variability

SPECT

- Radiation exposure
- Low sensitivity in multi-vessel disease
- Need for attenuation correction
- Anatomical assessment only possible in hybrid imaging
- Amount of residual viability often underestimated

CMR

- Prognostic significance less supported by randomized trials
- Limited by claustrophobia, metallic implants and kidney function
- Not yet fully validated in CTO patients

PET

- Radiation exposure
- Anatomical assessment only possible in hybrid imaging

3 questions must to be answered

- Is there any improvement in angina, exercise capacity and/or Qual. of life?
- Is there any reduction in MACE at long-term follow-up?
- What is the role of CTO revascularisation in patients with LV dysfunction?

Quality of life

- 3 out of the 4 main randomised trials available on this topic, EuroCTO, COMET-CTO, and IMPACTOR-CTO, demonstrated that patients' health status improved more significantly after CTO PCI than with OMT, while the DECISION-CTO trial[51] did not.

MACE REDUCTION AT LONG TURN FOLLOW-UP

- Two large prospective registries, the Korean registry and the Canadian Multicenter CTO Registry, showed a significant clinical benefit of CTO revascularisation over OMT alone at very long-term follow-up
- Conversely, the two other randomised trials, DECISION-CTO and EXPLORE, did not confirm a long-term MACE reduction with CTO revascularisation as compared with OMT

CTO REVASCULARISATION OF PATIENTS WITH REDUCED LVEF

- in REVASC trial the mean baseline LVEF was only mildly/moderately reduced in both the OMT and CTO PCI groups with one possible explanation for this being the neutral effect of coronary revascularisation on LV recovery

CTO detected

Symptom evaluation

Dyspnoea (RDS)

Angina (CCS, SAQ)

Health status QoL (EQ-5D)

YES

NO

Normal wall motion or hypokinesis in CTO territory

Akinesia or dyskinesia in CTO territory

Normal LV function

LV dysfunction

Significant ischaemia and viability*

Significant ischemia and viability*

YES

NO

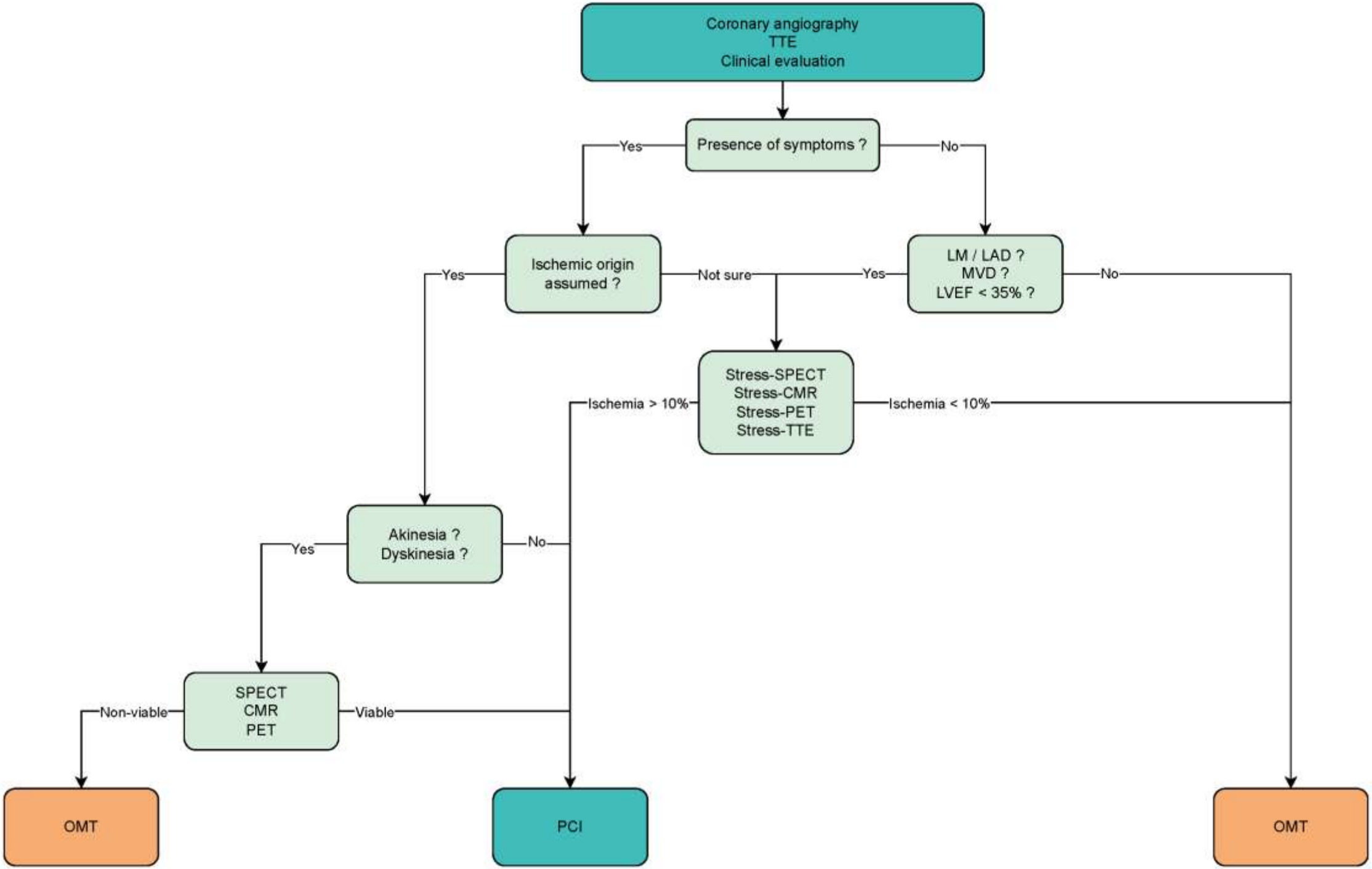
NO

YES

Revascularisation is advised

OMT and follow-up

Revascularisation might be considered in selected cases only§


Coronary angiography
TTE
Clinical evaluation
Presence of symptoms ?
Yes
No
Ischemic origin assumed ?
Yes
Not sure
LM / LAD ?
MVD ?
LVEF < 35% ?
Yes
No
Stress-SPECT
Stress-CMR
Stress-PET
Stress-TTE
Ischemia > 10%
Ischemia < 10%
Akinesia ?
Dyskinesia ?
Yes
No
SPECT
CMR
PET
Non-viable
Viable
OMT
PCI
OMT

CTO revascularisation indicated

Isolated CTO

Non-LAD CTO ↔ LAD CTO

CTO in the context of MVD

CTO in previous CABG

Heart Team evaluation

CTO complexity
- J-CTO score
- CT scan-derived J-CTO score

Local CTO PCI expertise

Porcelain aorta

Aortic arch atherosclerosis

Interventionalist

Anesthesiologist

Patient

Cardiac imager

Cardiac surgeon

Bleeding risk

Surgical risk
- STS score
- Logistic EuroSCORE II
- Frailty score

Availability of arterial or venous conduits

Concomitant relevant valvular heart disease

CTO PCI | **Hybrid revascularisation** | **CABG**

Risk Prediction Scoring Systems for CTO-PCI

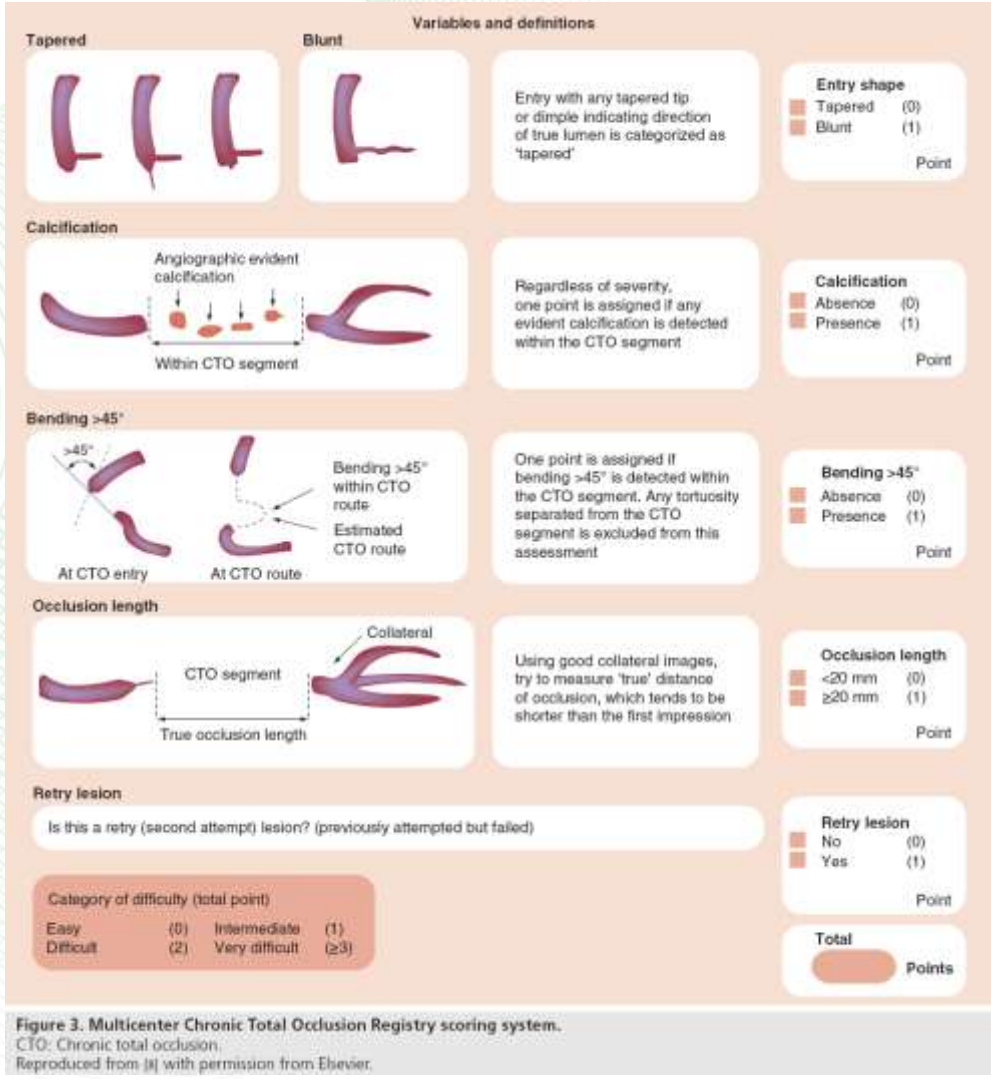
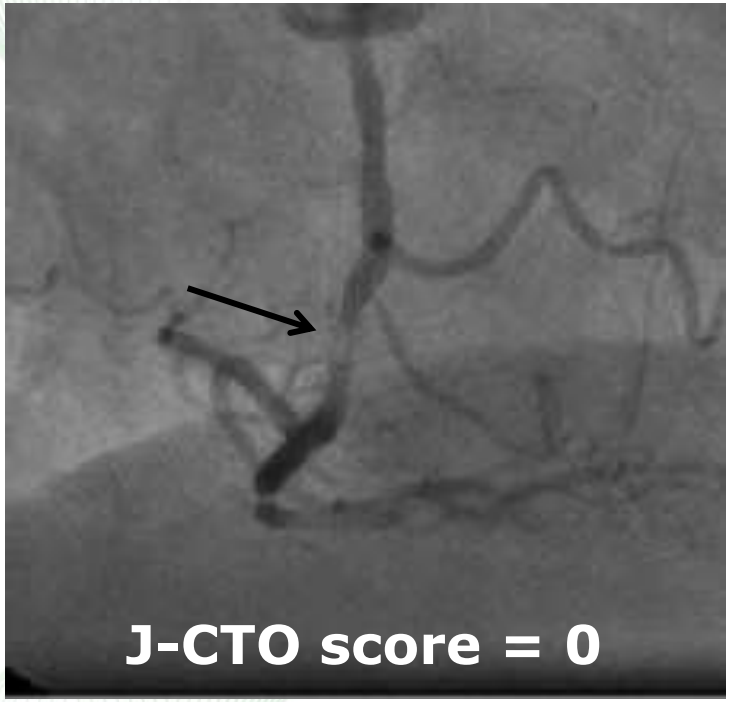


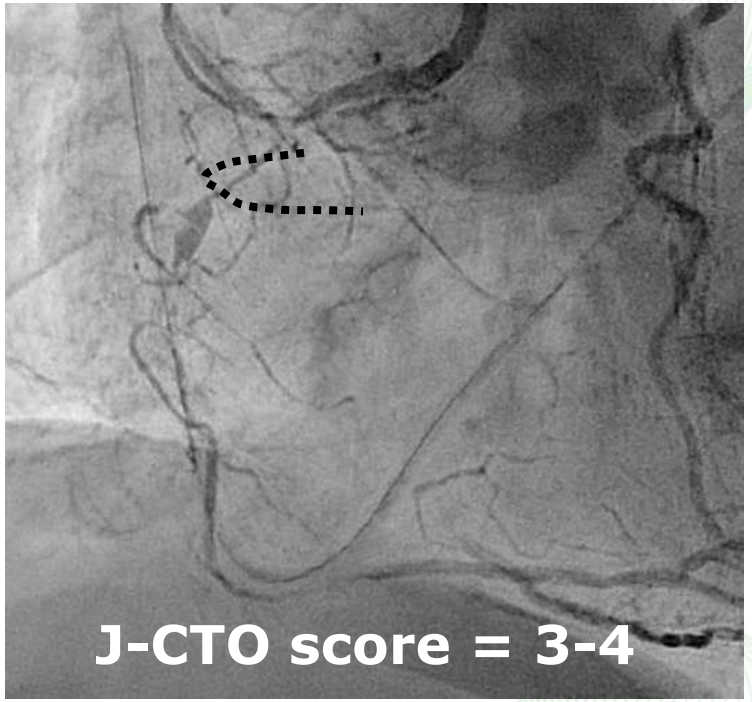
Figure 3. Multicenter Chronic Total Occlusion Registry scoring system.
CTO: Chronic total occlusion.
Reproduced from [a] with permission from Elsevier.

Developed to estimate the likelihood of successful antegrade guidewire crossing within 30 minutes based on 5 criteria:

- blunt proximal stump
- calcification
- at least 1 bend of >45° in the CTO entry or CTO body,
- occlusion length >20 mm,
- previously failed attempt

There are CTO's and CTO's





<u>can</u> be attempted by non-CTO operator

<u>Should not</u> be attempted by non-CTO operator

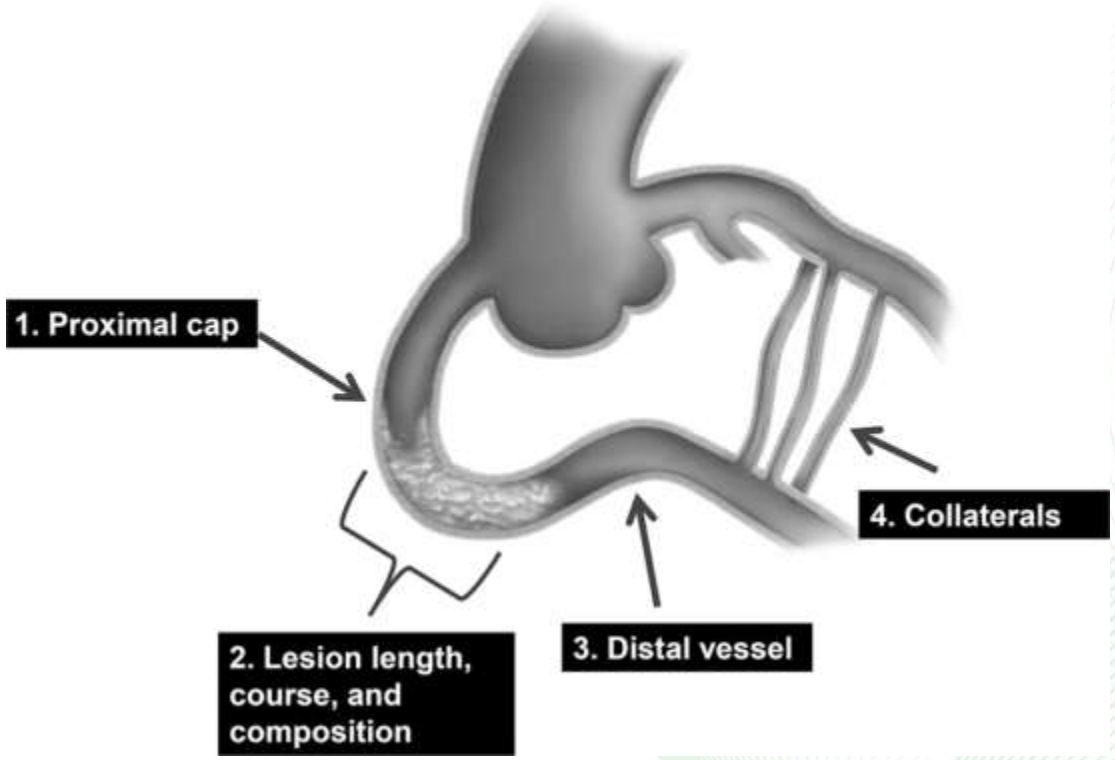
Angiographic Assessment and Strategy Selection

- A detailed understanding of the coronary anatomy is fundamental to successful CTO procedures.

- Some of the necessary information can be gained from a pre-procedure diagnostic angiogram, but dual catheter angiography is essential.

In general

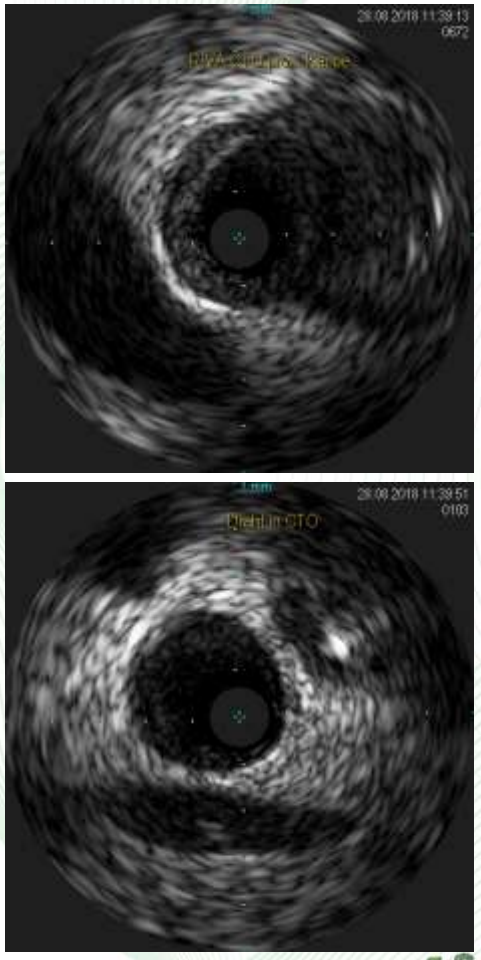
- diagnostic CA should be carefully evaluated to assess the characteristics of the proximal cap of the occlusion,
- the true length of the CTO segment,
- the quality of the distal vessel,
- presence and location of side branches,
- the size and course of collateral vessels.



IVUS

Three primary methods for current IVUS platforms:

- Identification of the proximal cap location using IVUS in the side branch;
- Real-time or subsequent confirmation of accurate wire penetration into the proximal cap;
- IVUS in the false lumen to direct true lumen wiring.



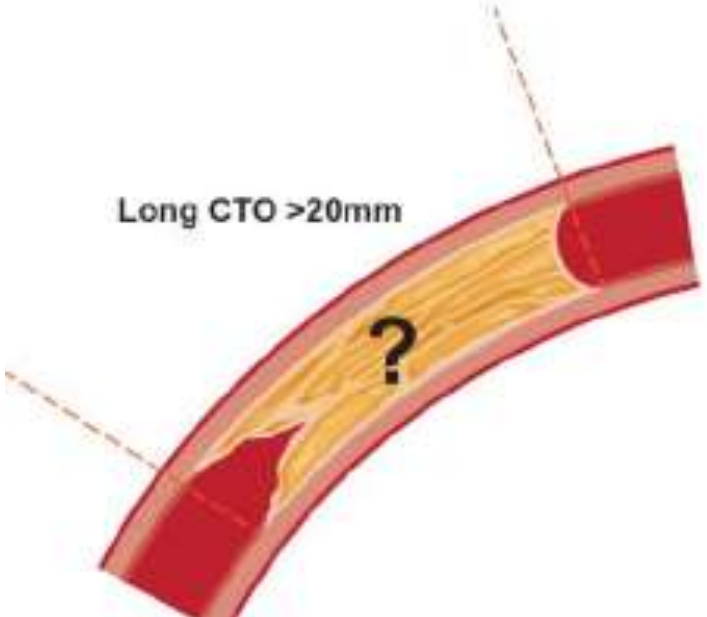
The proximal cap

- Tapered proximal cap may offer lower resistance to wire passage, and AW is more likely to be successful than in a CTO with a blunt proximal cap.

- The presence of a side-branch at a blunt proximal cap is common in long-duration CTOs. This may cause guidewires to deflect into the side-branch, making AW more challenging

The CTO ‘s body

- Lesion length progressively increasing >20 mm makes intimal wire passage less likely and increases procedure duration.



The Distal Cap and Landing Zone

- The vessel beyond the distal cap and before the origin of a major side-branch is known as the distal landing zone (LZ), referring to the area for potential re-entry during antegrade dissection and re-entry (ADR).

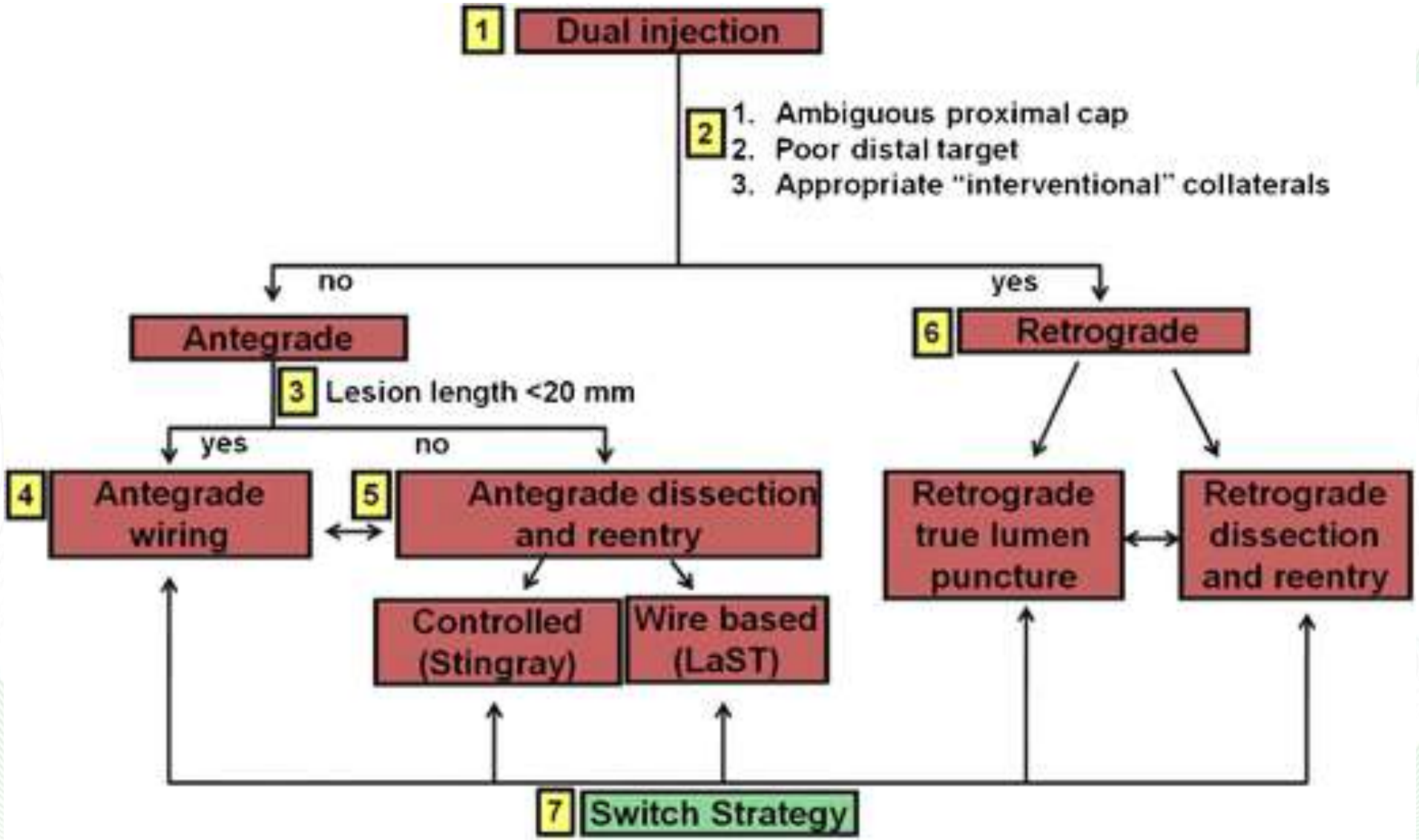
- If the distal cap is at or near a bifurcation of a significant side-branch, the chance of dissection extending across the branch and causing occlusion is increased, making ADR a less favourable strategy.

- If there is a heavily diseased LZ in close proximity to a major bifurcation, a primary retrograde strategy is indicated, provided this can be achieved safely.

Collateral Supply

- The diameter of the collateral, tortuosity and angle of entry and exit from vessels are other important features in determining whether the collaterals are suitable for use as a retrograde conduit.
- When visualisation of a collateral channel is challenging, selective imaging using a microcatheter may be considered.

Rentrop classification12	**Developed for occluded and non-occluded arteries**
0	no filling of collateral vessels
1	filling of collateral vessels without any epicardial filling of the target artery
2	partial epicardial filling by collateral vessels of the target artery
3	complete epicardial filling by collateral vessels of the target artery
Collateral connection grade11	**In CTOs, Rentrop 3 is prevalent in 85% of lesions, CC grading provides an additional differentiation**
CC0	no continuous connection
CC1	threadlike continuous connection
CC2	side branch–like connection (≥0.4mm)
CC3	>1mm diameter of direct connection (not included in the original description)


1 Dual injection
2 1. Ambiguous proximal cap
2. Poor distal target
3. Appropriate "interventional" collaterals
no
yes
Antegrade
6 Retrograde
3 Lesion length <20 mm
yes
no
4 Antegrade wiring
5 Antegrade dissection and reentry
Retrograde true lumen puncture
Retrograde dissection and reentry
Controlled (Stingray)
Wire based (LaST)
7 Switch Strategy

Antegrade Wiring

- AW is most likely to be successful where there is a clear, tapered proximal cap and the occlusion is short (<20 mm).
- Factors that should prompt consideration of a penetration wire are:
  - Blunt proximal cap – in longer-duration CTOs, the proximal cap tends to be blunt due to prolonged exposed to systemic arterial pressure, causing formation of dense fibrous tissue.
  - Heavy calcification at the proximal cap.
  - Presence of a side-branch or bridging collaterals at the proximal cap that often cause softer, jacketed wires to prolapse or deflect away from the cap.

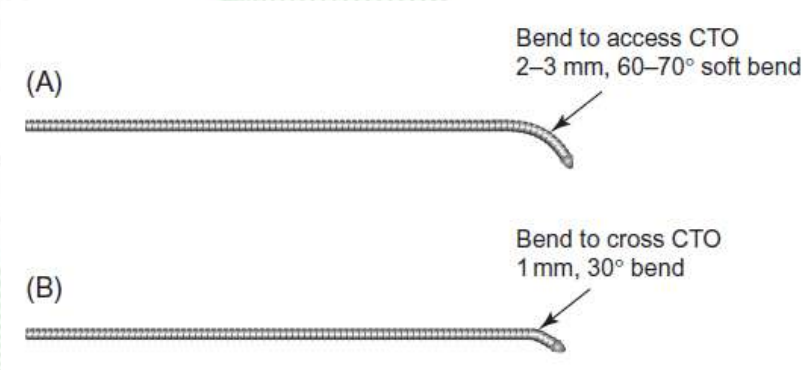
Wire Properties	Examples	Function
Low-gram weight, tapered tip, polymer jacket	Fighter (Boston Scientific) Fielder XT, Fielder XTA, Fielder XTR (Asahi Intecc)	Palpate proximal cap, loose tissue tracking within CTO body. Knuckle wire
Medium-gram weight, polymer jacket	Pilot 200 (Abbott) Gladius (Asahi Intecc) Crosswire NT (Terumo) Raider (Teleflex)	Palpate proximal cap, tracking within more resistant CTOs. Knuckle wire. Less likely to exit in tortuosity and ambiguity
Medium-gram weight, no polymer jacket	Gaia 2, Gaia 3, Gaia Next (Asahi Intecc) Judo 3, Judo 6 (Boston Scientific)	Crossing CTO body in more mature resistant lesions. Tactile feedback and torque transmission help in understood anatomy
High-gram weight, tapered, no polymer jacket	Confianza Pro12, Astato 8/20 & 8/40 (Asahi Intecc) Pro Via 15 (Medtronic) Progress 200T (Abbott) Hornet 14 (Boston Scientific)	Penetration wires for focused crossing of highly resistant segments
Dedicated knuckle wire	Gladius MG (Asahi Intecc)	Crossing long segments efficiently using blunt dissection, with a low risk of perforation
Collateral crossing wires for retrograde procedures	Sion, Sion Black, Suoh03 (Asahi Intecc) Samurai RC (Boston Scientific)	Low tip load, highly torquable and flexible shafts to adapt to channel shapes

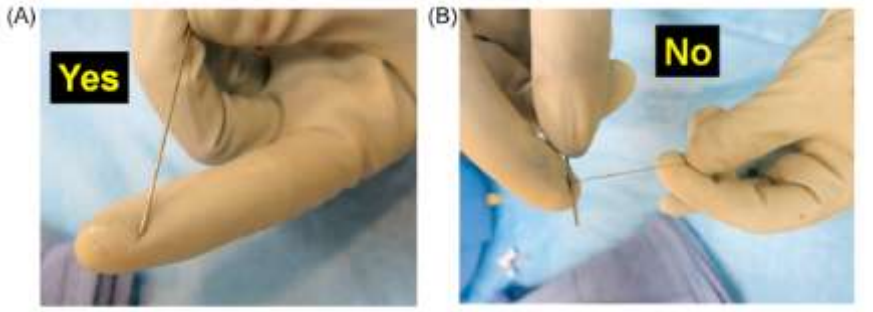
Guidewires are classified by their properties, which determine the function of the wire within a CTO procedure. CTO = chronic total occlusion.

Antegrade Wiring

- In general, wires should have minimal tip bend (15º–30º) approximately 1 mm from the tip for optimal performance in the CTO.

- A secondary bend further back in the wire aids in negotiating vessel tortuosity or awkward approach angles.



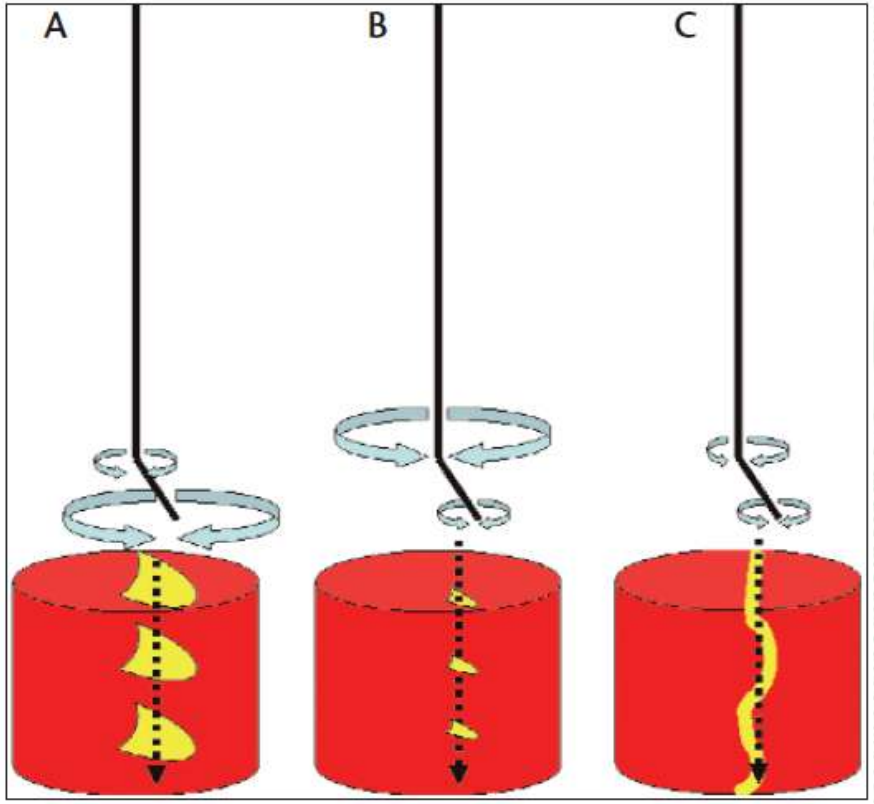


Antegrade Wiring

A. **Controlled Drill** - predicated on the supposition that a to-and-fro motion while torquing, being cautious to keep the drilling within a 90º arc, minimizes the likelihood of creating large dissections.

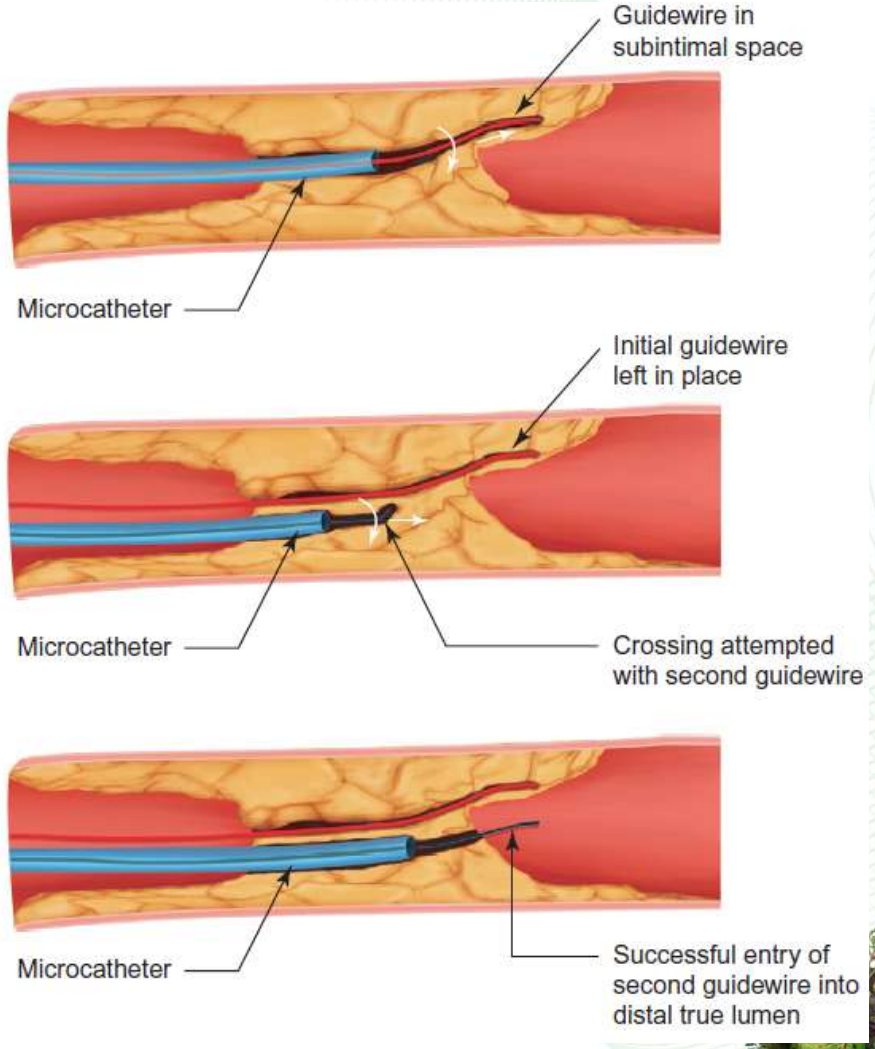
B. **Penetration Technique** - in which the wire is advanced along an imaginary vessel path with minimal rotation.

C. **Sliding Technique** - polymer-sleeved wire is negotiated with minimal force and rotation to negotiate preexisting microchannels



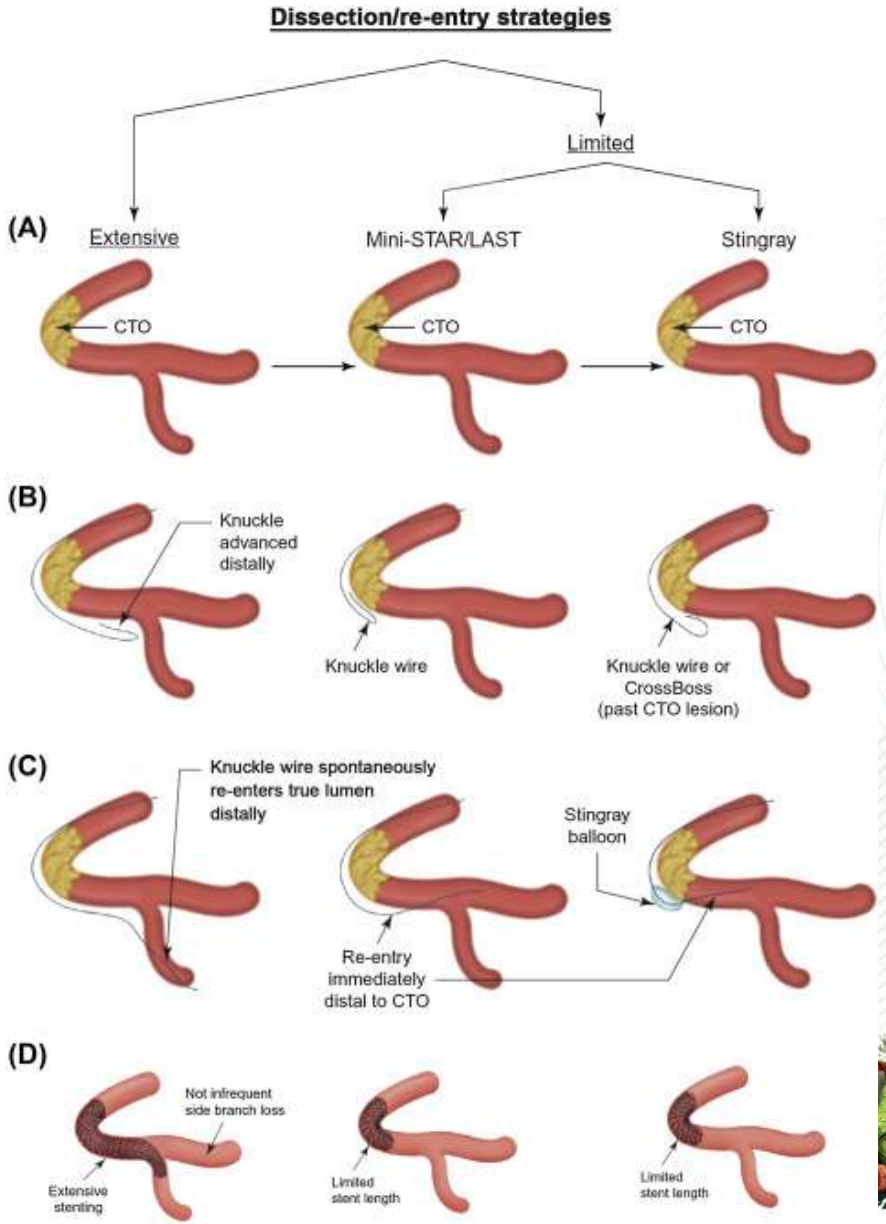
Parallel Wire Technique

- The parallel wire technique is a cornerstone of standard antegrade contemporary CTO PCI.
- The initial wire is left in place to serve as a visual marker and to obstruct entry into the false lumen.
- A second wire (with support catheter) can be advanced alongside, or in contact with, the original wire to the point where the initial wire left the occluded true lumen.



Antegrade Dissection and Re-entry

- ADR is a technique where the guidewire and/or equipment intentionally pass into a dissection plane before re-entering the distal vessel lumen at or beyond the distal cap.



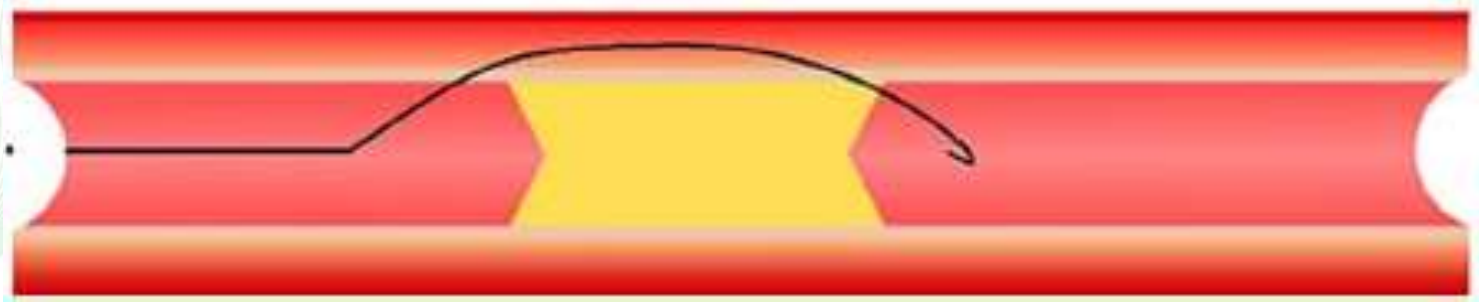
Subintimal Tracking And Re-entry -STAR

- Subintimal tracking and re-entry (STAR) was the first dedicated ADR technique to be described by Colombo et al.
- This involves passage of a looped or ‘knuckled’ guidewire into a dissection plane and advancing it until it enters the distal lumen, often at the site of a bifurcation, risking loss of branches.

Mini-STAR

- The mini-STAR technique is when an attempt is made to wire the occlusion as far as possible before entering a dissection plane, thereby theoretically minimising the length of extraplaque wire passage.

- The medium- and long-term outcomes from these techniques are poor



LAST

- Limited antegrade subintimal tracking and re-entry uses targeted re-entry by advancing a microcatheter within a dissection plane and attempting wire-based re-entry beyond the distal cap.

- The subintimal wire is exchanged for a penetration wire with a large primary bend, and this is directed towards the true lumen to re-enter.

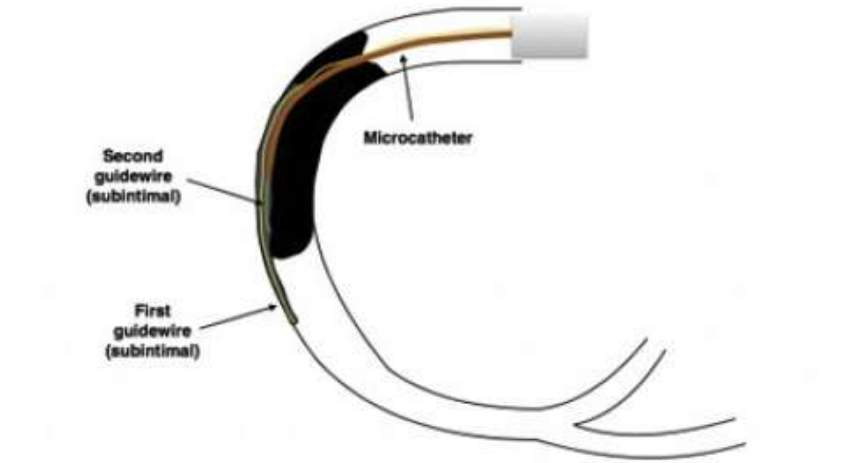
- This technique is also not reproducible and has largely been abandoned since the development of dedicated re-entry equipment for ADR.

AFR

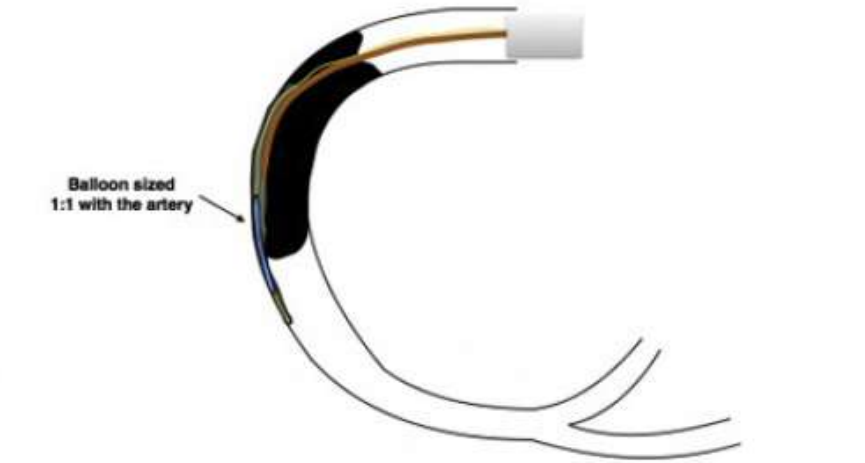
- Antegrade fenestration and re-entry (AFR) causes disruption within the vessel extraplaque by inflation of a 1:1-sized balloon through the CTO segment.

- This aims to create tears within the vessel media, thus allowing a soft polymer wire to cross fenestrations and reach the distal true lumen.

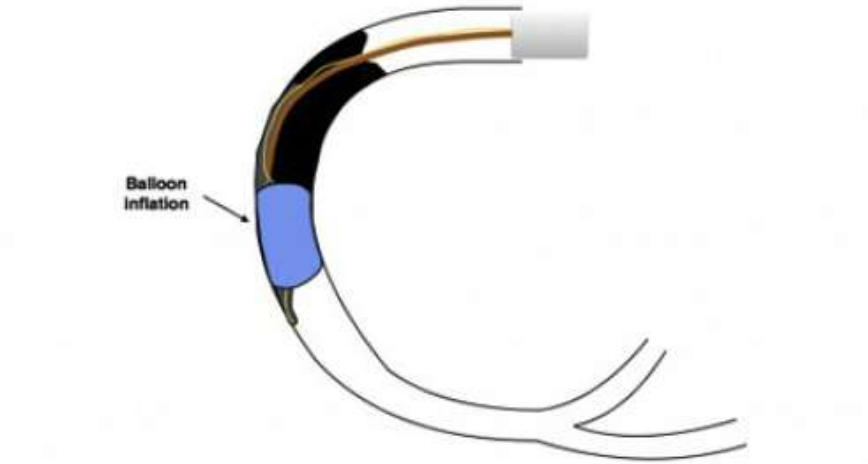
- Most likely, STAR and AFR will be reserved for bailout manoeuvres when targeted re-entry cannot be facilitated by targeted ADR or retrograde procedures.



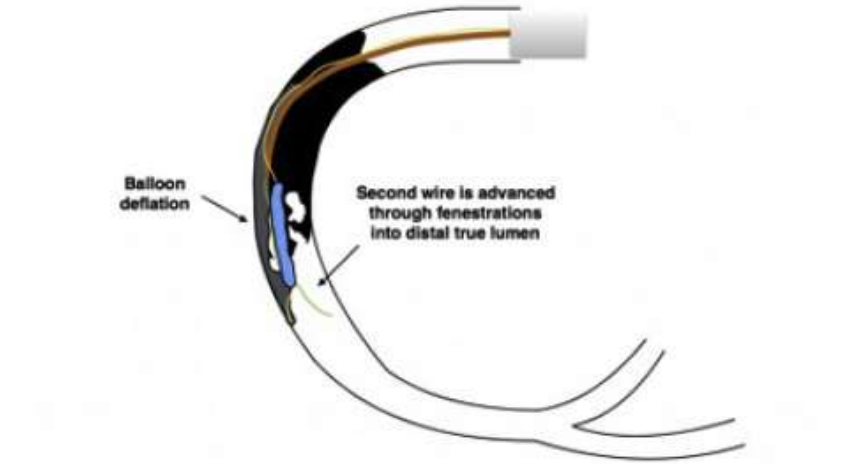
A second guidewire is advanced subintimally, up to the distal cap.



A balloon is advanced on the first wire across the distal cap.



The balloon is inflated.



Immediately after balloon deflation, the second wire is advanced into the true lumen.

VDAR

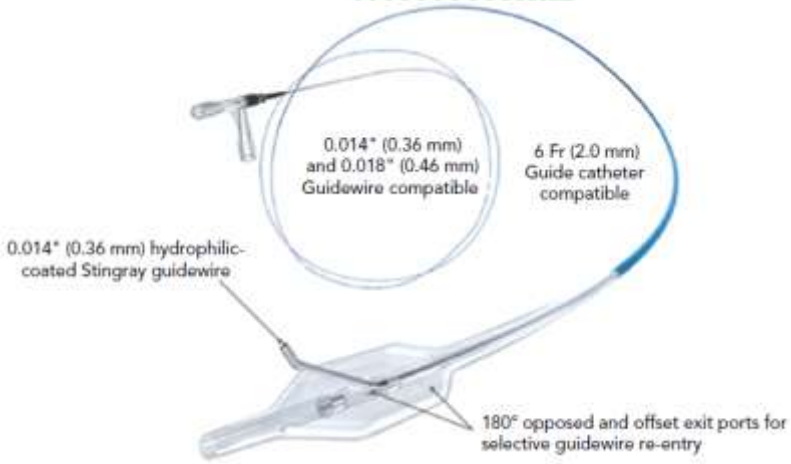
- Vessel Destruction and Repair technique (VDAR)

- A polymer-jacketed wire is advanced in the subadventitial space to a large side branch, with or without knuckling the tip.

- At this point, a support catheter is advanced to this space, and a penetration wire (9-g, 12-g Confianza Pro) is used to attempt pre-side-branch reentry.

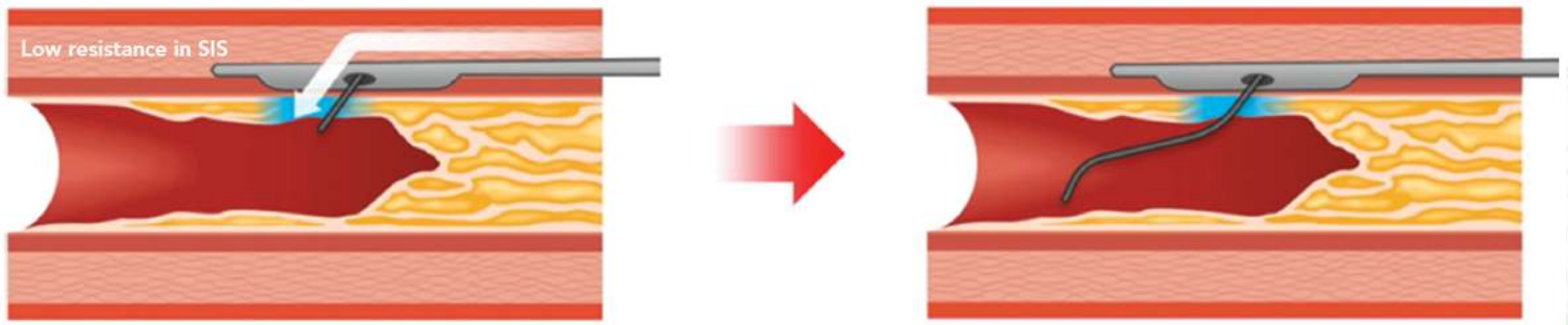
Device-based Re-entry Techniques

- The CrossBoss and Stingray system (Boston Scientific) continues to form the mainstay of targeted re-entry devices.



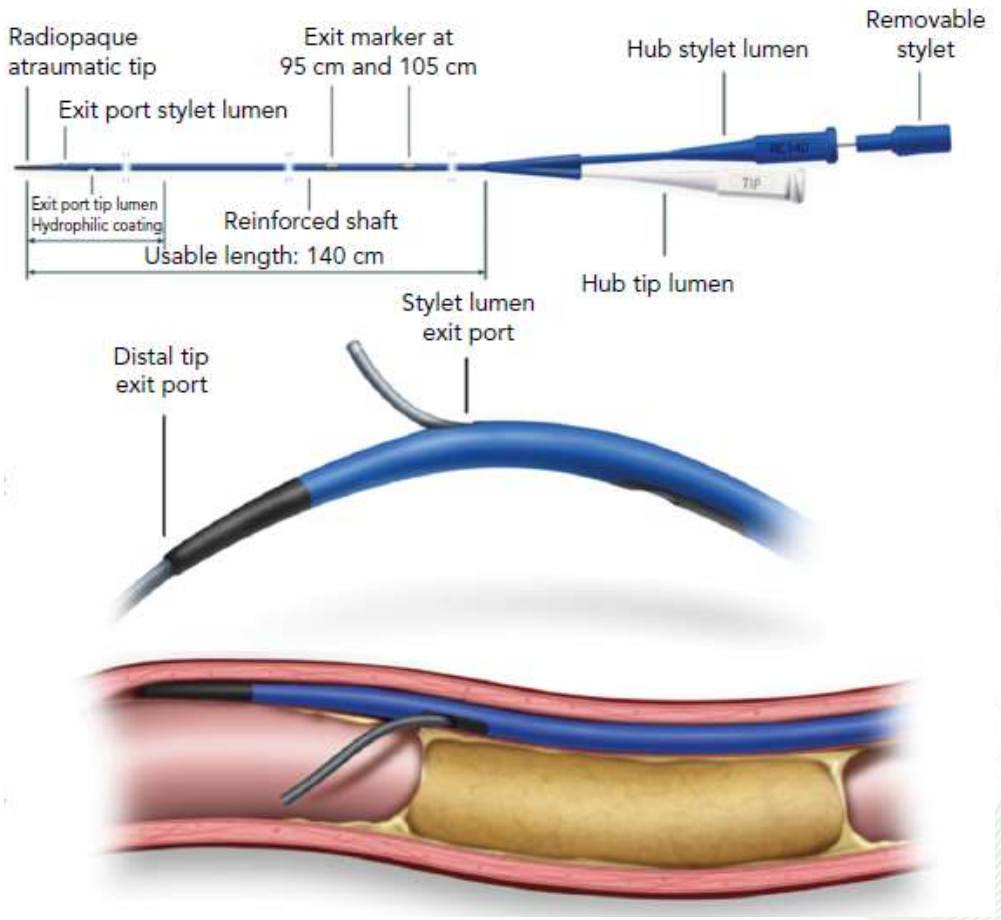
Device-based Re-entry Techniques

- The CrossBoss is a blunt tipped dissection catheter that will track through intimal plaque or create a controlled extraplaque dissection that facilitates delivery of the Stingray LP balloon beyond the distal cap.



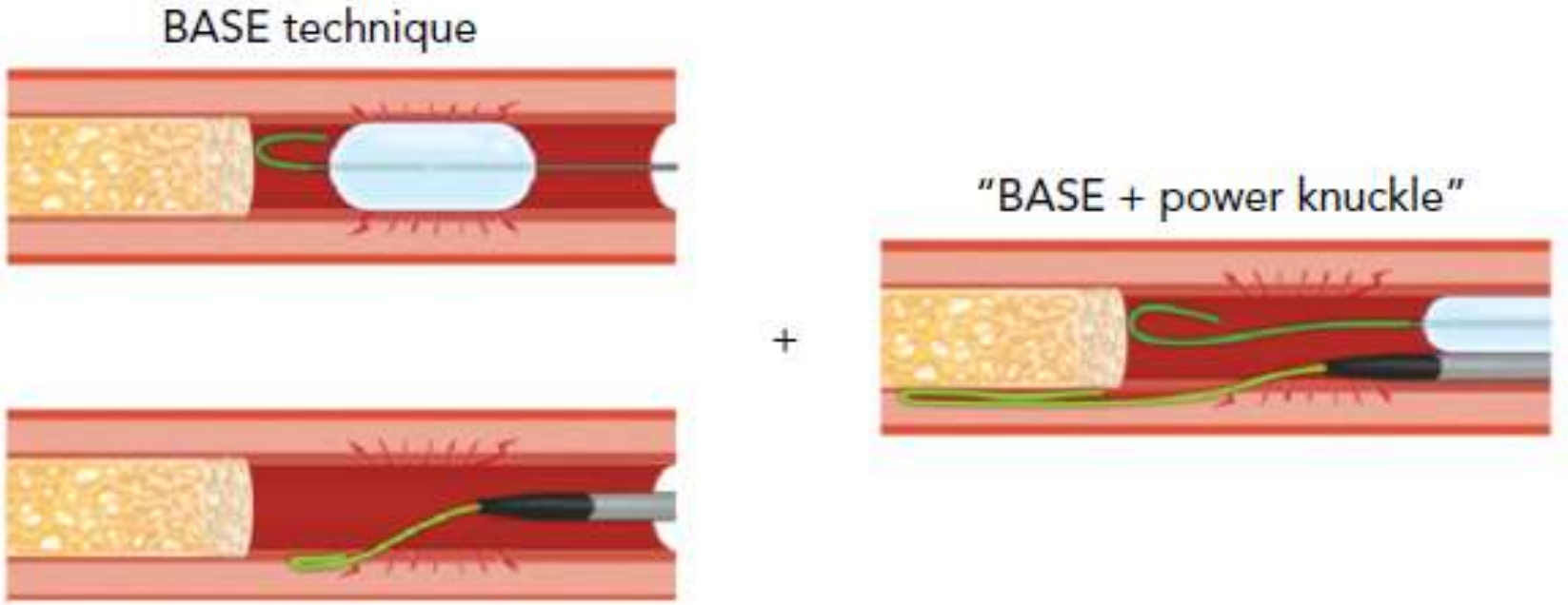
Device-based Re-entry Techniques

- The ReCross device (IMDS) is an over-the-wire, modified dual-lumen microcatheter. It has two exit ports close to the distal end of the device, oriented at 180o from each other, thereby providing some degree of control in guidewire redirection



Troubleshooting During ADR

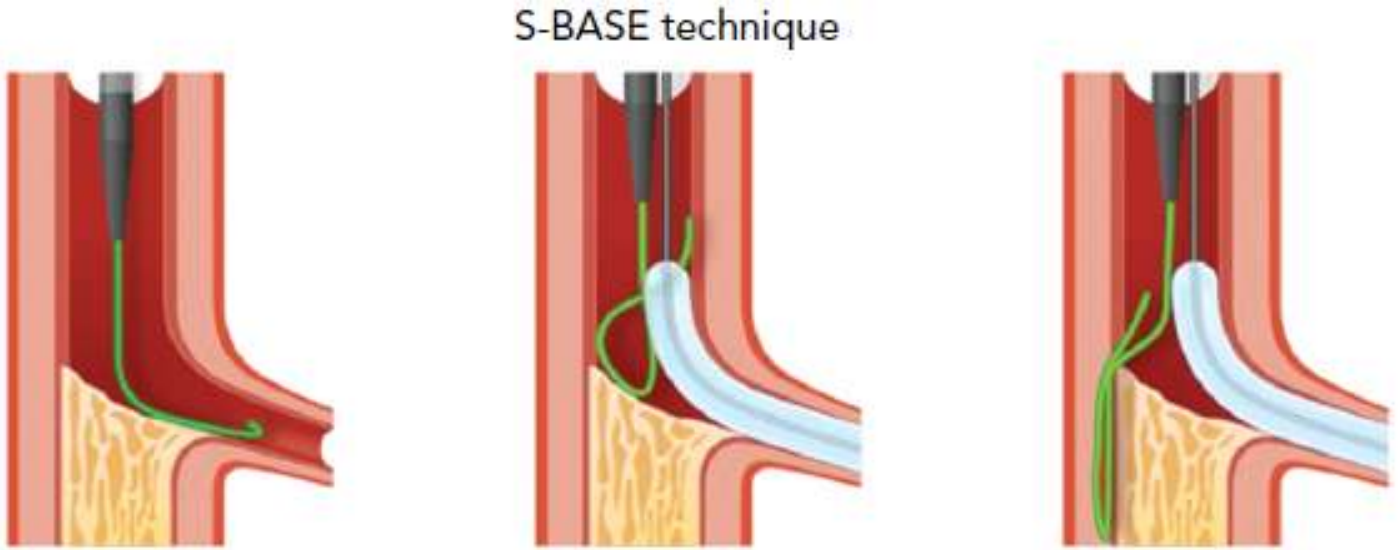
- Impenetrable Proximal Cap
  - Balloon-assisted subintimal entry (BASE)
  - Parallel anchor (power knuckle)

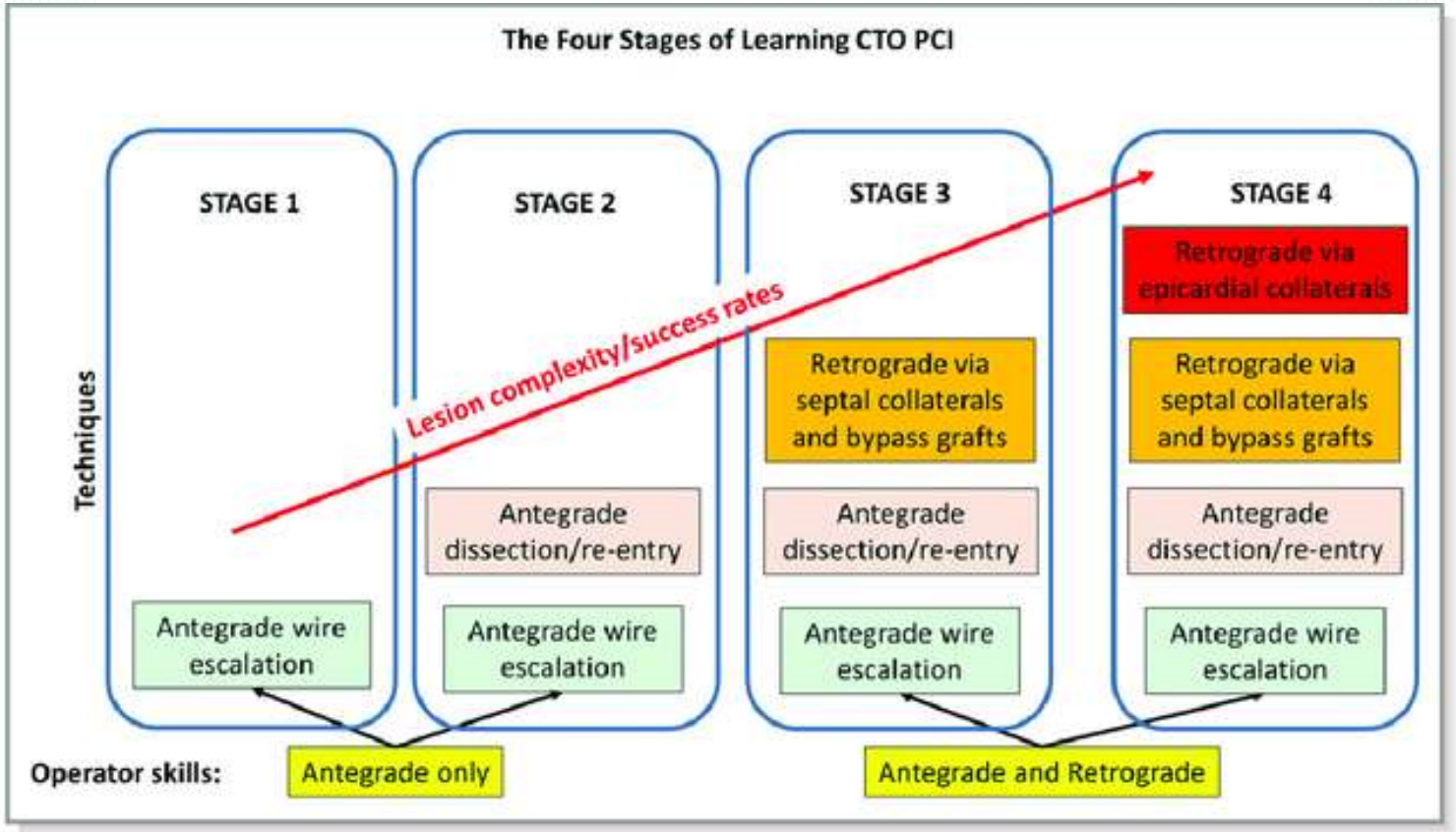


Troubleshooting During ADR

- When a side-branch is present at the proximal cap, a modification of this technique (side-BASE) can be used.

- A blocking balloon is positioned in the side-branch ca
di




The Four Stages of Learning CTO PCI
STAGE 1
STAGE 2
STAGE 3
STAGE 4
Lesion complexity/success rates
Techniques
Retrograde via epicardial collaterals
Retrograde via septal collaterals and bypass grafts
Retrograde via septal collaterals and bypass grafts
Antegrade dissection/re-entry
Antegrade dissection/re-entry
Antegrade dissection/re-entry
Antegrade wire escalation
Antegrade wire escalation
Antegrade wire escalation
Antegrade wire escalation
Operator skills:
Antegrade only
Antegrade and Retrograde

7 common principles that are widely accepted as best practices for CTO-PCI.

- 1. Symptom improvement is the primary indication for CTO-PCI.
- 2. Dual coronary angiography and structured review of the angiogramare key for planning CTO-PCI.
- 3. Use of a microcatheter is essential for optimal guidewire manipulation.

- 4. Antegrade wiring, antegrade dissection and reentry, and the retrograde approach are all complementary and necessary crossing strategies.

- 5. If the initially selected crossing strategy fails, efficient change to an alternative crossing technique increases the likelihood of success, shortens procedure time, lowers radiation and contrast use.

- 6. Specific CTO-PCI expertise and volume and the availability of specialized equipment will increase the likelihood of crossing success and facilitate prevention and management of complications, such as perforation.
- 7. Meticulous attention to lesion preparation and stenting technique, often requiring intracoronary imaging, is required to ensure optimum stent expansion and minimize the risk of short- and long-term adverse events.

Thank you for your attention