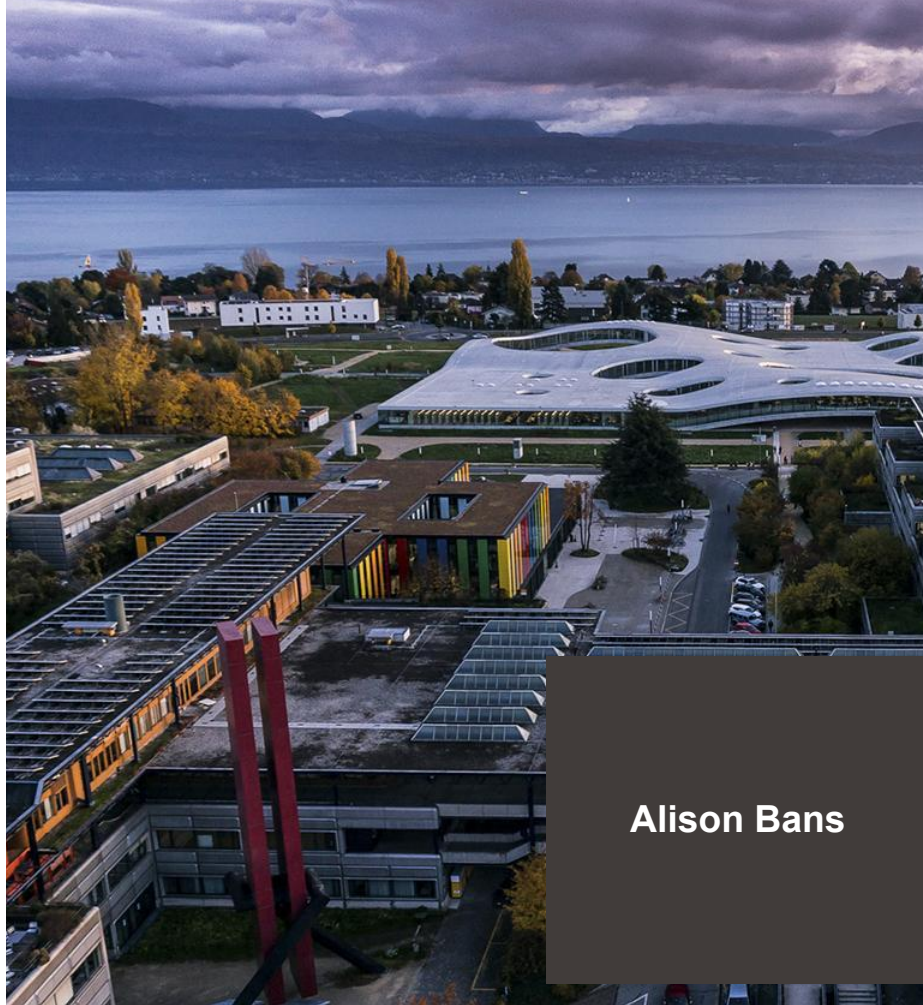




Cardiac Stent

Alison Bans

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Introduction

Cardiac Stent

What is a stent?

- Mesh like structure
- Arterial diameter control → Blood Pressure, Flow control

We will go through:

- Importance of the Cardiovascular System
- Cardiovascular Diseases
- Different types of stents
- Statistics

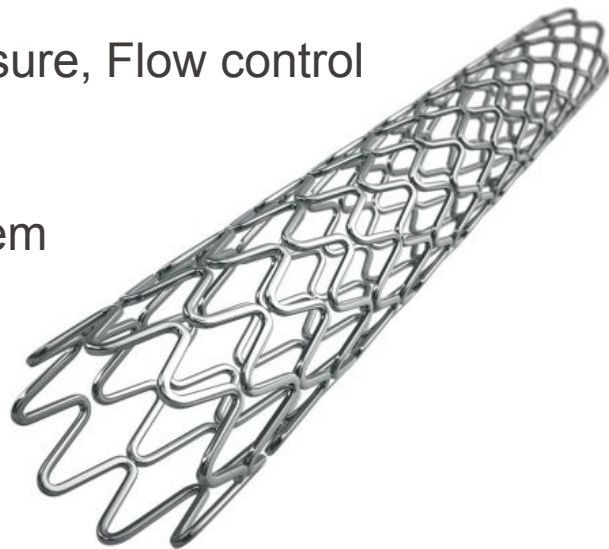


Figure 1. Bare Metal Stent

(Source: Dfornel 2021)

Physiology

Cardiovascular System

Cardiovascular System Properties

- Blood carries oxygen to cells
- Oxygen is used to synthesise ATP
- ATP is the primary energy source for cells

Parameter to control with stent

- Arterial diameter
 - Blood pressure
 - Blood flow

Physiological anomalies

- Stenosis → narrowing
- Aneurysms → dilation

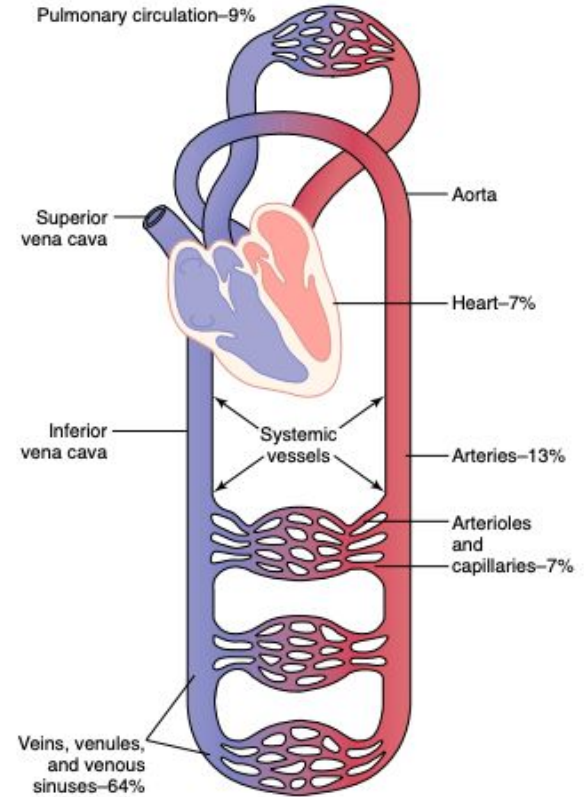


Figure 2. Cardiovascular system representation

(Source: Guyton et al. 1981)

Stents for Arterial Stenosis

Physiology

Arterial Stenosis

- Narrowing of the artery
- Formation of plaque
- Change in blood flow and pressure
- Can be in the coronary arteries (supply the heart), peripheral arteries (supply peripheral tissues and organs) and carotid (supplies the brain)
- Thrombus and embolism
- Myocardial infarction or stroke

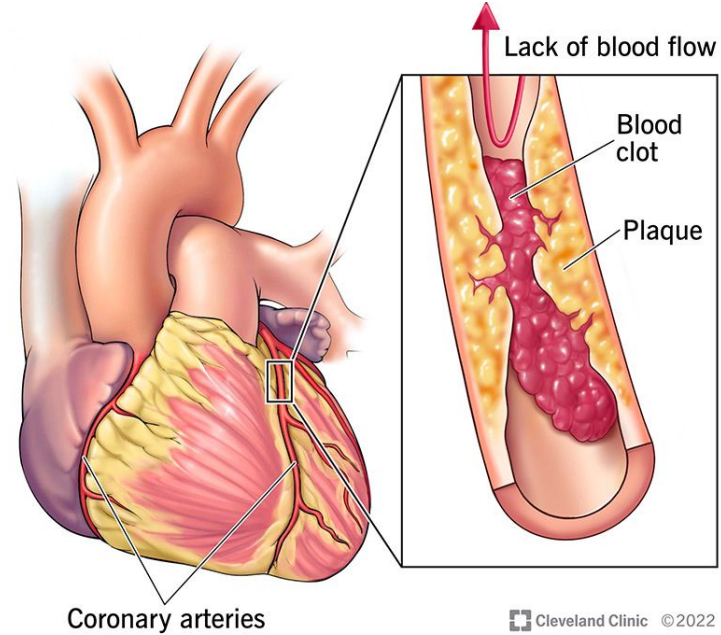


Figure 3. Coronary Artery Disease

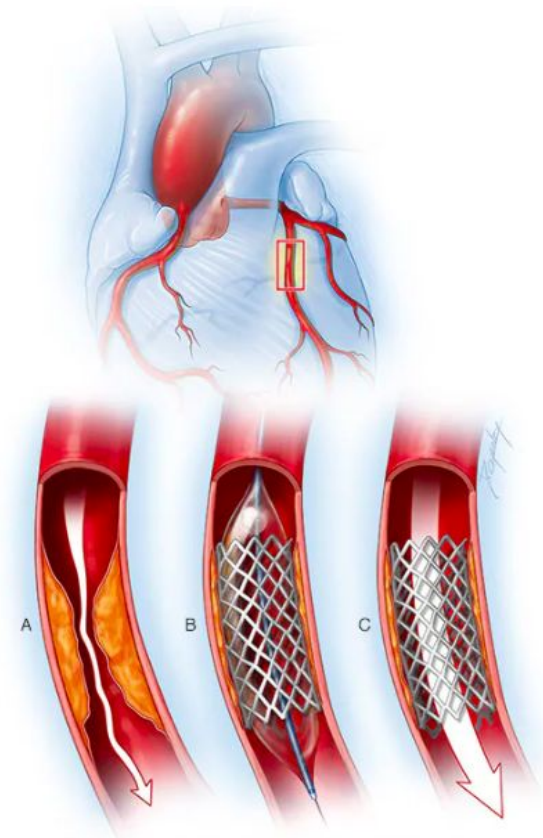
(Source: Cleveland Clinic 2022)

Technical Description

Stents for Arterial Stenosis

How can the stent help?

- Opening of the occlusion
- Can contain drugs (to slow down the restenosis)



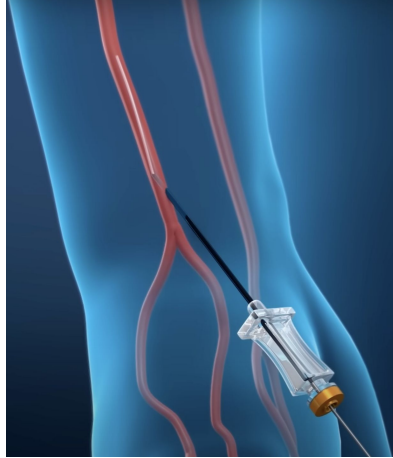
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Figure 4. Stent for Coronary Artery Disease

(Source: Mayo Clinic 2023)

Angioplasty

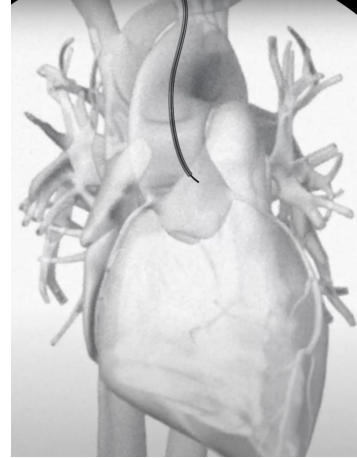
Procedure steps - Coronary stenosis



1. Needle into radial artery



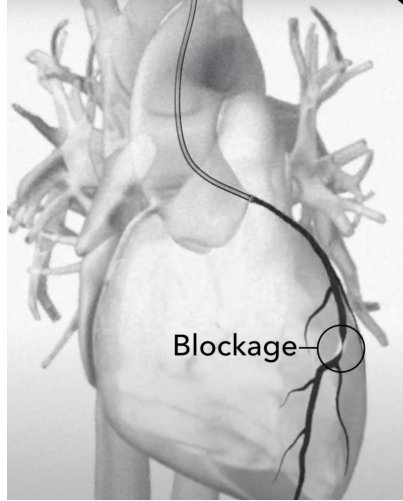
2. Insertion of the catheter and advancement of the guide wire to the heart



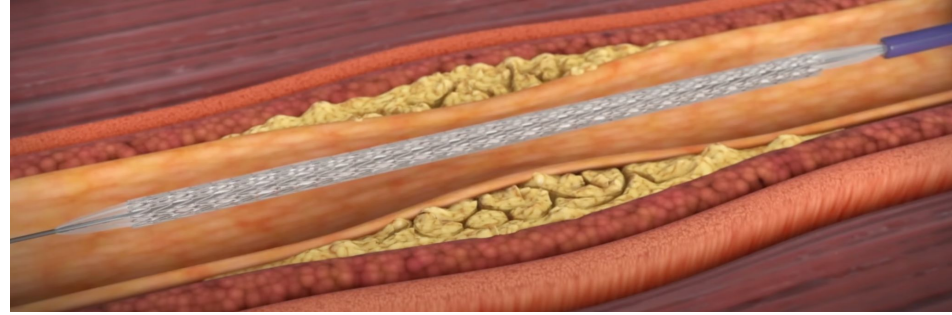
3. Catheter brought to the heart on top of guidewire and remove guide wire
Fluoroscope : X-ray device to check the procedure real time

Angioplasty

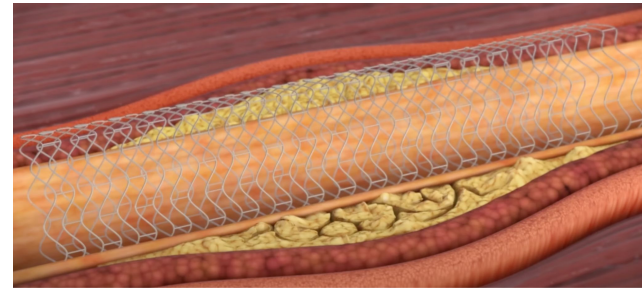
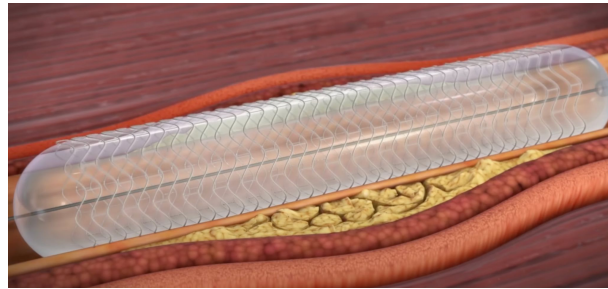
Procedure steps - Coronary Stenosis



4. Tip of the catheter at the entrance of the artery, dye injection



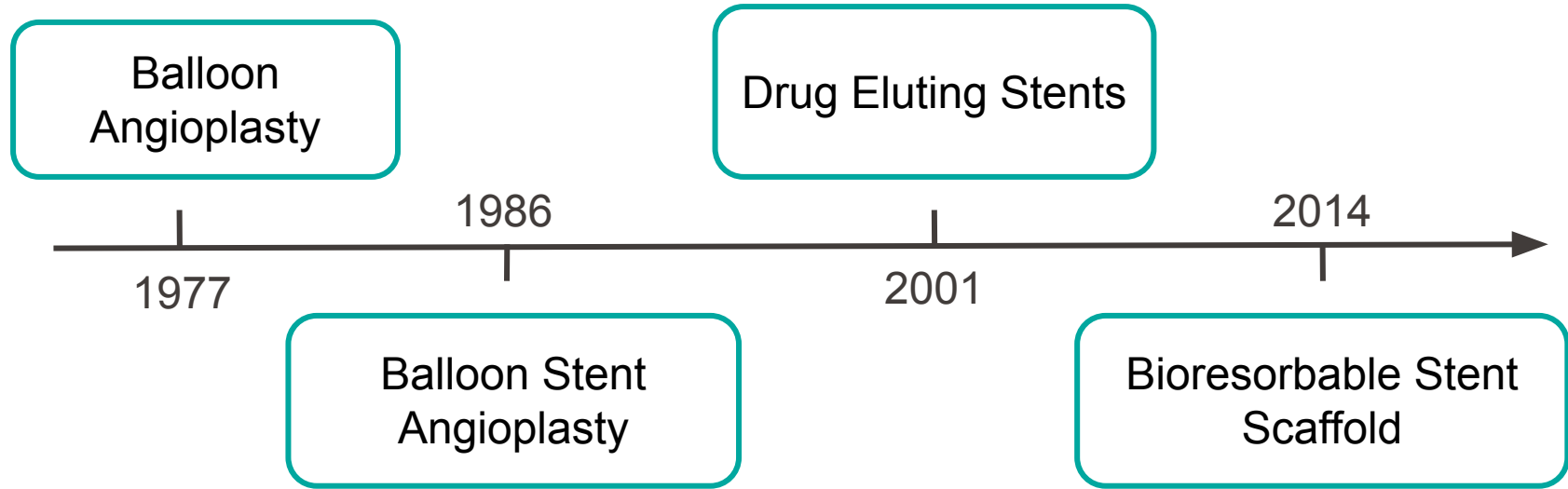
5. Guide wire with balloon and stent to the blockage



6. Inflate balloon, deflate balloon, and remove guide wire

History

Angioplasty



History

Bare metal stent

Advantage: mechanical structure → reduction of restenosis rate

First materials: 316L stainless steel → cobalt chromium metal alloy (lower thickness for increased radial strength, lower restenosis rate)

Material characteristics

- (1) Elasticity/plasticity – expansion,
- (2) Rigidity – dilatation control
- (3) Resistance against elastic recoil

History

Bare metal stent

Concerns:

- Radio-opacity → coating or markers
- Metal ion release → nickel-free alloy or coating

Main limitation **X**: Restenosis

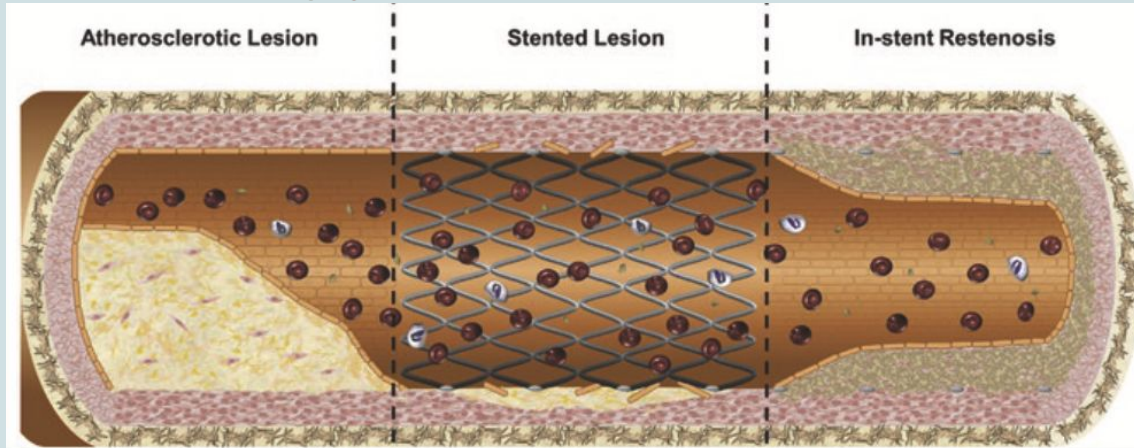


Figure 5. Restenosis

(Source: King et al. 2020)

History

Drug eluting stent

<u>First Generation</u>	
Advantage ✓	Antiproliferative drugs to reduce restenosis (50-70%)
Drugs	Sirolimus and paclitaxel
Stent material	Stainless steel
Drug release	Biostable polymer coating (durable) to control the release
Limitations ✗	Thick strut, late stent thrombosis

History

Drug eluting stent

<u>Second Generation</u>	
Advantage ✓	Lower thrombosis rate
Drugs	Zotarolimus, everolimus, ridaforolimus
Stent material	Cobalt-chromium or platinum chromium alloy
Improvements ✓	Thinner, more biocompatible, easier to deliver
Drug release	Biodegradable polymers to control the release
Limitations ✗	Delayed endothelial cell growth due to drugs, very late stent thrombosis

History

Bioresorbable stent

Advantage 	No residue left to induce inflammation
Material	Bioresorbable materials instead of metals (e.g. Poly(L-lactic acid) - PLLA, or Magnesium)
Absorption	6-24 months
Limitations 	Limited radial resistance, polymer-induced inflammation, in-stent thrombosis

History

Recent Advances

1. Partial drug delivery → promote healing

2. Biomolecules or antibodies to mimic natural tissue → reduce inflammation

3. Antibodies to capture progenitor cells → promote healing

4. Closed cells stent → reduce injury site size exposed to blood

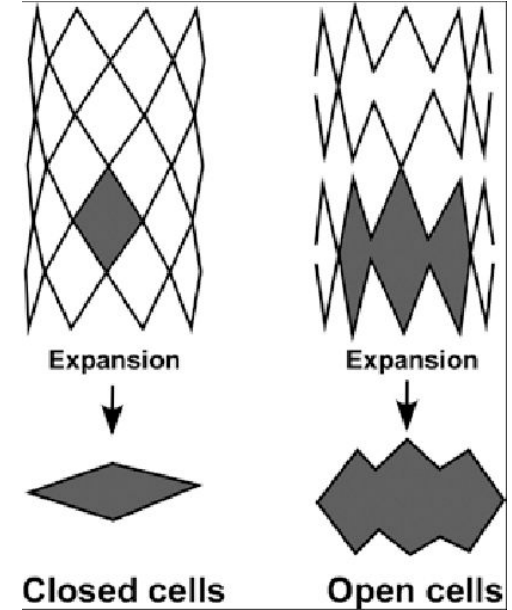


Figure 6. Open vs Closed cells

(Source: Research gate)

Stents for Aneurysms

Physiology

Aneurysms

Enlargement of the artery's diameter

Rupture can cause death especially in abdominal aorta and brain

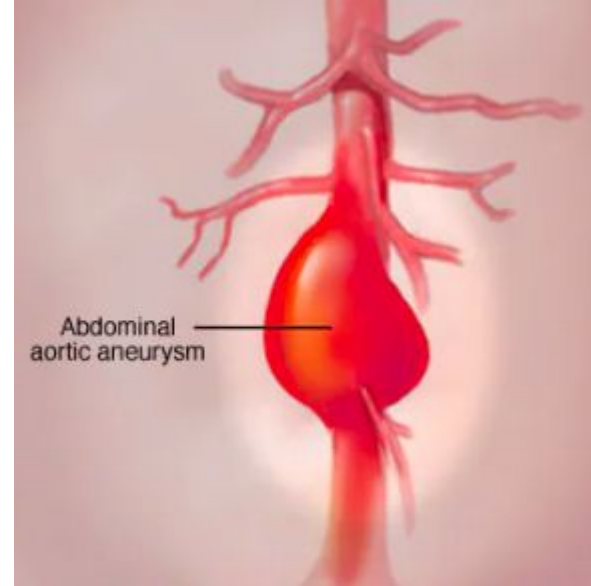


Figure 7. Abdominal Aortic Aneurysm

(Source: Mayo Clinic, 2023)

Technical Description

Stents for Arterial Aneurysm

How can a stent-graft help?

- Reduce blood flow to the aneurysm
- Support of the arterial wall

Benefit

Not invasive

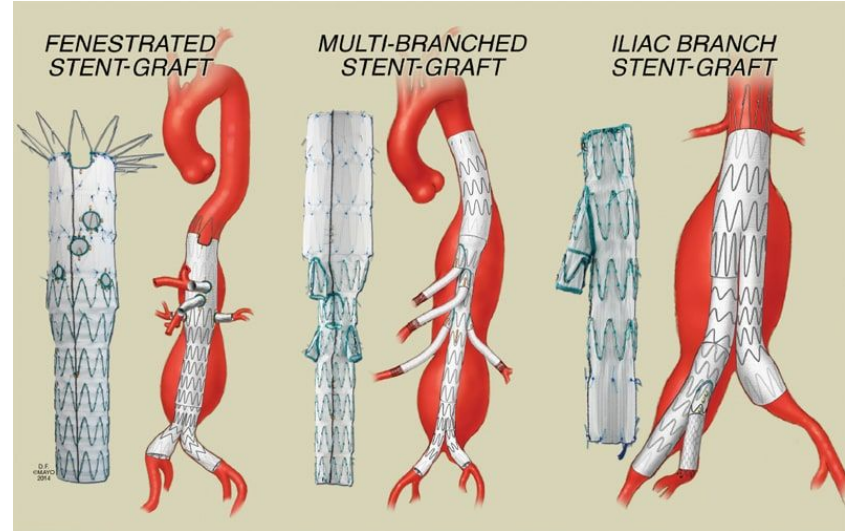


Figure 8. Stent Graft for Abdominal Aortic Aneurysm

(Source: Mayo Clinic)

Endovascular Aneurysm Repair

Procedure steps - Abdominal Aorta Aneurysm



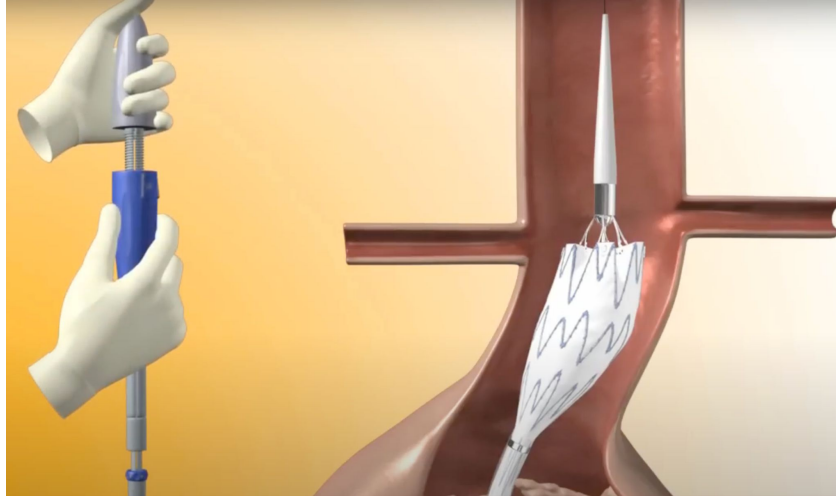
1. Place the delivery system through the femoral artery



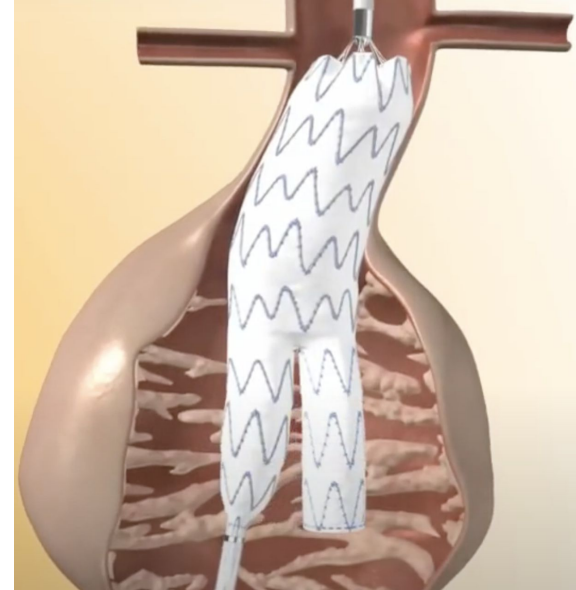
2. Check the markers to ensure good placement

Endovascular Aneurysm Repair

Procedure steps - Abdominal Aorta Aneurysm



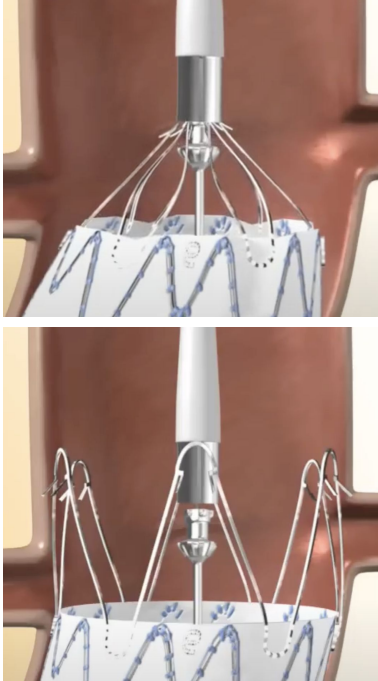
3. Deploy the top of the stent-graft and check its position with respect to the renal arteries using angiography



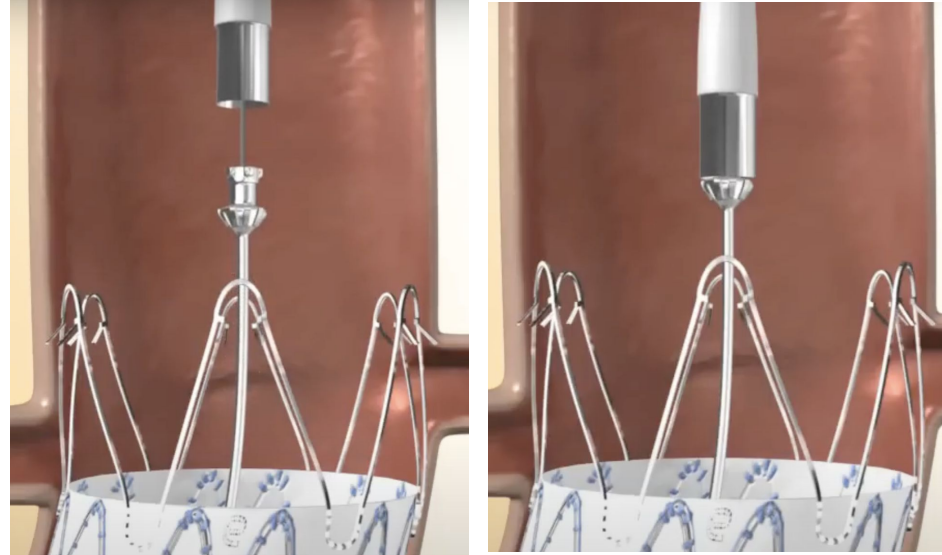
4. Deploy further to until the contralateral stub leg is released
Check the placement using angiography

Endovascular Aneurysm Repair

Procedure steps - Abdominal Aorta Aneurysm



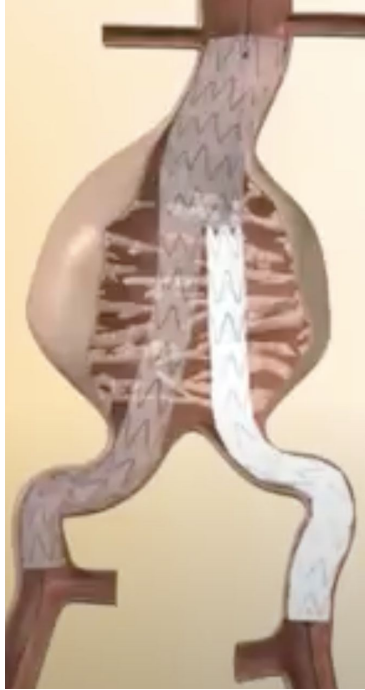
5. Release suprarenal stent with anchoring pins



6. Recapture the tip and remove the delivery system

Endovascular Aneurysm Repair

Procedure steps - Abdominal Aorta Aneurysm



7. Insert the stent graft in the contralateral leg



6. Optional: deploy balloon to remove wrinkles or folds and to model the stent graft to wall

History

Endovascular Aneurysm Repair (EVAR)

Initial trials of
adding a
material to
mimic arterial
wall

First in-man Test

1997

1998

2001

Early
1990s

First Animal Trials

First iliac artery
branching system.
Hooks used to avoid
migration

Design

Stent-Graft Design

Key factors of stent design Influence on radial force

- Diameter
- Wire thickness
- Axial length
- Material type

⇒ Good sealing vs low trauma

Key factors of graft design

- Strength
- Elasticity
- Non-linearity
- Anisotropy
- Radial compliance

⇒ Graft must resemble the arterial wall

35 million cardiac cycles per year

Stent

Nitinol

- Superelastic shape memory
- Biocompatibility
- Resistance to corrosion and fatigue
- MRI compatibility

Graft

Polyethylene terephthalate

- Strong and rigid
- Woven or knitted designs

Polytetrafluoroethylene

- Flexible
- Hydrophobic
- Porous

Manufacturing Stent



Laser cut sheet forming

- Cut pattern on flat sheet
- Form cylindrical shape

Wire forming

- Bend wires to desired shape
- Join wires (e.g. welding)

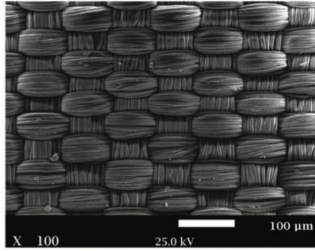
Laser cut tube forming

- Cut pattern on tube

Manufacturing

Graft

Woven forming techniques



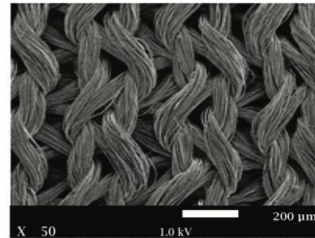
Weave



Smooth, durable, non-reactive



Lack of radial flexibility



Knit



Radial flexibility



Dilation over time, highly porosity

Statistics and Outlook

Medical Significance

Statistics

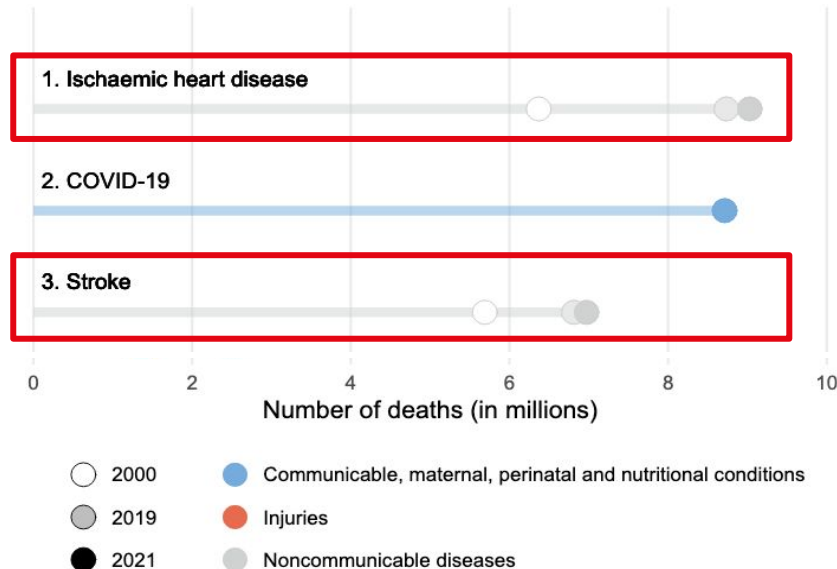


Figure. Leading causes of death in 2021

(Source: WHO)

Ischaemic Heart Disease

Principle: Blocked Coronaries → Decrease in O₂ supply to heart muscle → Cardiac arrest

Cause: Coronary artery stenosis

Stroke

Principle: Decrease in O₂ supply to the brain → Brain cells die → Cerebral death

Causes: Carotid artery stenosis, brain artery stenosis, brain artery aneurysm rupture

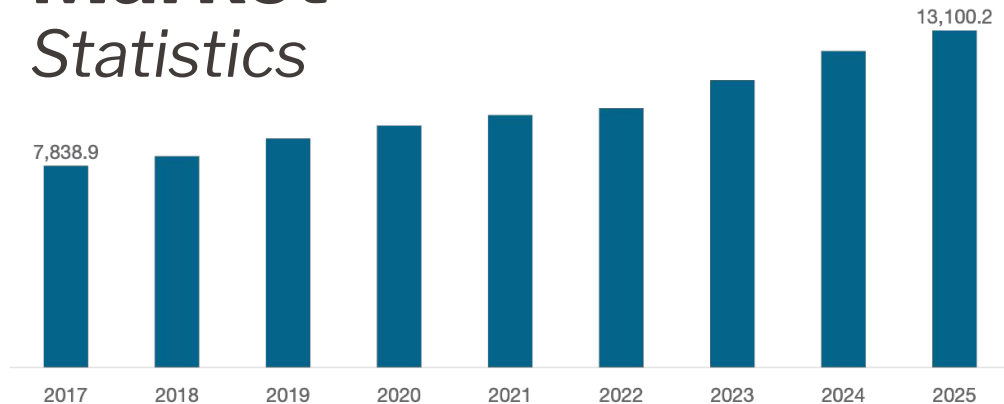
Medical Significance

Statistics

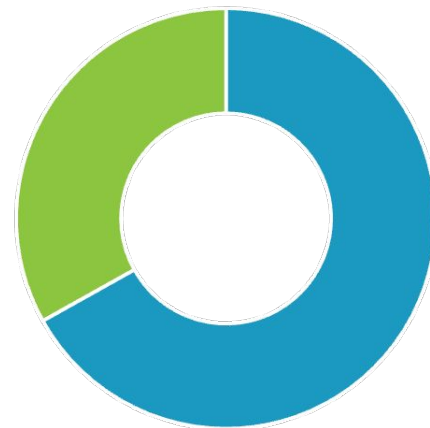
Key risk factors for strokes and heart attacks

- Smoking → $\frac{1}{3}$ of heart attack deaths & 1.3 billion smokers
- Lack of physical activity
- Nutrition
- Obesity
- Cholesterol
- Diabetes
- High blood pressure

Market Statistics



Global Cardiovascular Stents Market Size, 2015-2025
(US\$ Million)



Coronary Stenting
Peripheral Stenting

Global Cardiovascular Stents Market Share, By Procedure Type, 2017

Medtronic



Abbott

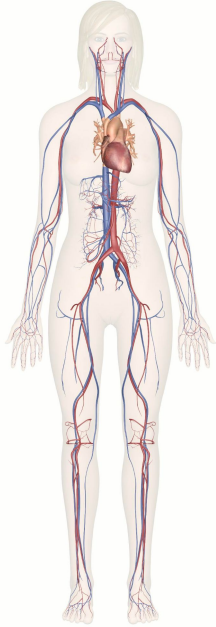


BIOTRONIK

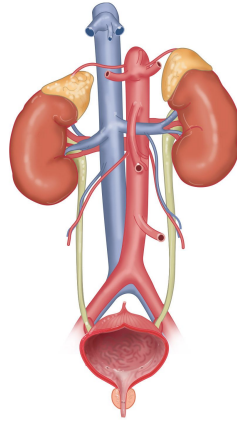
Boston
Scientific

Future Perspectives

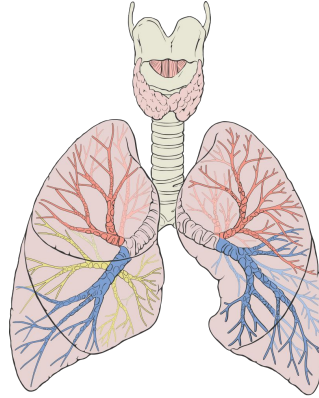
Physiological systems using stents



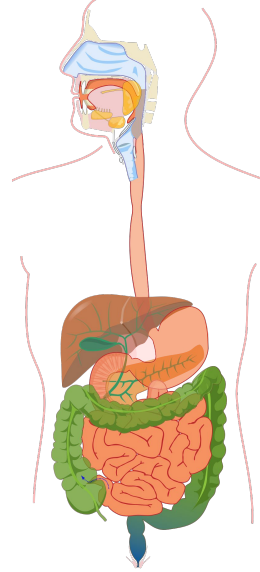
Cardiovascular



Urinary



Pulmonary

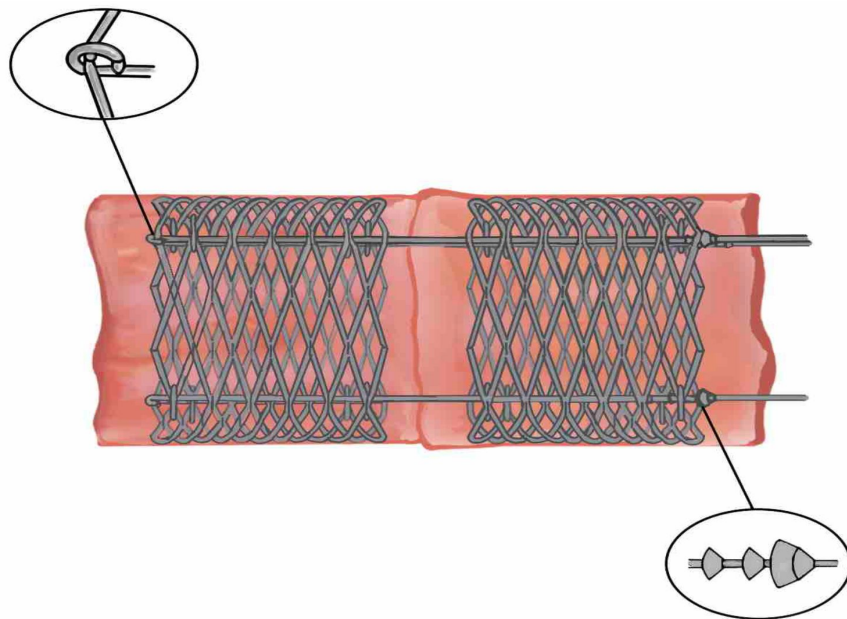


Gastrointestinal

Future Perspectives

Hypothetical

- **Other uses:** stents for bronchial anastomosis ?
- **Manufacturing:**
3D printing of stents recently (Ullah et al. 2024)
- **New material ?**
- **New coating ?**



Thank you for your attention !

Figures

Dfornell (2021) *Resolute onyx 2.0 mm stent performs well in small vessels, DAIC*. Available at: <https://www.dicardiology.com/content/resolute-onyx-20-mm-stent-performs-well-small-vessels> (Accessed: 06 November 2024).

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