

Endovascular Stenting

Vascular injury, thrombosis and neointimal restenosis

Pathology-centered lecture

Dr Abu Suraih Sakhri

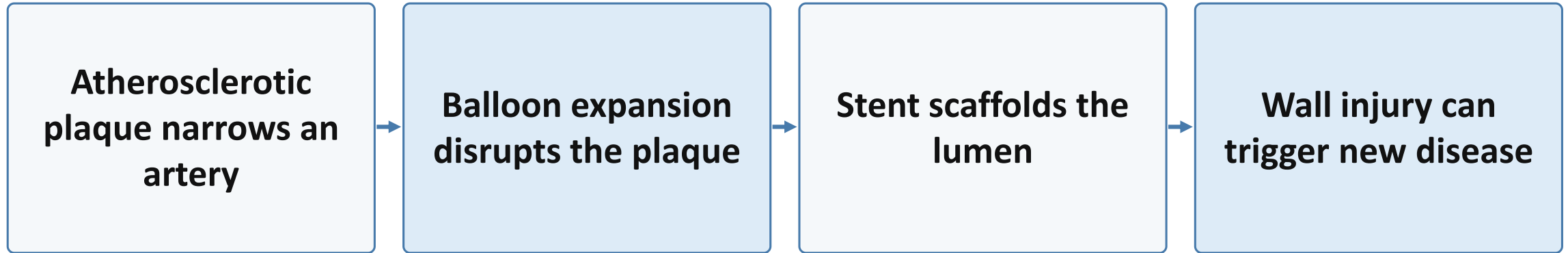
MBBS, MD (Pathology)

www.abusuraihsakhri.com

Learning goals

- Explain why balloon angioplasty is usually coupled with stent placement.
- Distinguish acute stent thrombosis from later neointimal restenosis.
- Trace vascular injury to smooth-muscle migration, proliferation and matrix deposition.
- Interpret the pathology of drug-eluting stents as a benefit–healing trade-off.

Stenting addresses a mechanical lesion

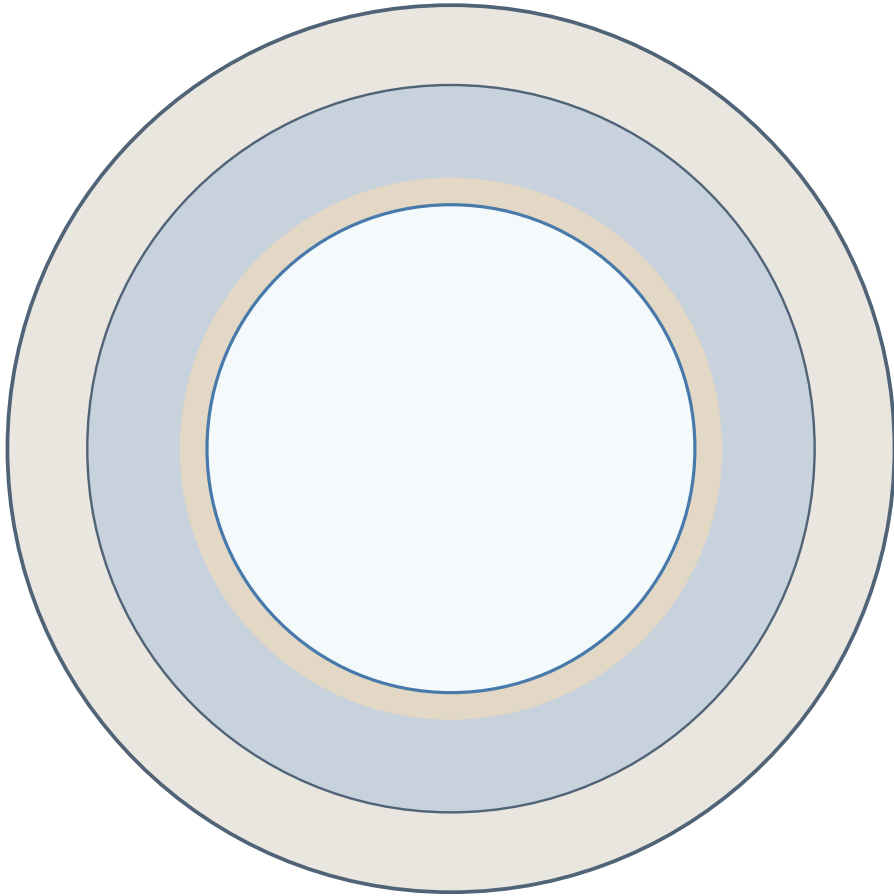


Mechanical restoration of caliber does not eliminate the tissue response to intervention.

Coronary stenoses are the principal example

- The Robbins discussion emphasizes arterial stenoses, particularly coronary arteries.
- Plaque enlargement progressively compromises the blood-flow lumen.
- Endovascular treatment aims to enlarge the lumen without replacing the vessel.
- The treated vessel remains biologically reactive after mechanical expansion.

Normal arterial wall: Layers at risk



Schematic cross-section

- Intima: Endothelial lining with a thin matrix compartment.
- Media: Circumferential smooth muscle and structural support.
- Adventitia: Outer connective-tissue compartment.
- Intervention affects the lumen-facing intima and underlying wall.

The endothelium is a functional surface

- Intact endothelial cells help regulate blood flow and thrombosis.
- Normal endothelium balances antithrombotic and prothrombotic properties.
- Loss or dysfunction of the lining shifts the wall toward thrombosis.
- This explains the importance of endothelial injury after stenting.

Smooth muscle has two relevant phenotypes

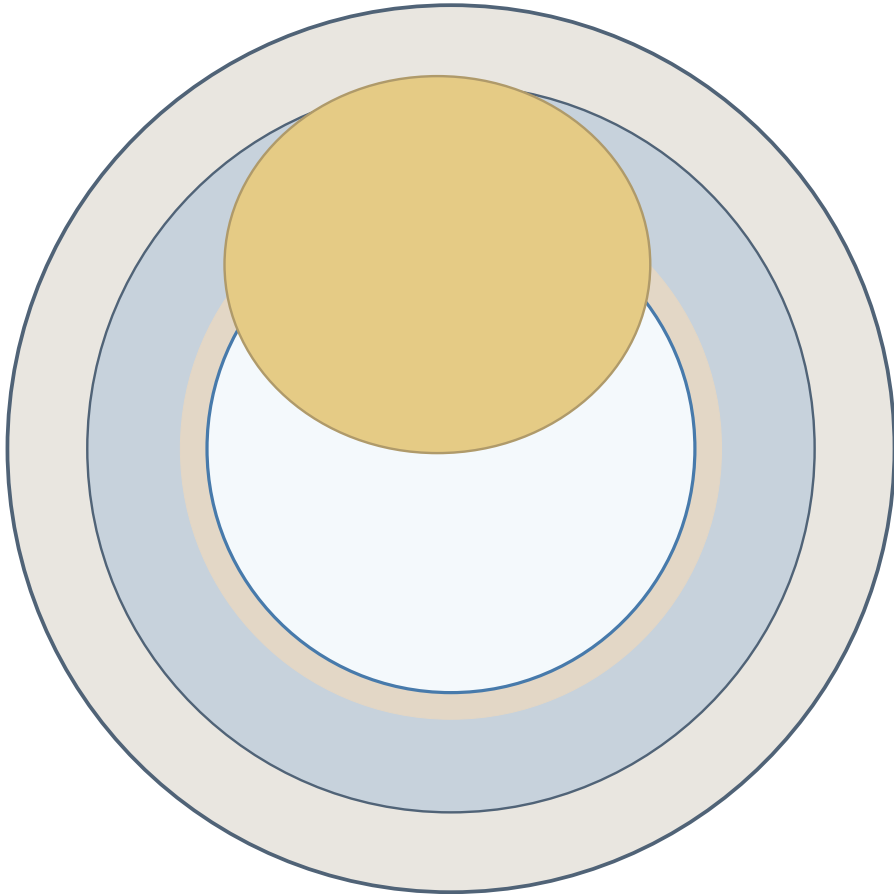
Contractile medial SMC

- Predominantly quiescent
- Regulates arterial tone
- Provides mechanical support

Proliferative neointimal SMC

- Responds to injury signals
- Migrates and expands in the intima
- Synthesizes extracellular matrix

Atherosclerotic plaque narrows the lumen



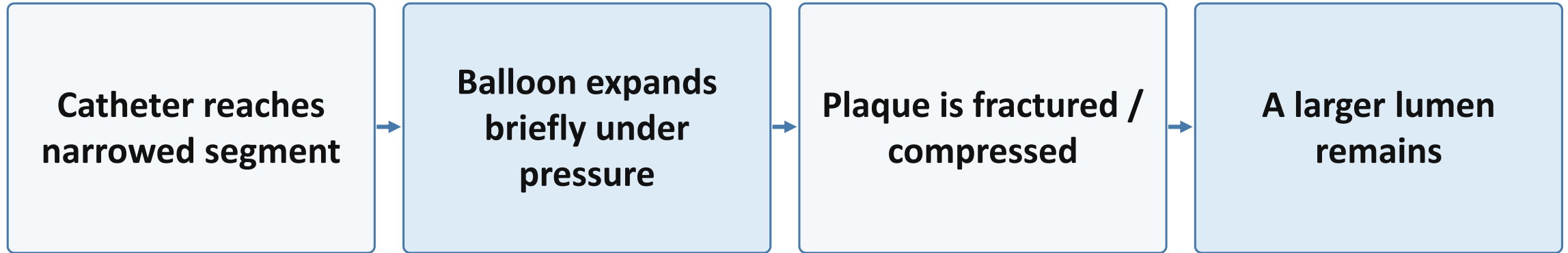
Eccentric plaque — schematic

- Atheromatous material occupies the intimal compartment.
- Lesions are commonly eccentric rather than concentric.
- Advanced plaque growth eventually constricts the residual lumen.
- Restricted flow provides the rationale for revascularization.

Stenosis links anatomy to ischemia

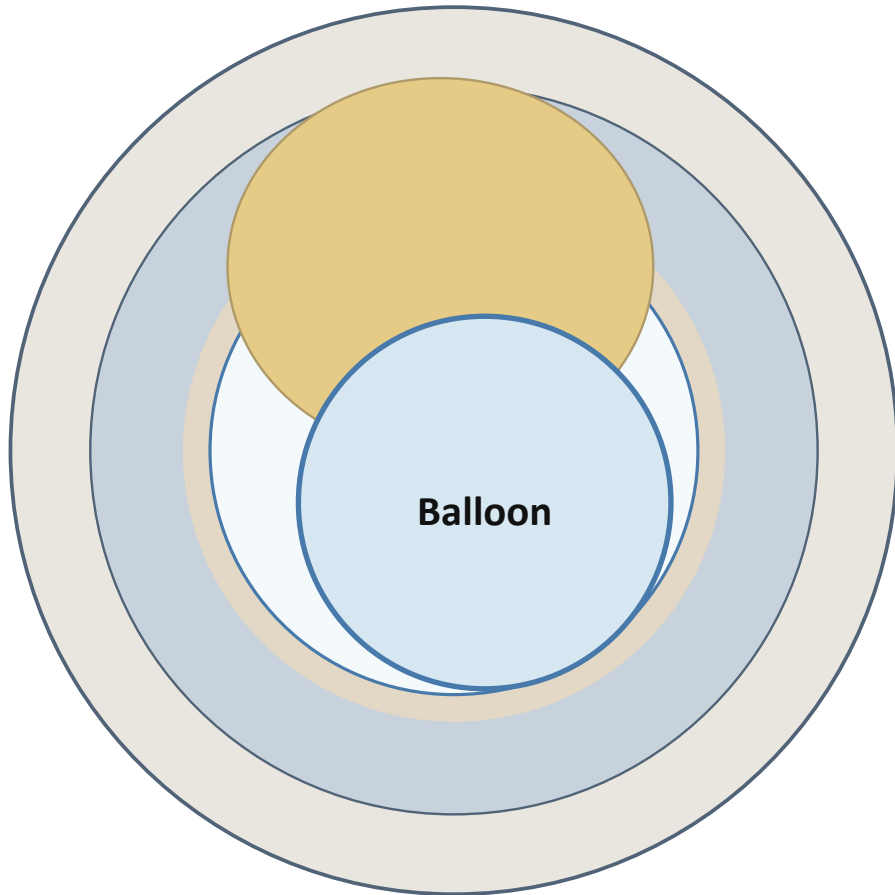
- A narrowed arterial lumen increases resistance to flow.
- At severe narrowing, perfusion may no longer meet tissue demand.
- Anatomical re-expansion can improve symptoms by restoring flow.
- The intervention is directed at stenosis, not the systemic cause of atherosclerosis.

Balloon angioplasty: Sequence



Balloon expansion restores lumen caliber by exerting force on the plaque.

Balloon angioplasty disrupts obstructing plaque



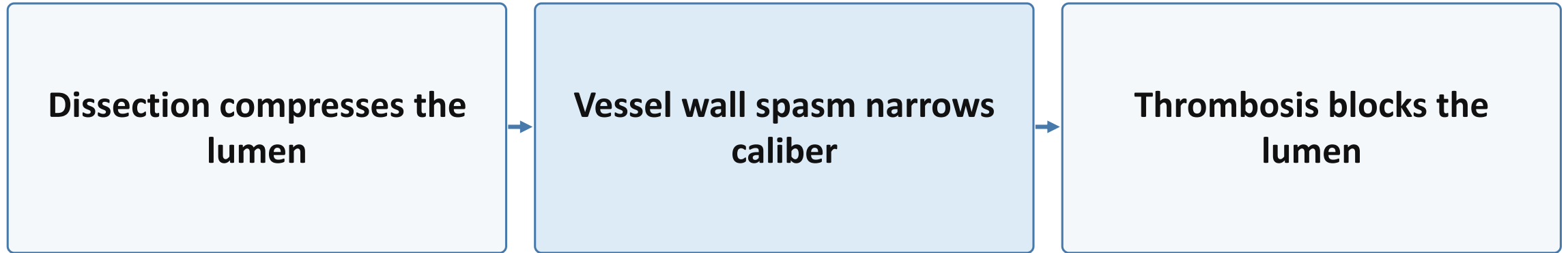
Balloon expansion — schematic

- Transient balloon inflation applies radial force to the lesion.
- The force can rupture or split the obstructive plaque.
- Luminal enlargement is immediate but may be mechanically unstable.
- Local injury initiates the vascular repair response.

Clinical improvement does not guarantee patency

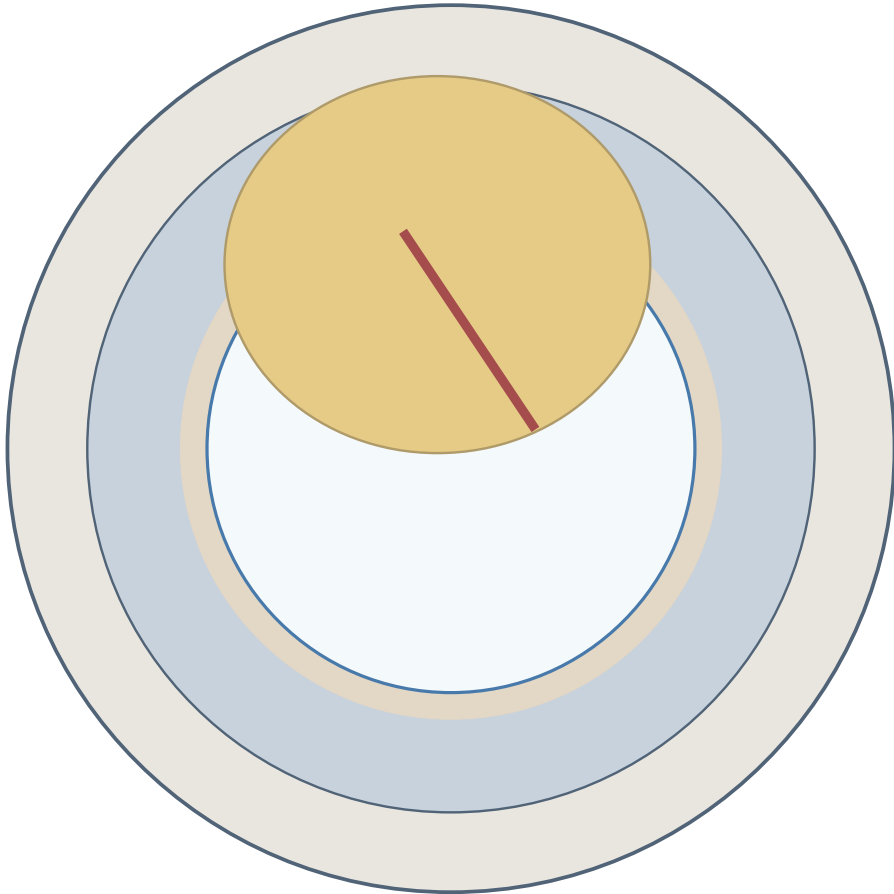
- Angioplasty can initially alleviate symptoms of stenosis.
- Rapid reclosure remains an important limitation of balloon-only treatment.
- The problem may be mechanical, vasomotor or thrombotic.
- Stent deployment specifically addresses several mechanical causes.

Three routes to abrupt reclosure



Abrupt reclosure has three distinct mechanistic explanations.

Angioplasty-related dissection



Flap — schematic

- Plaque and wall disruption may produce an intimal flap.
- A mobile flap can project into the lumen.
- Resulting compression may produce abrupt closure.
- Stent struts can hold the flap against the wall.

Vasospasm is a second closure mechanism

- Contraction of mural smooth muscle reduces vessel caliber.
- Angioplasty may trigger spasm in the treated segment.
- A narrowed lumen can reappear even without neointimal growth.
- An expanded metallic scaffold mechanically restricts recoil or spasm.

Thrombosis is a distinct acute hazard

- Balloon-induced injury exposes a thrombogenic vascular interface.
- An intraluminal clot can obstruct blood flow rapidly.
- This is different from gradual tissue proliferation.
- Deployment of a stent does not itself abolish thrombotic risk.

Mechanical versus thrombotic reclosure

Structural / vasomotor

- Dissection: Flap impinges on lumen
- Spasm: Wall constricts
- Stent can stabilize the affected region

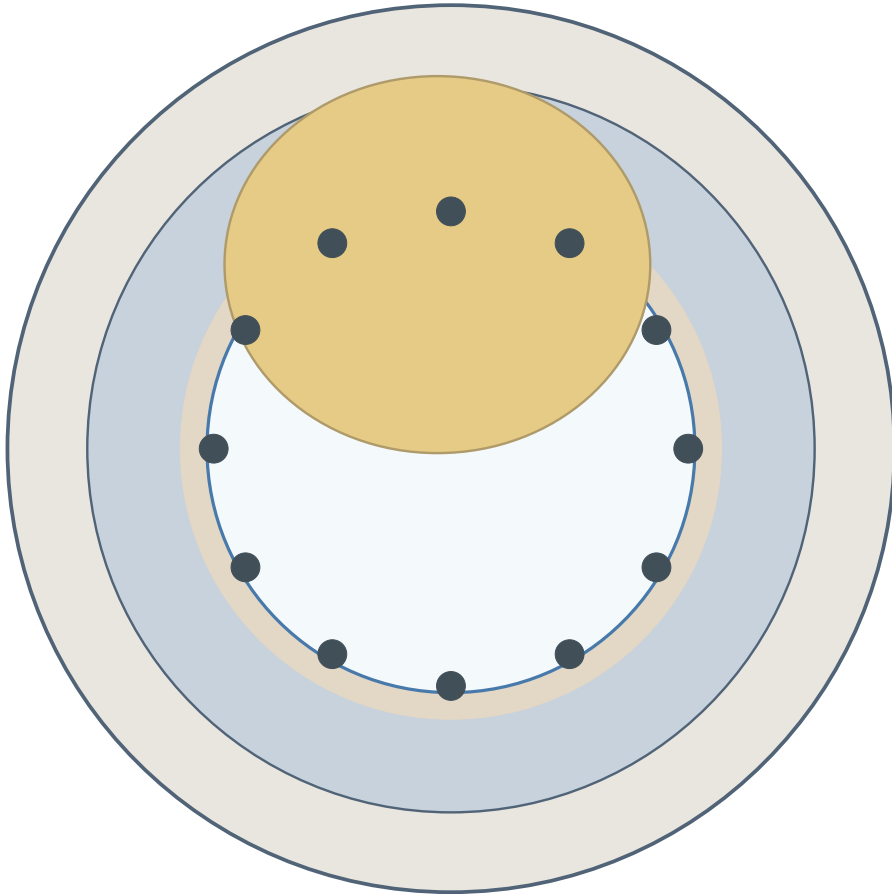
Thrombotic

- Platelet-rich thrombus may form after injury
- Occlusion can occur abruptly
- Requires antithrombotic protection

Coronary stents are expandable metal meshes

- A stent is a tubular metallic lattice deployed within the treated artery.
- Its architecture supplies radial support to the vessel wall.
- The device becomes part of the blood-contacting environment.
- It changes mechanics immediately and cellular responses afterward.

Scaffolding produces a more regular lumen



Stent struts — schematic

- Struts oppose the vessel wall after expansion.
- The stent holds a larger and more regular lumen.
- Local scaffolding reduces inward motion of wall flaps.
- The wall is still injured and therefore prone to repair responses.

What a stent fixes mechanically



Radial scaffolding counteracts inward movement of the arterial wall.

The stent changes vessel-wall geometry

- Expansion enlarges the passage through the diseased segment.
- Scaffolding apposes intimal flaps to the arterial wall.
- The treated lumen becomes less susceptible to spasm-driven collapse.
- Long-term patency still depends on biological healing.

Before and after stent placement

Before

- Plaque restricts the flow channel
- Disrupted intima may protrude
- Spasm may narrow the vessel

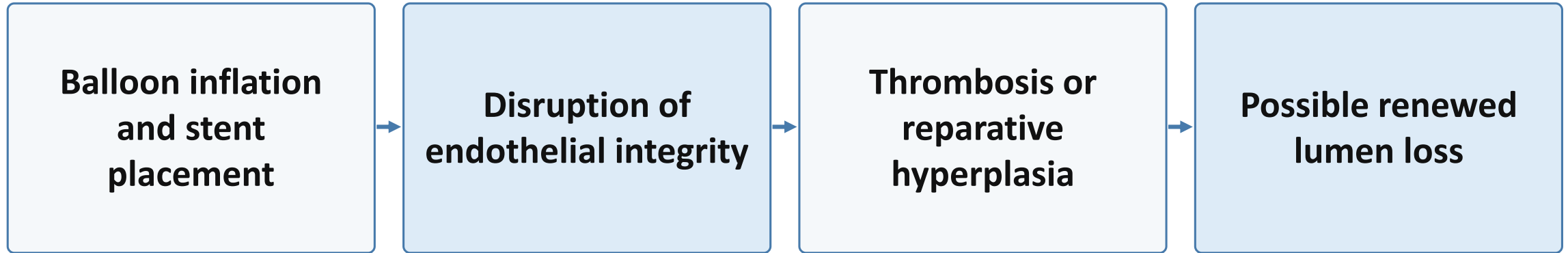
After

- Mesh supports a wider lumen
- Intimal flaps are constrained
- Endothelial injury and thrombotic risk remain

The source describes widespread combined use

- That more than 95% of coronary endovascular procedures combine angioplasty and stenting.
- The stated rationale is prevention of abrupt, mechanically driven reclosure.
- This is a source-specific utilization statement, not a freshly verified current registry statistic.

A successful device can still injure tissue

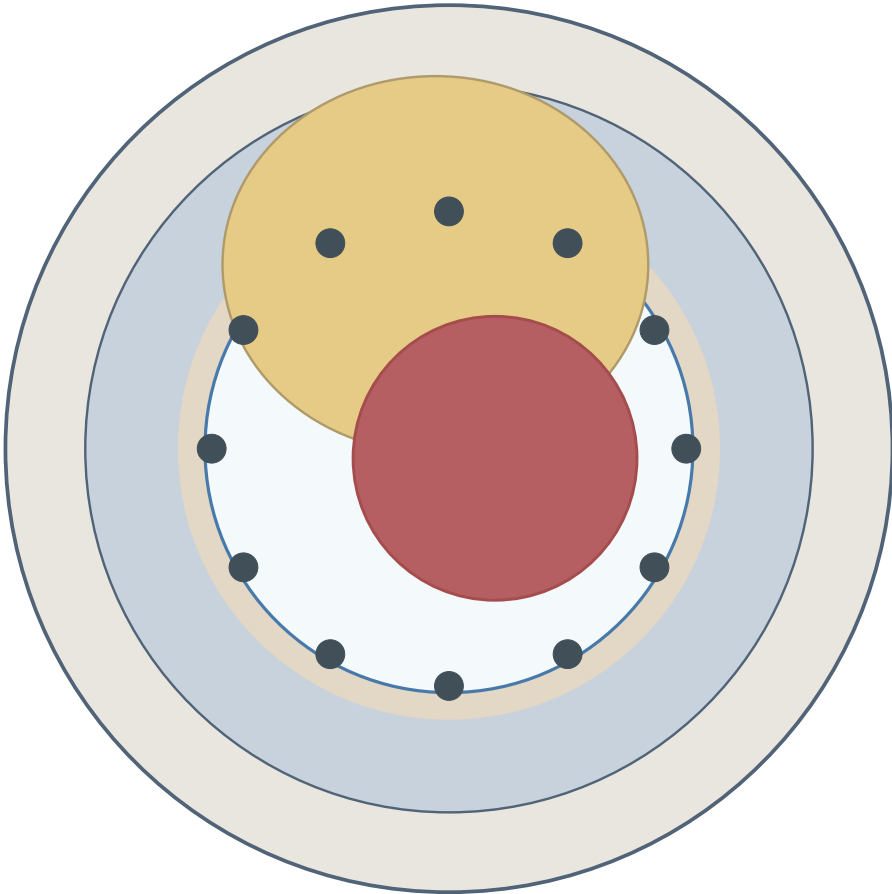


Acute thrombosis and delayed hyperplasia are different consequences of injury.

Stent implantation creates a thrombogenic interface

- An intact endothelial barrier is disrupted during intervention.
- Exposed damaged surfaces favor platelet adhesion and clot formation.
- The metallic framework does not replace antithrombotic endothelial function.
- Acute thrombosis can therefore follow technically successful stenting.

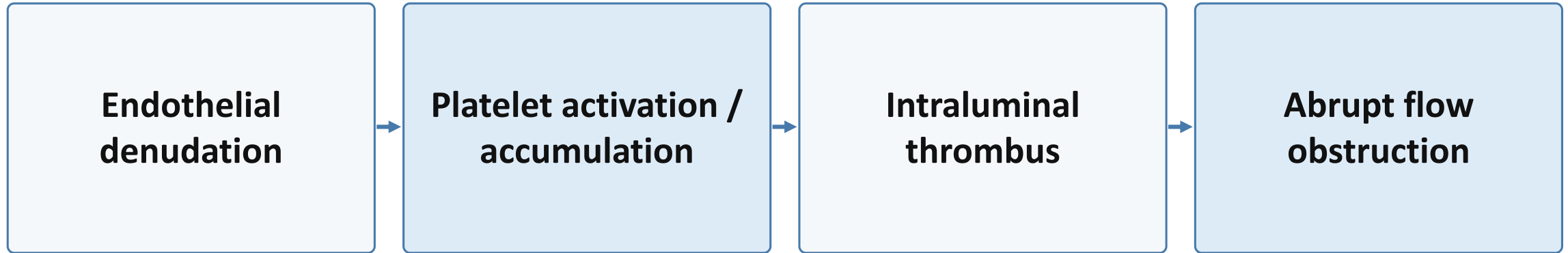
Acute post-stenting thrombus



Thrombus — schematic

- The stent maintains a mechanical lumen but cannot guarantee flow.
- Endothelial injury makes occlusive thrombosis possible.
- Thrombus occupies the blood-flow channel.
- This is an early complication rather than a fibromuscular repair lesion.

Early thrombotic occlusion: Causal chain



An acute thrombus can obstruct the entire treated lumen.

Why antithrombotic treatment matters

- Immediate post-stenting thrombotic risk.
- Antiplatelet agents are described as the principal preventive therapy.
- The objective is to avert acute, potentially catastrophic stent occlusion.
- Drug choice and duration require contemporary clinical guidance outside this source-based lecture.

Thrombosis and neointimal restenosis differ

Thrombotic occlusion

- Clot forms within the lumen
- Associated with the early injury period
- Clinical problem: Sudden loss of patency

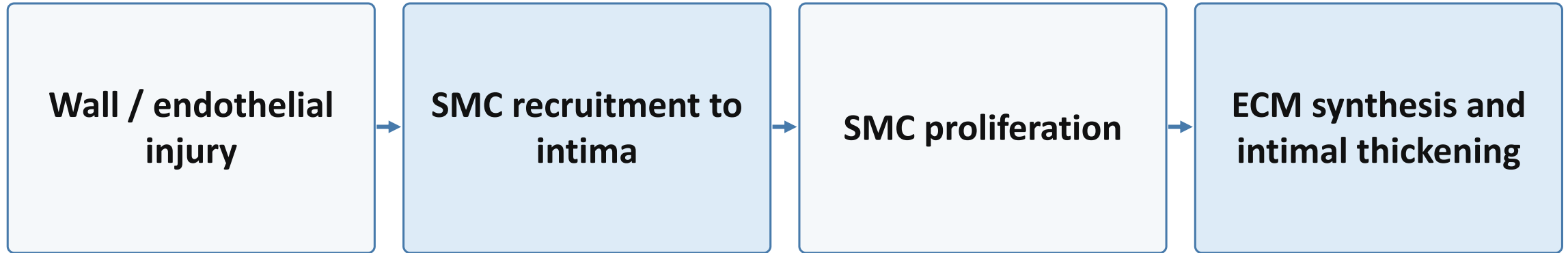
Neointimal restenosis

- Smooth muscle + matrix expand the intima
- Develops through tissue-repair processes
- Clinical problem: Progressive lumen encroachment

Injury triggers a stereotyped repair program

- Vascular trauma elicits the same general healing response seen after other vessel insults.
- Smooth muscle cells accumulate in the injured intima.
- Extracellular matrix production expands the new tissue layer.
- The resulting repair tissue can narrow a lumen that was just restored.

Neointimal hyperplasia: Core sequence



The apparent repair response can paradoxically re-create stenosis.

The cellular origin of the neointima

- Smooth muscle cells can enter the intima from the vascular media.
- Circulating smooth-muscle precursors can also contribute.
- These cells expand and produce extracellular matrix.
- Their repair-like behavior resembles fibroblasts in a healing wound.

Contractile-to-synthetic phenotype shift

Before injury

- Medial SMCs mainly contractile
- Relatively nonproliferative
- Regulate tone and vessel mechanics

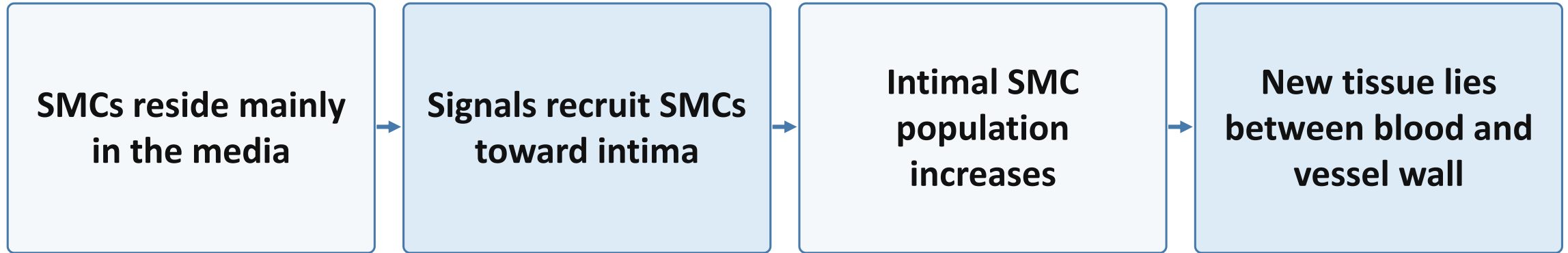
After injury

- Neointimal SMCs more proliferative
- Greater matrix biosynthesis
- Reduced contractile emphasis

Signals that drive smooth-muscle responses

- Platelets, endothelial cells and macrophages release growth factors or cytokines.
- Thrombin and activated complement also stimulate the repair phenotype.
- These signals favor SMC migration, proliferation and matrix production.
- The response can diminish after endothelial recovery.

Smooth-muscle migration changes lesion location



SMC migration places proliferative cells at the lumen-facing surface.

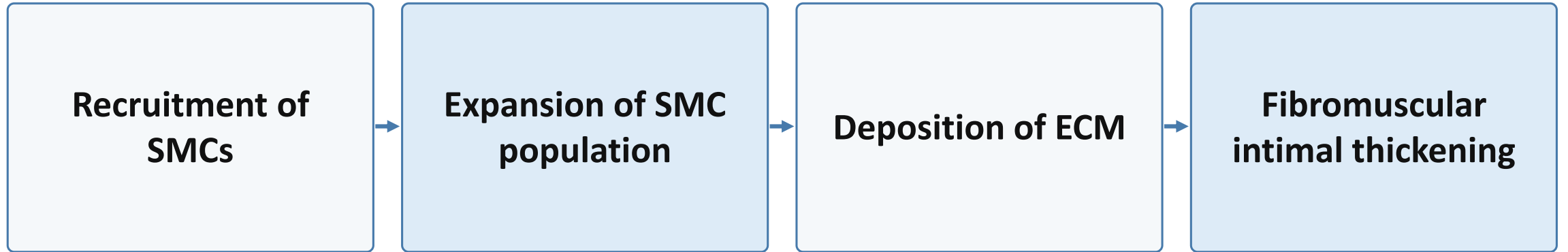
Proliferation amplifies the response

- A post-injury SMC phenotype can enter a proliferative state.
- Expanding intimal cell numbers increase lesion volume.
- This is a tissue-growth process, not thrombus deposition.
- Antiproliferative stent drugs target this component of restenosis.

Matrix accumulation is equally important

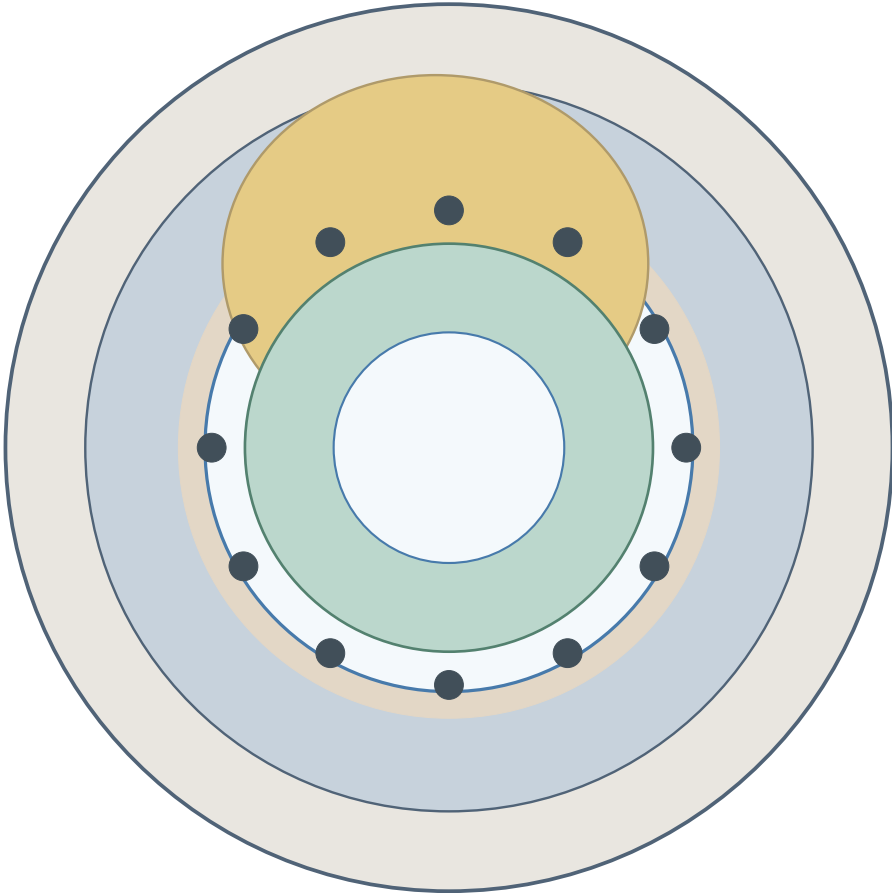
- Activated SMCs synthesize collagen, elastin and proteoglycans.
- Matrix is a structural component of the new intimal tissue.
- Combined SMC accumulation and matrix deposition thicken the intima.
- The pathologic consequence depends on the remaining lumen.

Neointima is composed of cells and matrix



Neointimal expansion progressively reduces the open lumen.

Restenosis: Tissue grows inside the stent



Late neointima — schematic

- Stent struts remain embedded near the expanded wall.
- A new cell- and matrix-rich intima develops over the struts.
- Neointimal tissue reduces the residual open lumen.
- The device may remain mechanically expanded despite tissue obstruction.

Why the healed vessel may narrow again

- Initial lumen gain is mechanical; Later lumen loss is biologic.
- SMC migration and proliferation increase cellular content.
- Extracellular matrix adds noncellular tissue volume.
- Concentric intimal growth may produce clinically relevant obstruction.

The macroscopic pattern of restenosis

- The original atherosclerotic plaque persists after intervention.
- Robbins Figure 11.33 describes residual yellow plaque material.
- A newer tan-white concentric intimal lesion lies internal to the old plaque.
- This layered pattern separates underlying disease from postprocedure repair.

The microscopic pattern of restenosis

- A thickened neointima overlies and separates metallic stent wires.
- Neointimal expansion intrudes into the luminal space.
- The Robbins example uses a Movat-stained tissue section.
- The caption describes matrix staining as gray-green.

Old plaque and new intima are not equivalent

Atherosclerotic substrate

- Pre-existing intimal plaque
- Lipid-rich atheromatous material may remain
- Initiates the need for intervention

Post-stent lesion

- Repair-associated fibromuscular neointima
- SMCs + ECM cover stent struts
- Can create restenosis without plaque reaccumulation

Clinical time course of in-stent restenosis

- Neointimal proliferation is a delayed consequence of vascular injury.
- Clinically important re-narrowing within 6–12 months.
- The cited estimate is up to one-third of patients after stenting.
- This is a textbook-described historical estimate, not a device-specific current rate.

Early and delayed hazards can be distinguished

Immediate / early

- Stent-associated thrombosis
- Mechanism: Endothelial damage and clot
- Clinical behavior: Abrupt occlusion

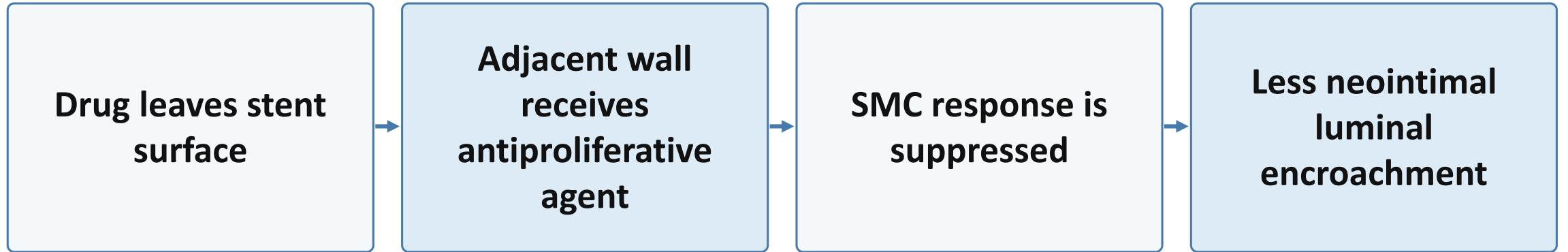
Months later

- Proliferative in-stent restenosis
- Mechanism: SMCs + ECM
- Clinical behavior: Progressive loss of lumen

Drug-eluting stents target the cellular response

- A drug-eluting stent releases antiproliferative drug into adjacent vessel tissue.
- The intended effect is suppression of SMC activation and proliferation.
- Reduced intimal hyperplasia helps preserve the luminal area.
- Drug delivery changes healing biology; It does not remove the original plaque.

Drug-eluting stent: Mechanism



Local drug delivery interrupts the cellular growth response.

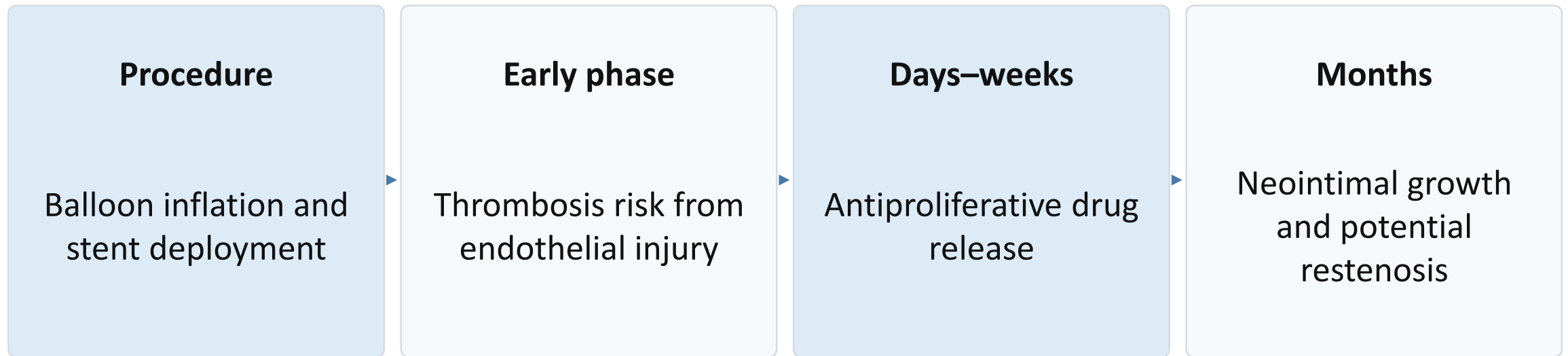
Sirolimus and paclitaxel are source examples

- Sirolimus as an antiproliferative stent drug.
- Paclitaxel is also cited as an example.
- Both are introduced here for their suppression of vascular SMC responses.
- No drug dose, platform comparison or release kinetics by device is specified.

Drug exposure is shorter than the clinical effect

- Drug elution over days to weeks.
- The intended effect on neointimal growth extends beyond release itself.
- Restenosis reduction is assessed at a much later time point.
- Short elution does not imply rapid endothelial recovery.

The time scales are different

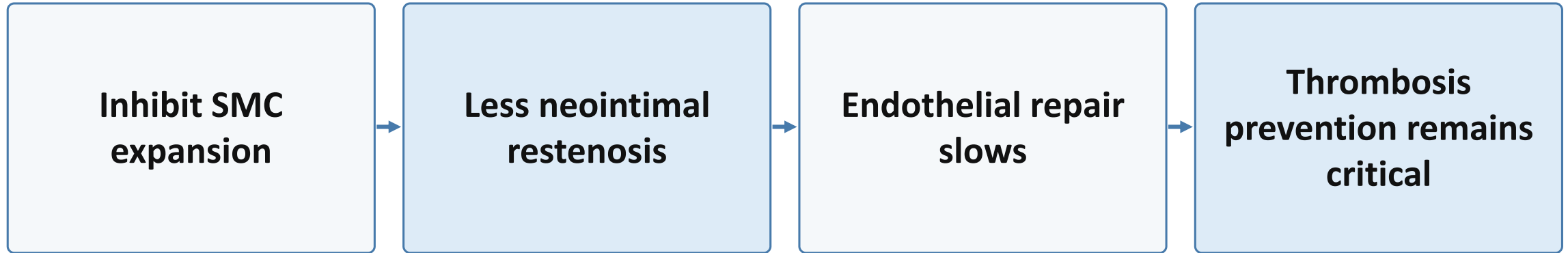


Late outcomes cannot be inferred from device expansion alone.

The source reports reduced restenosis at one year

- Drug-eluting stents reduce one-year restenosis by 50%–80%.
- The passage does not specify which trials, comparators or stent models define the range.
- Treat this as a textbook estimate, not a universal absolute-risk reduction.
- Do not interpret it as an individual patient's predicted response.

Biological trade-off of antiproliferative therapy



Reduced neointimal proliferation may coexist with slower surface healing.

Reendothelialization closes the injury cycle

- The endothelium can regenerate over previously denuded surfaces.
- Adjacent endothelial cells and circulating precursors may participate in repair.
- Normalization of the lining helps restrain excessive SMC responses.
- Antiproliferative stent therapy can prolong this restorative process.

Delayed healing affects antithrombotic needs

- Drug-eluting stents reduce proliferative restenosis but slow endothelial recovery.
- Robbins therefore describes extended antithrombotic treatment after deployment.
- The same section chiefly identifies platelet antagonists as protection against thrombosis.
- Specific contemporary regimens cannot be determined from this excerpt.

Conventional and drug-eluting devices

Metallic scaffold (without drug)

- Expands and regularizes the lumen
- Stabilizes flaps, limits spasm
- Still permits neointimal growth

Drug-eluting scaffold

- Same mechanical scaffolding function
- Local antiproliferative action
- Reduced neointimal growth; Slower endothelial recovery

Stent benefits and risks are linked

Early mechanical benefit

- Larger, more uniform residual lumen
- Less flap-related compression
- Protection against mechanically mediated reclosure

Ongoing biologic liabilities

- Immediate risk of thrombotic occlusion
- Late fibromuscular intimal thickening
- Delayed healing after antiproliferative stents

Recognize three mechanisms of lumen loss

Dissection

Wall flap compresses the expanded lumen

Thrombosis

Blood clot acutely obstructs the lumen

Neointimal growth

SMCs and ECM create new intimal tissue

Teaching case: Abrupt postprocedure closure

A stenotic coronary artery is dilated and a metallic mesh stent is deployed. Shortly afterward, flow suddenly falls.

Interpret the mechanism

- Which early complication must be considered?
- Why does mechanically successful expansion not prevent it?

Case resolution: Acute stent thrombosis

- Endothelial disruption creates a thrombotic substrate.
- A clot can form within the newly treated segment despite scaffolding.
- This differs from tissue-rich restenosis, which takes time to develop.
- Platelet antagonism as preventive therapy.

Teaching case: Re-narrowing months later

A coronary stent remains in position, but the treated segment narrows again several months after implantation.

Interpret the mechanism

- What type of lesion is most characteristic?
- Which cell and extracellular component create it?

Case resolution: Neointimal restenosis

- Smooth muscle cells accumulate and proliferate within the intima.
- The cells deposit extracellular matrix around and over the stent struts.
- The expanding neointima progressively diminishes the lumen.
- A retained stent does not exclude a new biological stenosis.

Teaching case: An antiproliferative trade-off

A stent is coated to release a drug that reduces smooth-muscle proliferation after vessel injury.

Interpret the mechanism

- Which delayed complication is the coating designed to limit?
- Which restorative process may also be prolonged?

Case resolution: Control versus healing

- Drug delivery suppresses the proliferative neointimal response.
- This lowers the probability of re-narrowing account.
- Endothelial restoration may also proceed more slowly.
- The trade-off motivates continued attention to thrombotic protection.

Stenting and grafting share a repair response

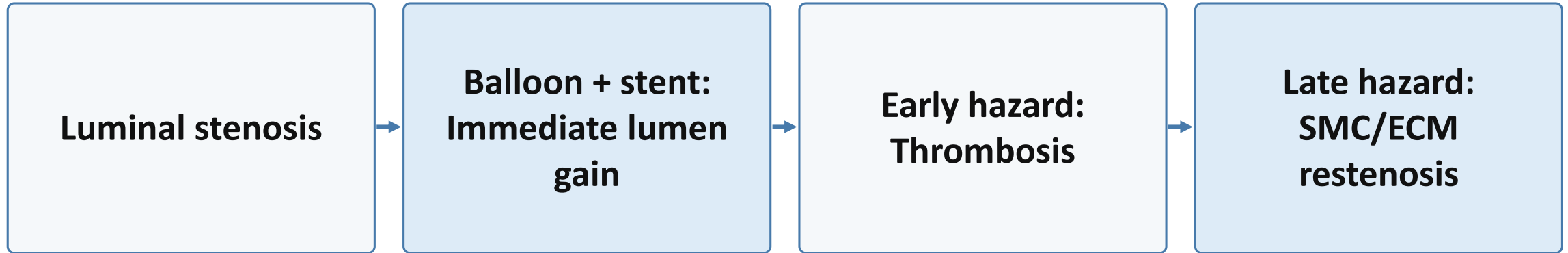
Stent-injured native artery

- Balloon and strut trauma damage the wall
- SMCs and matrix enlarge the neointima
- Restenosis occurs within the supported segment

Vascular graft / bypass

- Abnormal mechanical forces can injure vessels
- SMCs and matrix thicken the intima
- Stenosis may arise at graft interfaces

Integrated pathology: Intervention to outcome



The clinical result depends on mechanical success and vascular healing.

Five findings worth retaining

- Stents provide a more regular, supported lumen after angioplasty.
- Early failure may result from acute thrombosis despite scaffolding.
- Late failure often reflects SMC-rich, matrix-rich neointimal proliferation.
- Drug elution suppresses hyperplasia but can delay reendothelialization.
- Device mechanics and vessel biology must both be considered.

Self-assessment: Mechanistic checkpoints

- Why can angioplasty alone be followed by abrupt lumen closure?
- Which stent feature stabilizes intimal flaps?
- What distinguishes neointima from a fresh thrombus?
- How does drug elution modify both restenosis and healing?

Selected textbook source

Robbins, Cotran & Kumar: Pathologic Basis of Disease

11th edition (2026) · Chapter 11: Blood Vessels

Arterial wall and intimal response: pp. 442–445

Atherosclerosis / stenosis: pp. 454–457

Pathology of intervention and stenting: pp. 477–478