# Assessment and Vascular Management of the High Risk Foot


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ANZSVS
Australian and New Zealand Society for Vascular Surgery

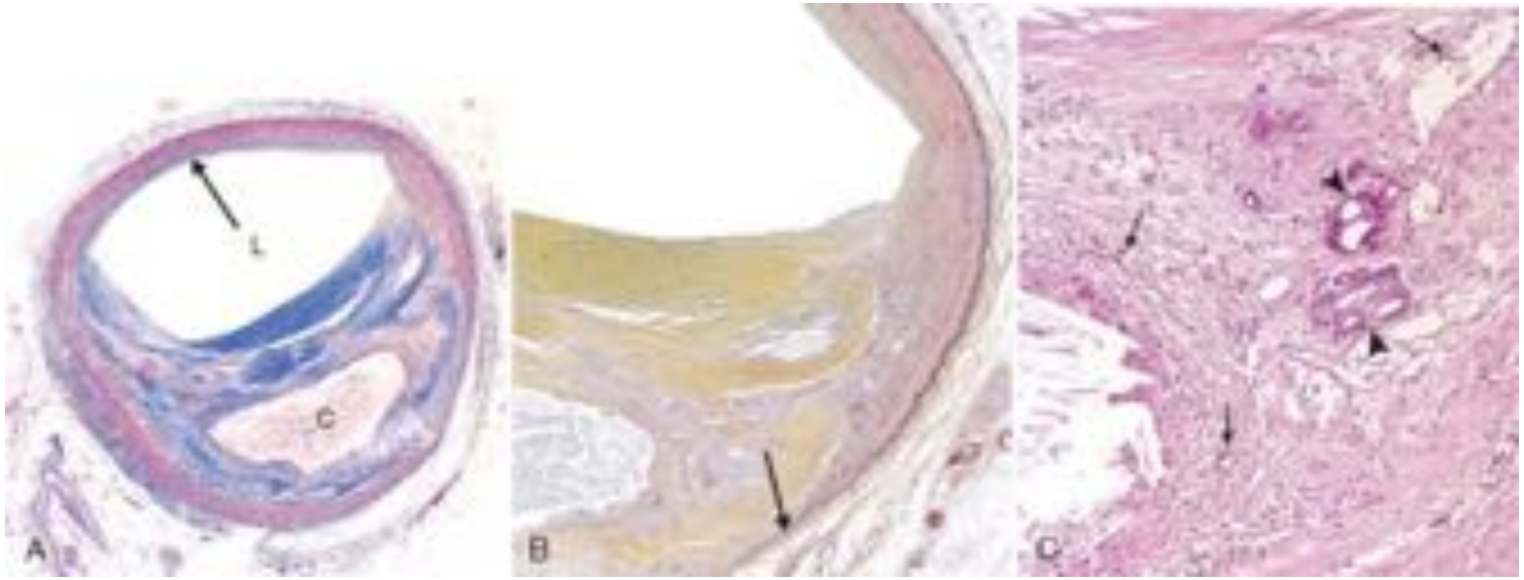
THE UNIVERSITY OF MELBOURNE

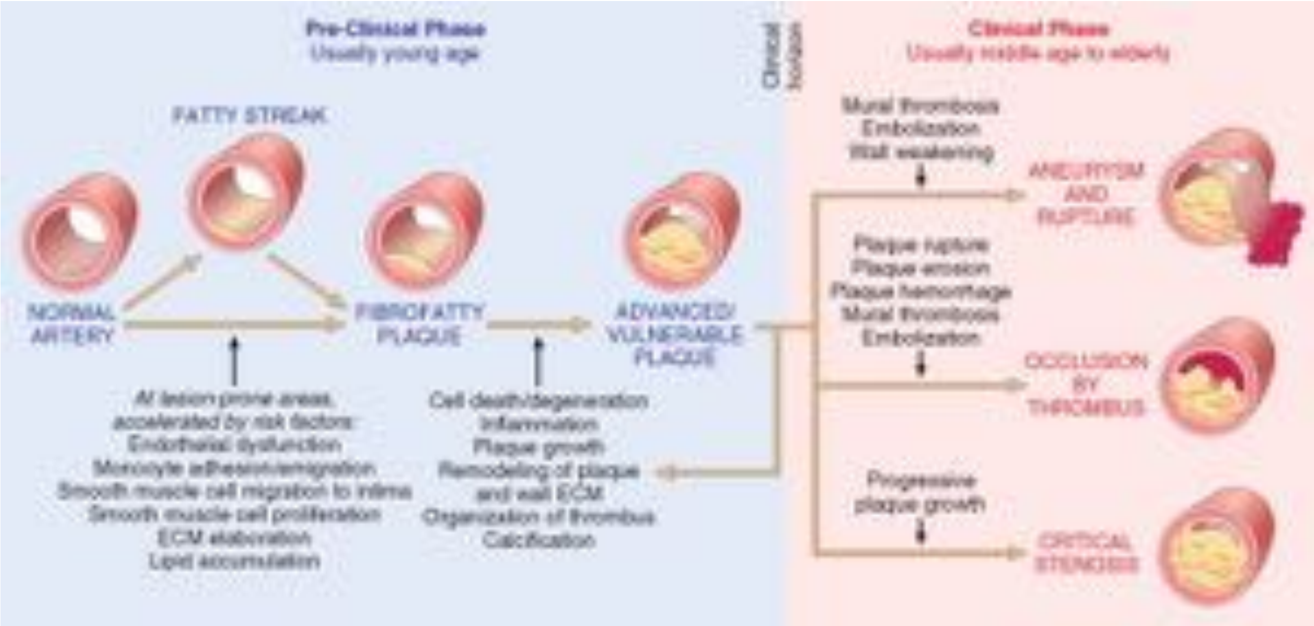
Austin HEALTH

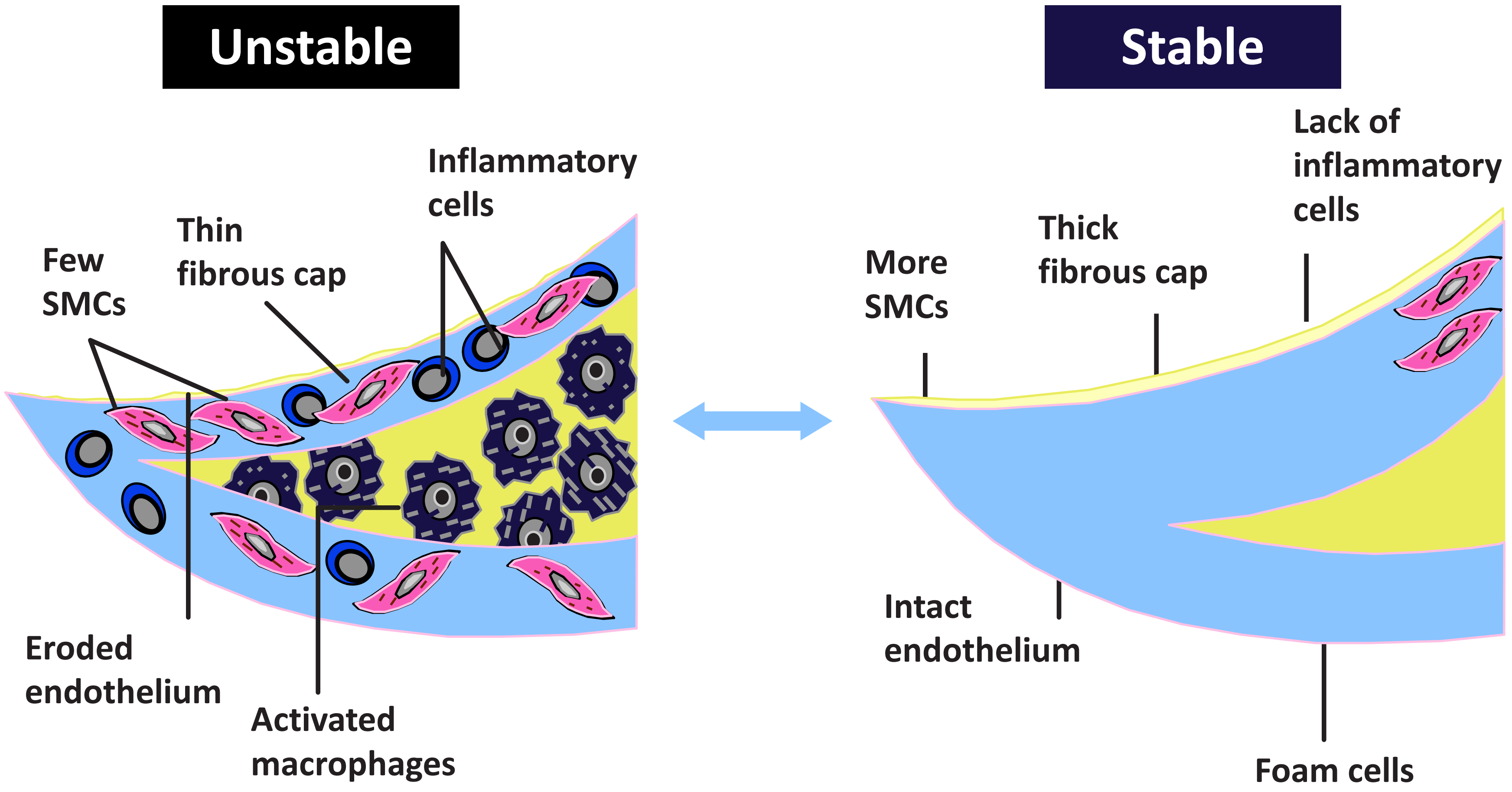

Wound Healing Environment
Arterial Perfusion
Venous Drainage
Multifactorial Approach
Microbiology
Nutrition
Neuropathy & Pressure Care
Diabetes
The Unusual

# Atherosclerosis

- Risk Factors
  - Age
  - Gender
  - Hypertension
  - Dyslipidaemia
  - Diabetes
  - Family History
  - Smoking



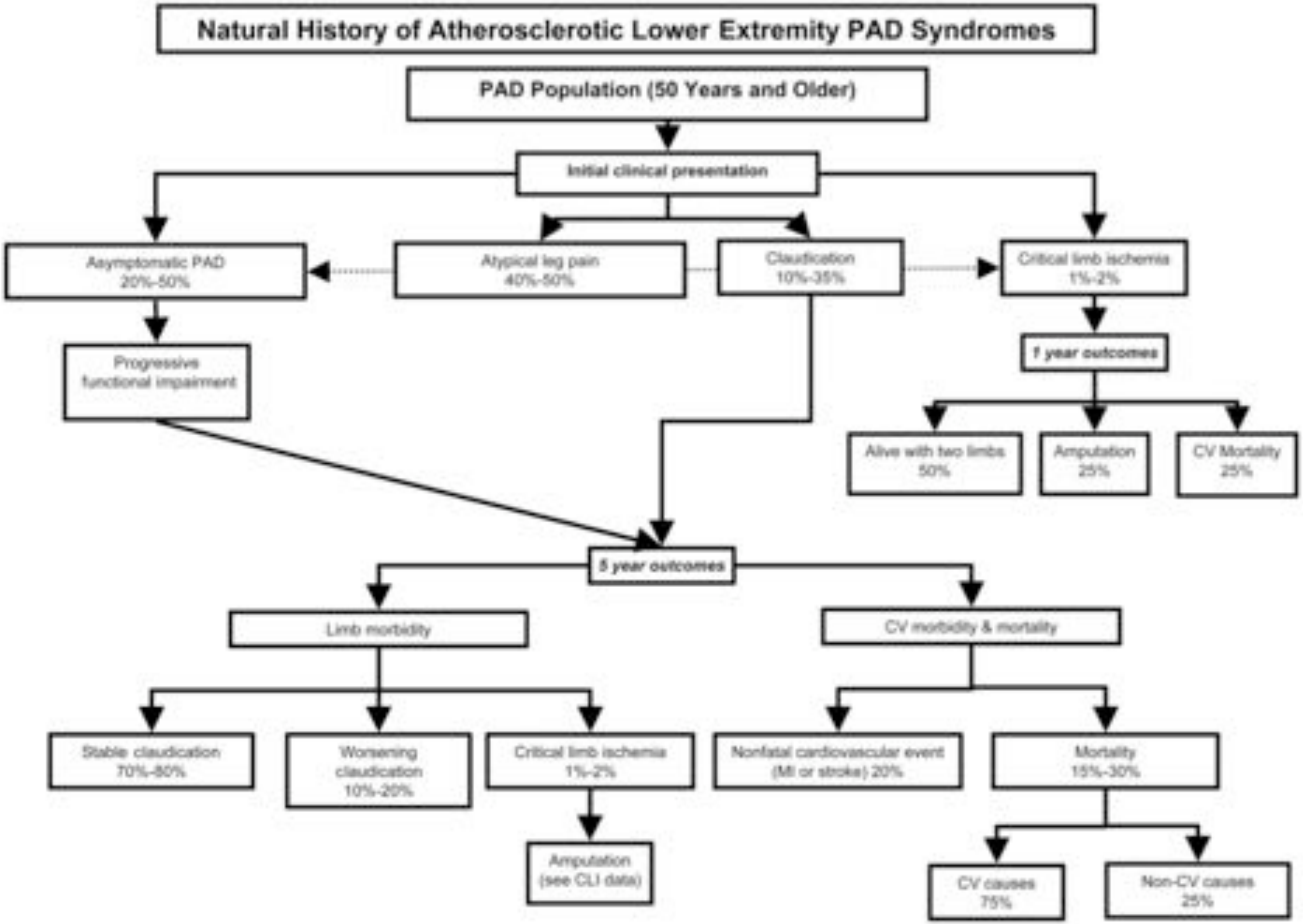



Libby P. Circulation. 1995;91:2844-2850.

# Why is arterial perfusion important?

- 12% of the adult population[1,2]
- 20% of the population aged >70
- Associated with 6-fold increase in CV mortality[3]

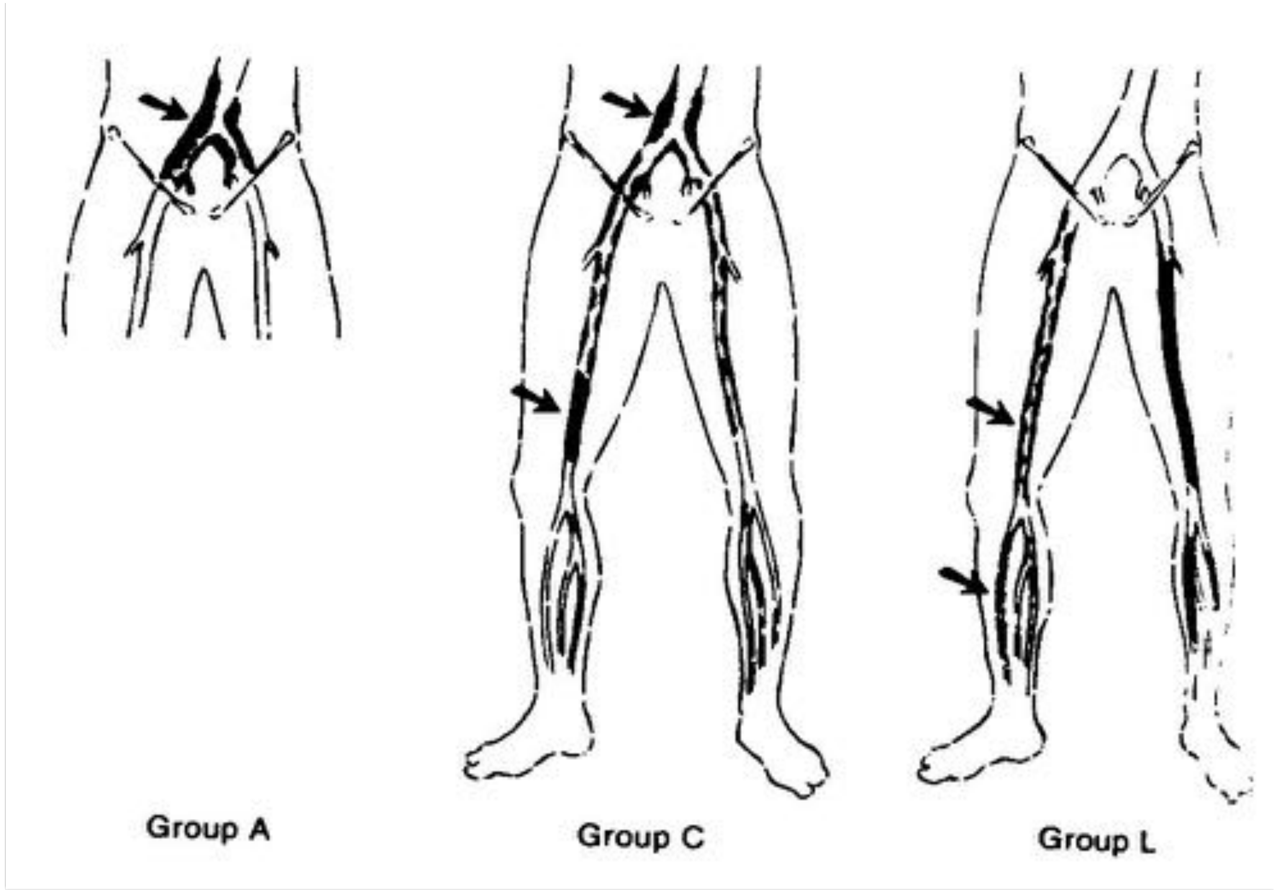
1 Nicolaides AN. *Symposium*. Nov. 1997.
2 Hiatt WR, et al. *Circulation.* 1995; 91:1472-1479.
3 Criqui MH, et al. *N Engl J Med.* 1992; 326:381-386.



Natural History of Atherosclerotic Lower Extremity PAD Syndromes
PAD Population (50 Years and Older)
Initial clinical presentation
Asymptomatic PAD 20%-50%
Atypical leg pain 40%-50%
Claudication 10%-35%
Critical limb ischemia 1%-2%
Progressive functional impairment
1 year outcomes
Alive with two limbs 50%
Amputation 25%
CV Mortality 25%
5 year outcomes
Limb morbidity
CV morbidity & mortality
Stable claudication 70%-80%
Worsening claudication 10%-20%
Critical limb ischemia 1%-2%
Amputation (see CLI data)
Nonfatal cardiovascular event (MI or stroke) 20%
Mortality 15%-30%
CV causes 75%
Non-CV causes 25%

# Patterns of atherosclerosis

- Typically affects branch points (turbulence, shear stress) HOWEVER
- Atherosclerosis can occur anywhere



# Clinical History

# Global Assessment

- Presenting complaint
- Past Medical History
- Cardiovascular Risk Factors
- Family History
- Functional assessment
- Psychosocial factors

# Symptoms

| Fontaine Stages | | Rutherford Grades | |
|---|---|---|---|
| I | Asymptomatic | 0 | Asymptomatic |
| IIa | Mild Claudication | I | Claudication |
| IIb | Mod-Severe Claudication | | |
| III | Ischaemic Rest Pain | II | Rest Pain |
| | | III | Minor Tissue Loss |
| IV | Ulceration/Gangrene | IV | Ulceration/Gangrene |

# Claudication

- Latin: *claudus* — lame, limping
- Pain which affects the ability to walk
- Intermittent Claudication

**Intermittent ischaemic claudication**

- Muscular pain, ache, cramp
- Develops on walking a fixed distance / metabolic activity
- Resolves on pausing, resting (timeframe: minutes)
- Unaffected by posture or position
- Able to resume for slightly shorter distance / workload

# Claudication — Differentials

- **Arterial Ischaemia**
- **Neurogenic**
  - Radiculopathy
  - Spinal Canal Stenosis
- **Arthrogenic**
  - Hip / Knee Arthritis
- **Venous Insufficiency**
- **Chronic Compartment Syndrome**
- **Plantar Fasciitis**
- **Baker's Cyst**

# Critical Limb Ischaemia

- “Short Distance” Claudication
- Rest Pain
- Tissue Loss

- 25% 1-year probability of amputation
- 25% 1-year cardiovascular mortality

# Rest Pain

- Occurs in the most distal region of the limb
- Implies perfusion so poor that unable to maintain aerobic metabolism in skin, tissue and nerves at rest
- Exacerbated by limb elevation (often at night)
- Relieved by dependency
- NOT the same as wound pain

# Clinical Examination

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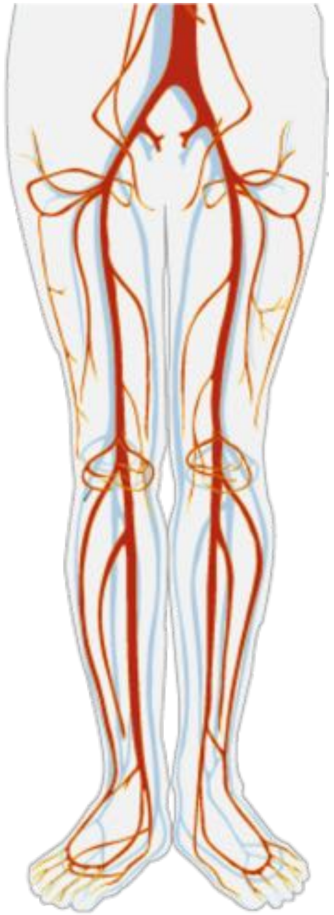
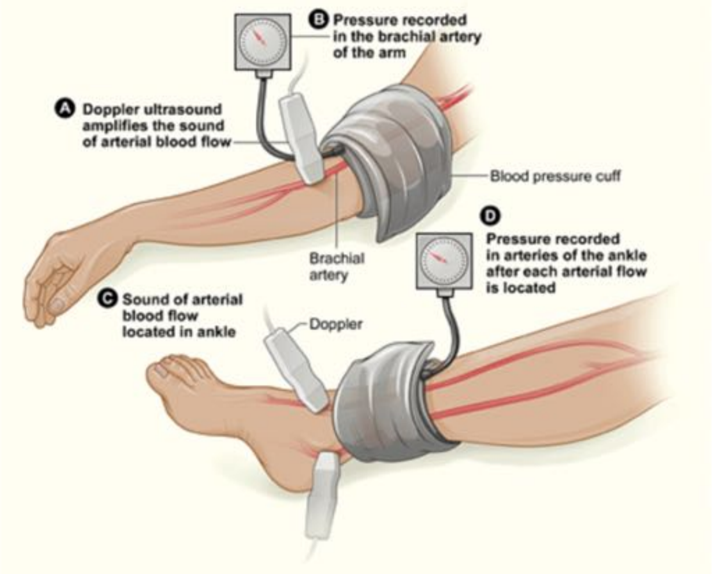
# Clinical Examination

- Inspection
  - Pulse Examination
  - Thrills
  - Bruits
  - Capillary Refill
  - Ulceration / Necrosis
- Bedside Tests
  - Buerger's Test
  - Ankle Brachial Indices



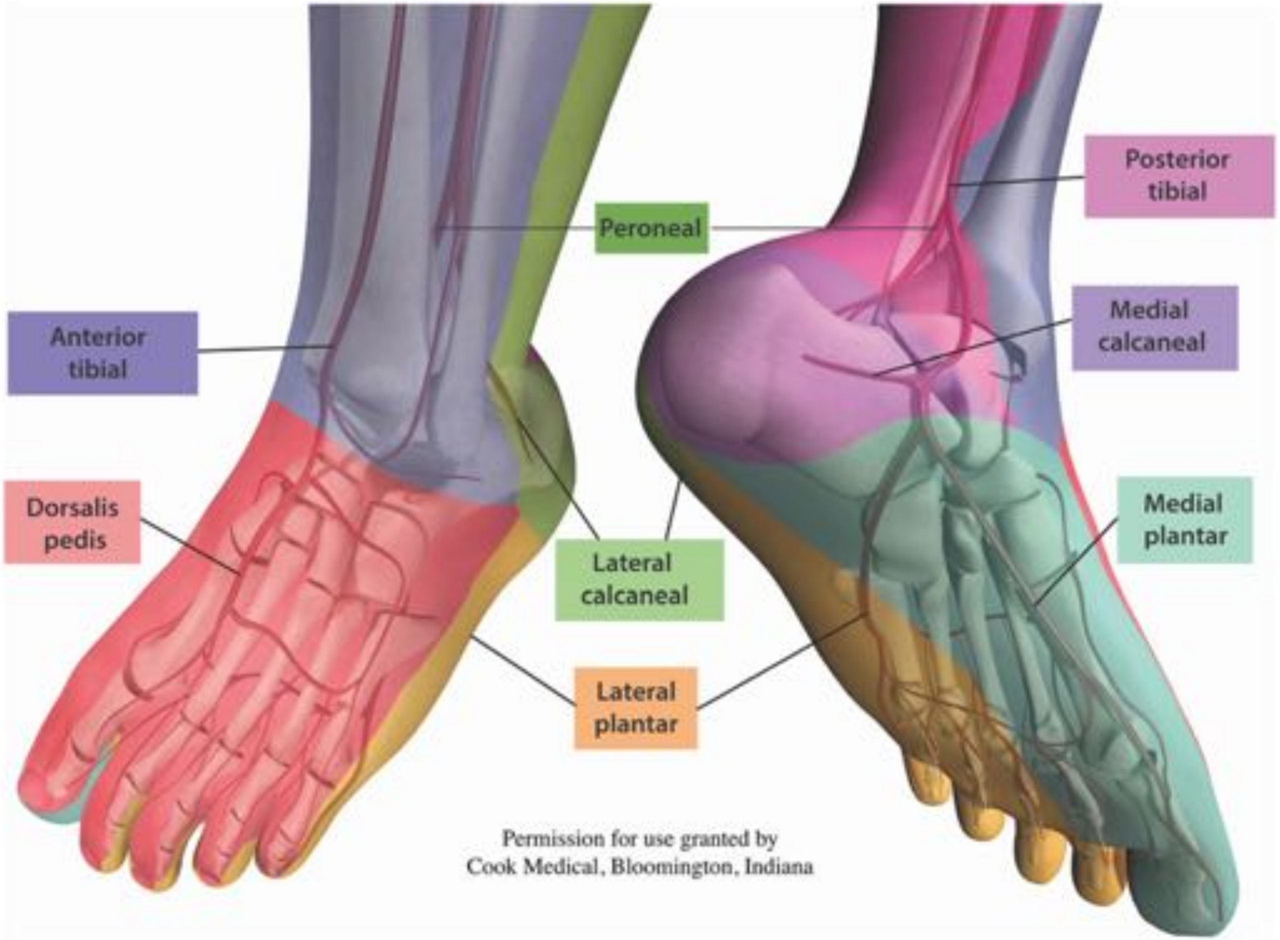
# Buerger's Test

# Ankle Brachial Indices / Segmental Pressures




- May not be reliable in calcified or incompressible vessels
- Global assessment not reflective of parallel tibial artery disease
- Toe Pressures + doppler vs PPG
- Transcutaneous Oxygen Measurement

# The Angiosome Concept



# Investigations

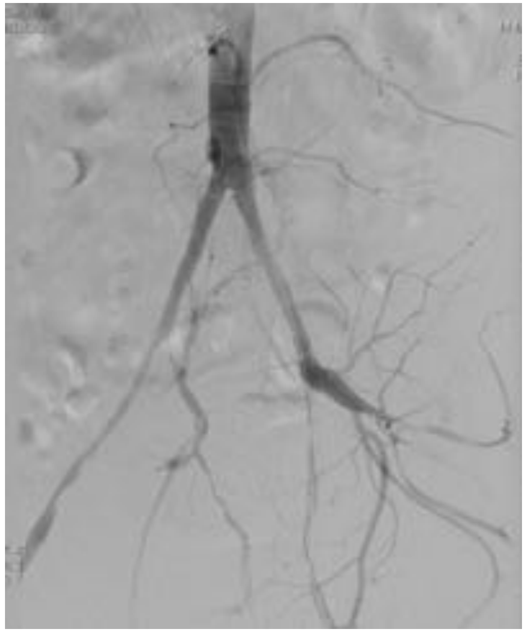
# 2D Angiography

**Advantages**

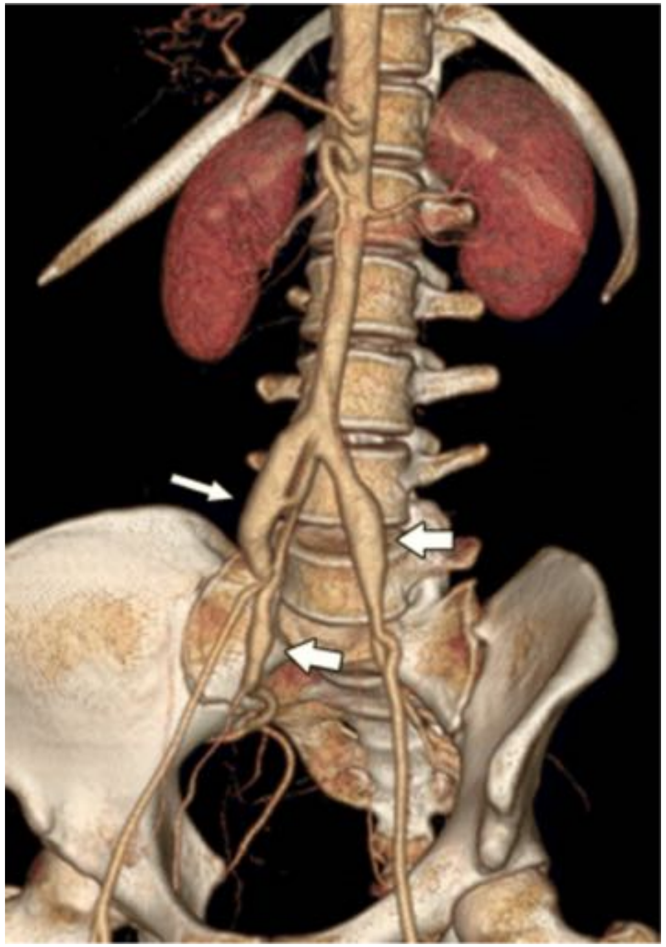
- High quality images
- Arch assessment
- Intracranial assessment
- Temporal information
- Now digital - no film involved
- Able to Intervene

**Problems**

- 2D / single planar
- Subtraction artefact



# MRI / MRA / CTA



# 3D Angiography

**CT Angiography**

- Volume acquisition
- IV contrast-based in (monitored) arterial phase
- Traditional CT artefacts
- Relies on Hounsfield Unit filtering / windowing
- Calcification artefact
- 2D Axial vs Volume rendered vs MIP imaging
- Allows 3D manipulation
- Allows assessment of non-target tissues

**MR Angiography**

- Non-contrast
- 2D Time-of-Flight (Better for slow-flow)
- 3D Time-of Flight (Sagittal / Any Plane)
- Gadolinium Contrast
- 3D Time-of-flight
- Artefacts vary with acquisition technique
- Flow voids
- Flow direction
- Venous contamination

# Principles of Ultrasound

High-frequency ultrasound (usually 3-12MHz) is transmitted through soft tissue with an average speed of 1540 m/sec

**Bone transmits sound faster**

**Water transmits sound more slowly**

At acoustic boundaries some sound waves are transmitted and some are reflected

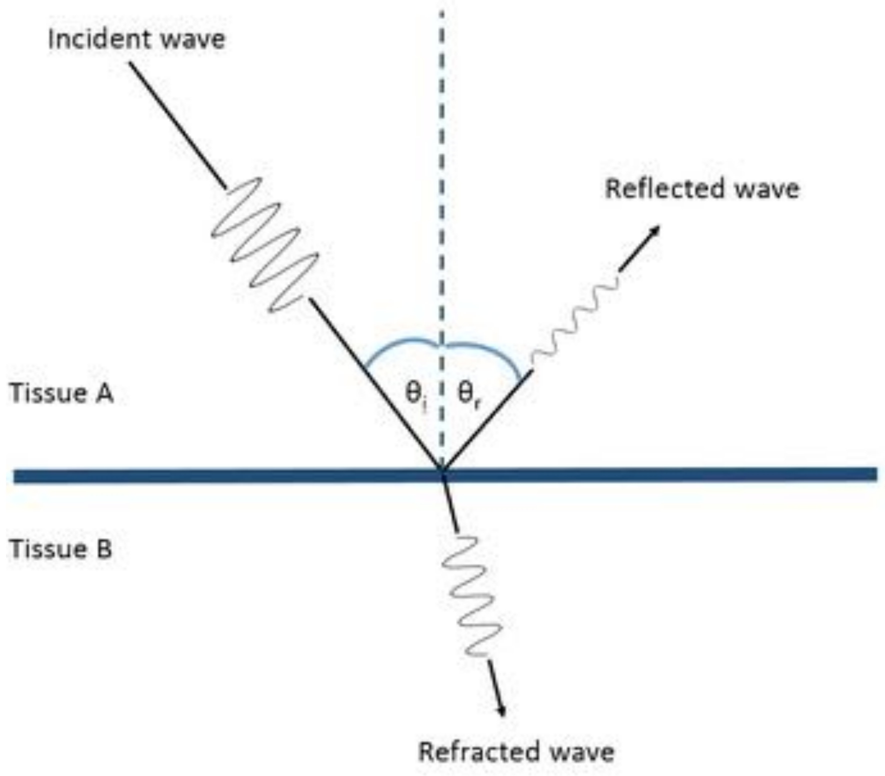
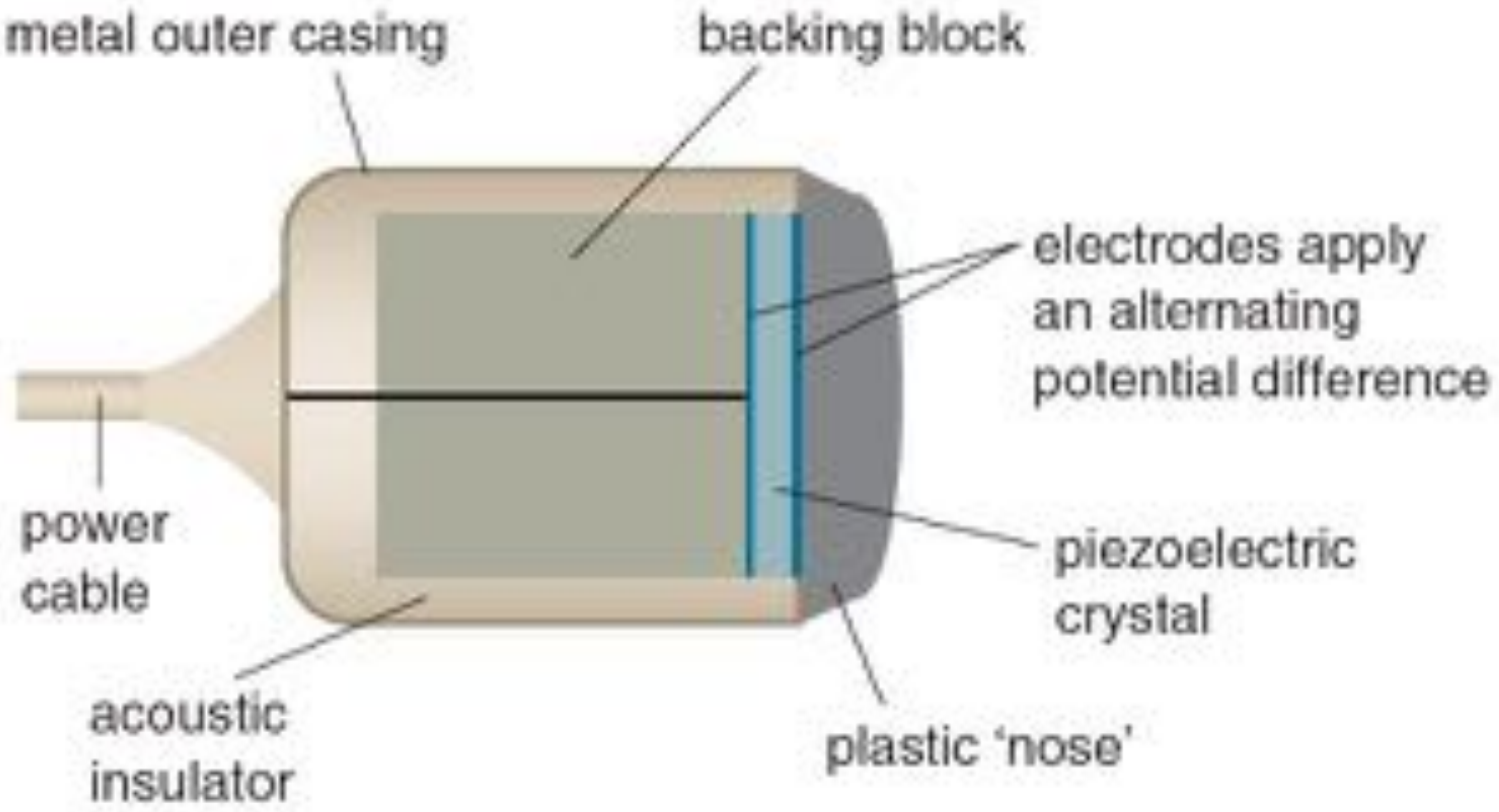
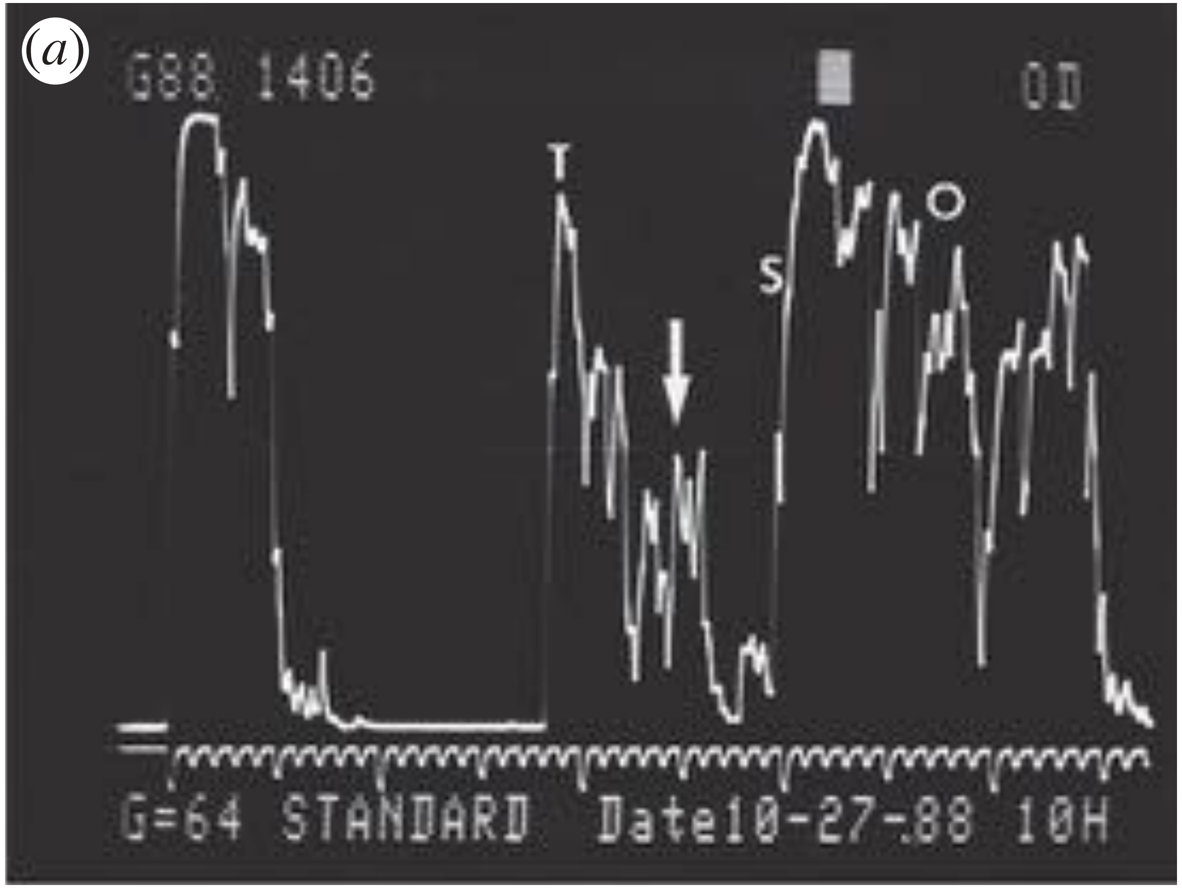



Image courtesy of Dr Jeffrey Cheng, Radiopaedia.org, rID: 55792

# US Probe Construction



# A (Amplitude) Mode




Received signals displayed on a graph

Y-axis = Amplitude

X-axis = Time = Distance

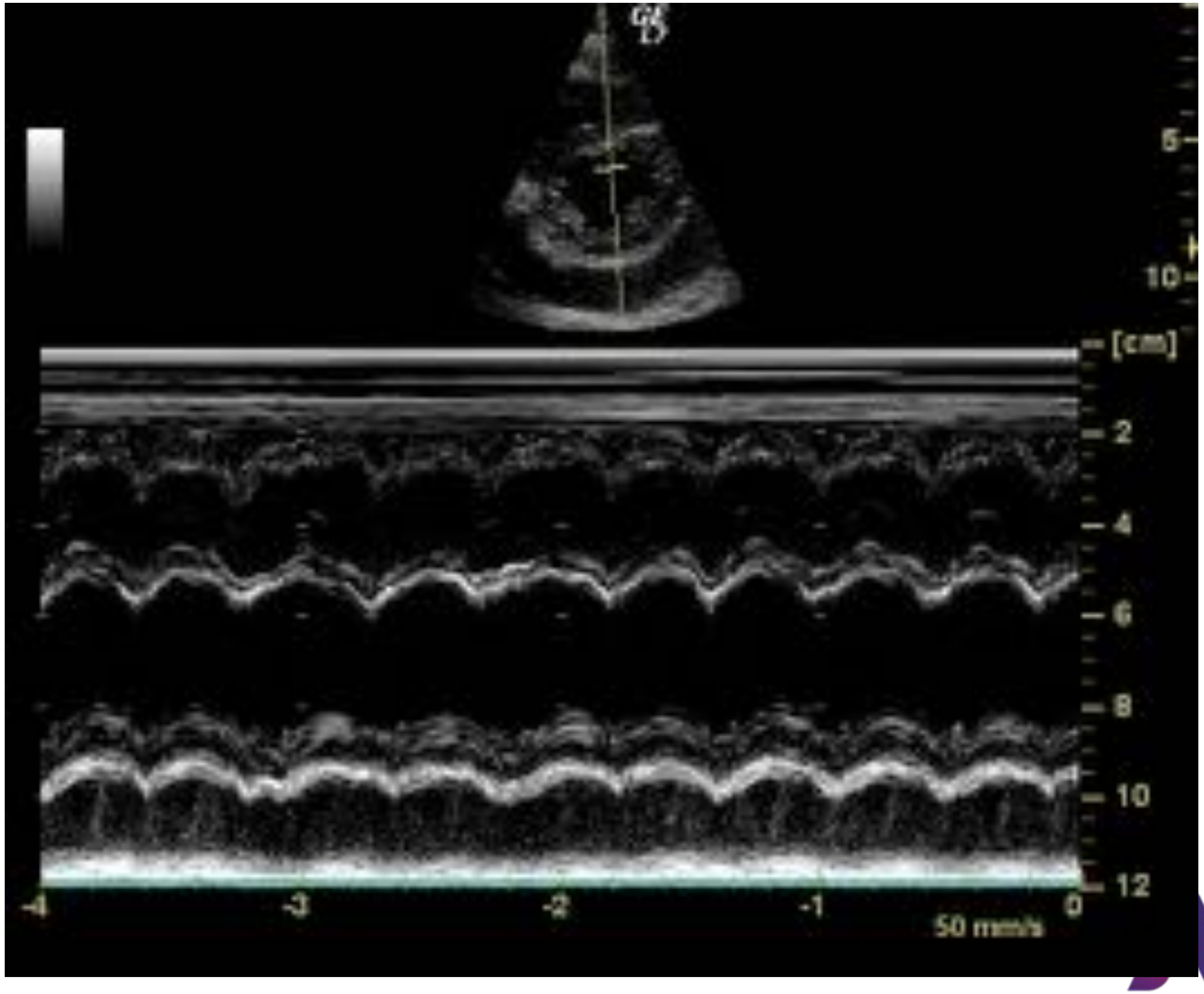
Source: Powers, Kremkau. Medical Ultrasound Systems. Interfae Focus. 2011. DOI 10.1098/rsfs.2011.0027

# M (Motion) Mode imaging

A single ping is sent and echoes are listened for in one line

The louder the returned echo, the brighter the spot

This line image is projected over time to generate an M-mode image



# 2D B (Brightness) Mode Imaging

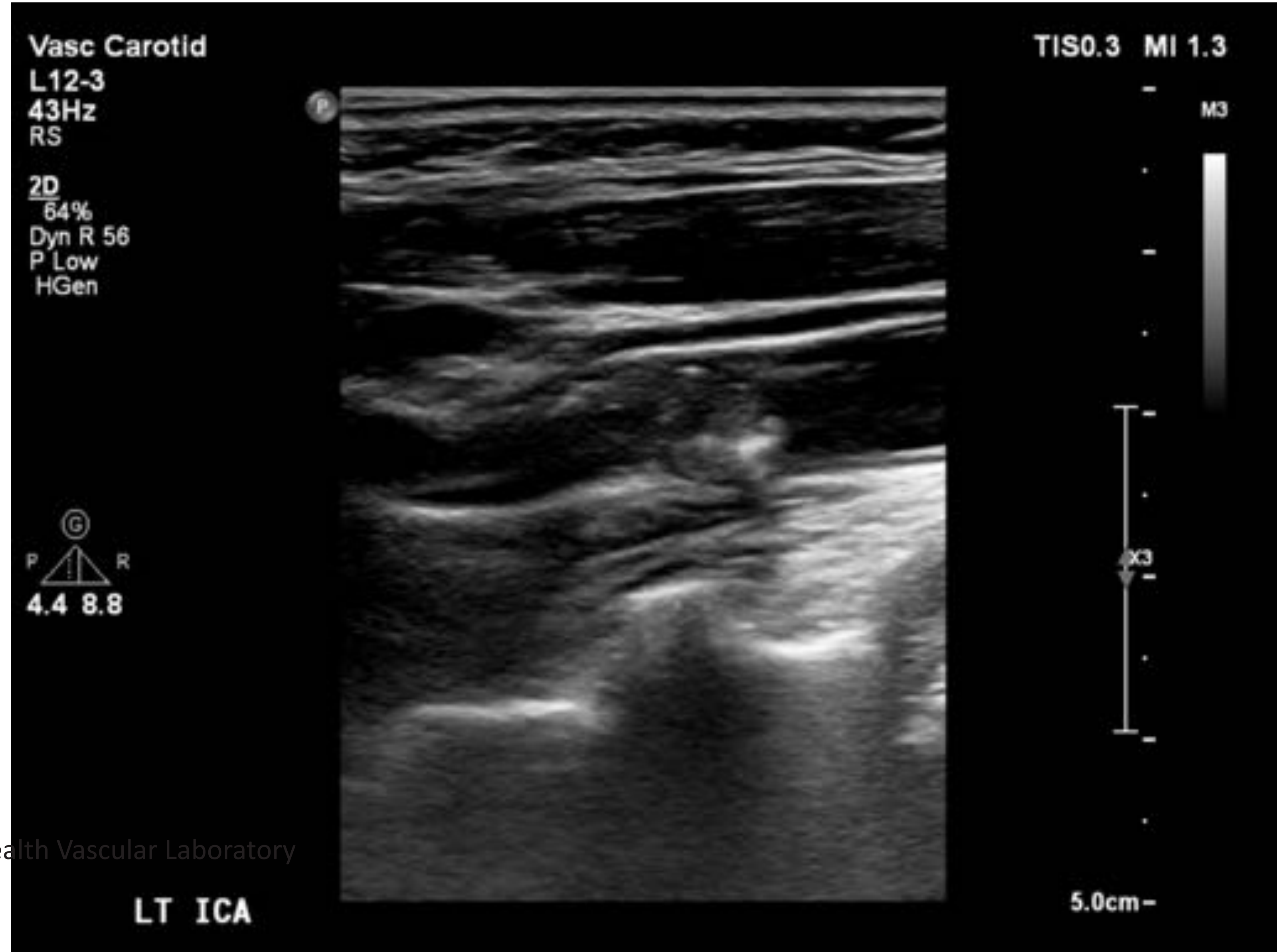
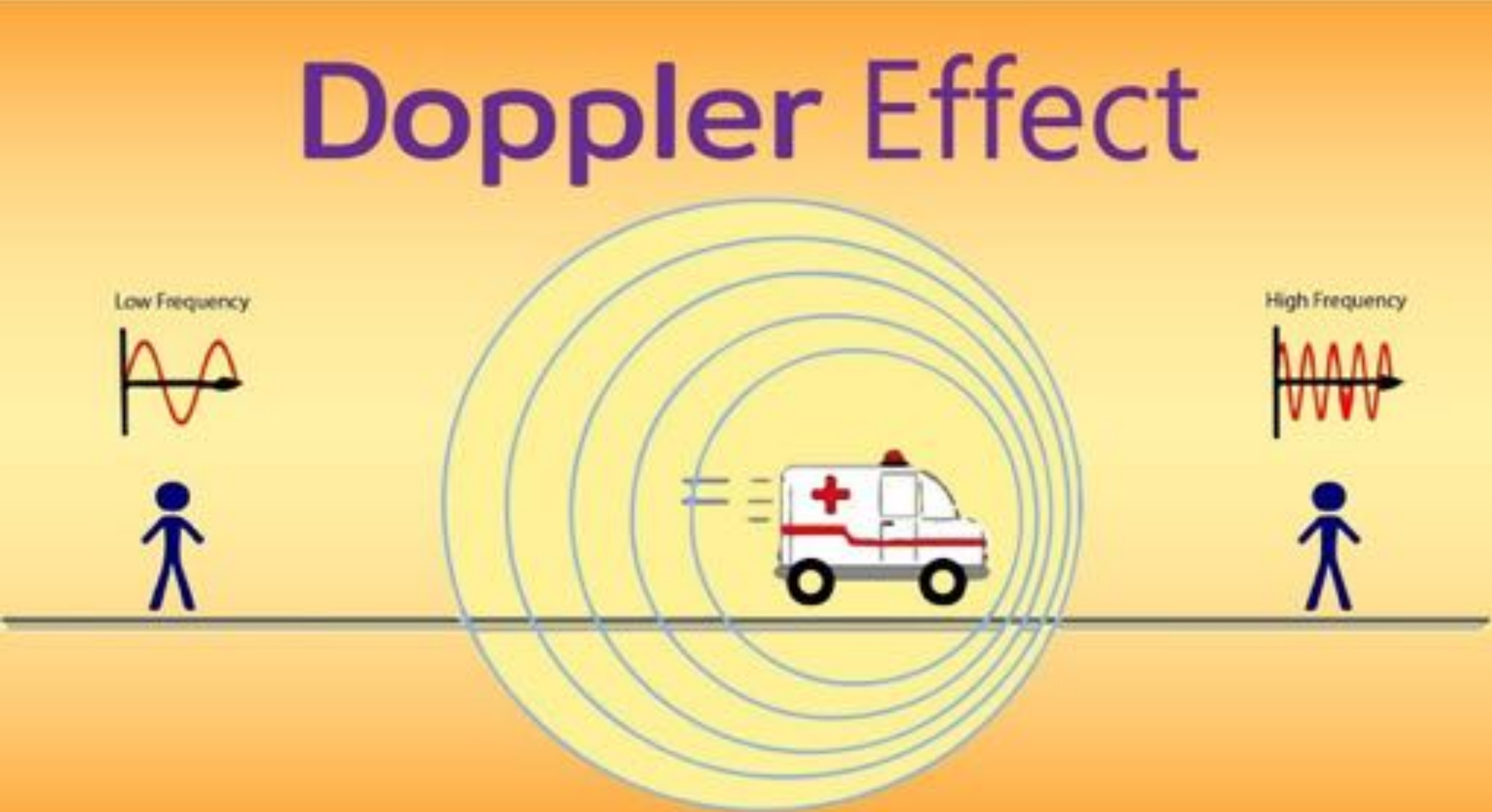



Image: J Chuen, Austin Health Vascular Laboratory




Source: http://www.redchairblogs.com/starstruck/2018/03/08/finding-the-first-galaxies/

# Doppler Ultrasound

The received echoes are normally at the same frequency as the sent "ping"

If the received echo is at a different frequency then:

**Either from a different point source (not transducer), or**

**From a moving echogenic source**

The velocity of the moving echogenic object can be calculated via the Doppler equation

$$f_d = f_r - f_t = \frac{2 \cdot f_t \cdot \cos\theta \cdot V}{c}$$

# Continuous Wave Doppler

Principle of handheld doppler probe

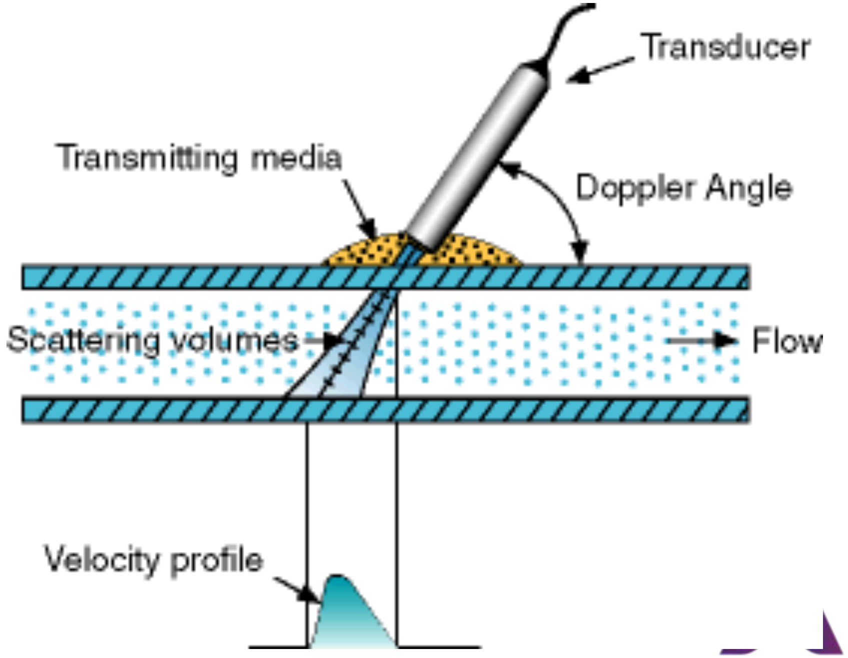
Continous high-frequency signal sent out

Second crystal listens continuously for echoes

Subtracted frequency signal is played back in audible frequency range

**Cannot** assess direction of flow

**Cannot** control the area being sampled (gate)



# Pulse Wave Doppler

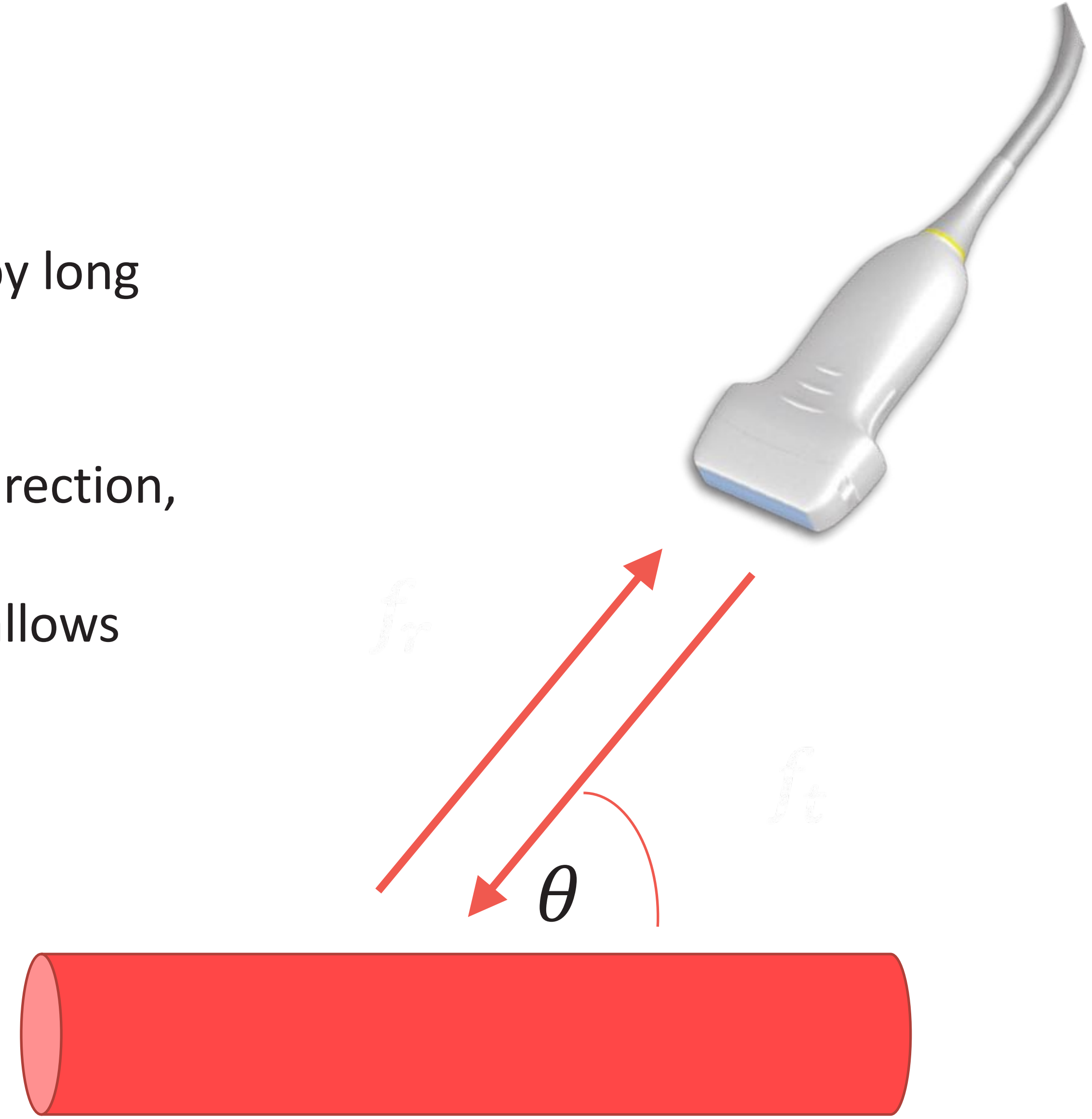
Short burst of ultrasound is transmitted followed by long period of listening for echoes

Repeated many times a second

Received signals analysed for frequency change (direction, magnitude)

Selective temporal analysis of the received signal allows "gating" of the doppler signal

$$f_d = f_r - f_t = \frac{2 \cdot f_t \cdot \cos\theta \cdot V}{c}$$

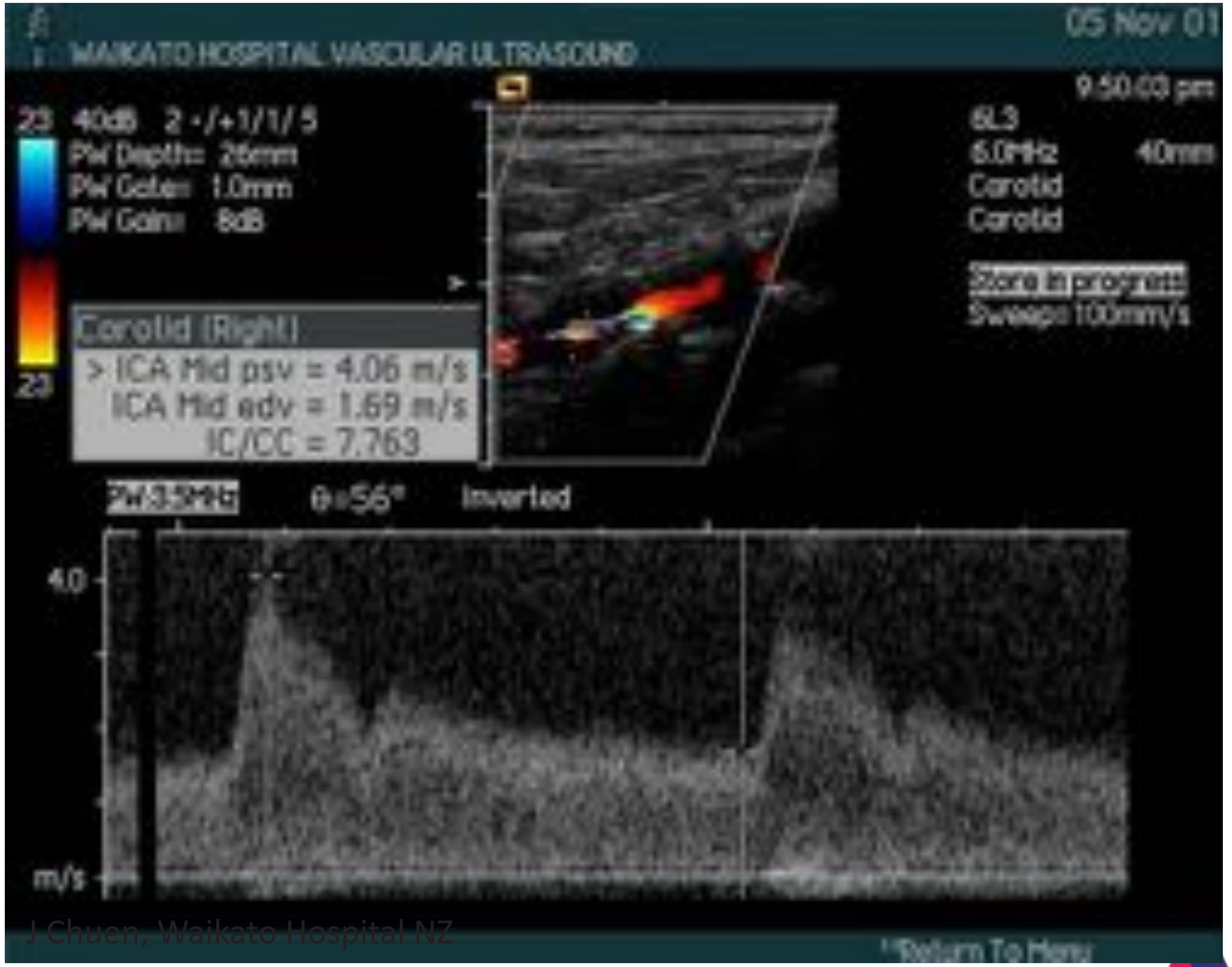


# Spectral Analysis

Echoes are collected after each pulse ping (Pulse Wave Doppler) and timed to only collect from a Sample Volume (gated)

A Fast-Fourier Transformation (FFT) is applied to extract the individual return frequencies which are displayed over time

Velocities are calculated from the Doppler equation



# Colour Doppler

The spectral analysis for multiple sample volumes is stratified into ranges of forward and reverse flow

This is then projected onto the 2D B-mode image as colour blocks representing estimated velocity

Power doppler analyses the amplitude of the doppler signals, not frequency


# Spectral Changes in Stenoses

Increase in peak systolic velocity

Spectral Broadening

Loss of Spectral Window

Can be complicated!

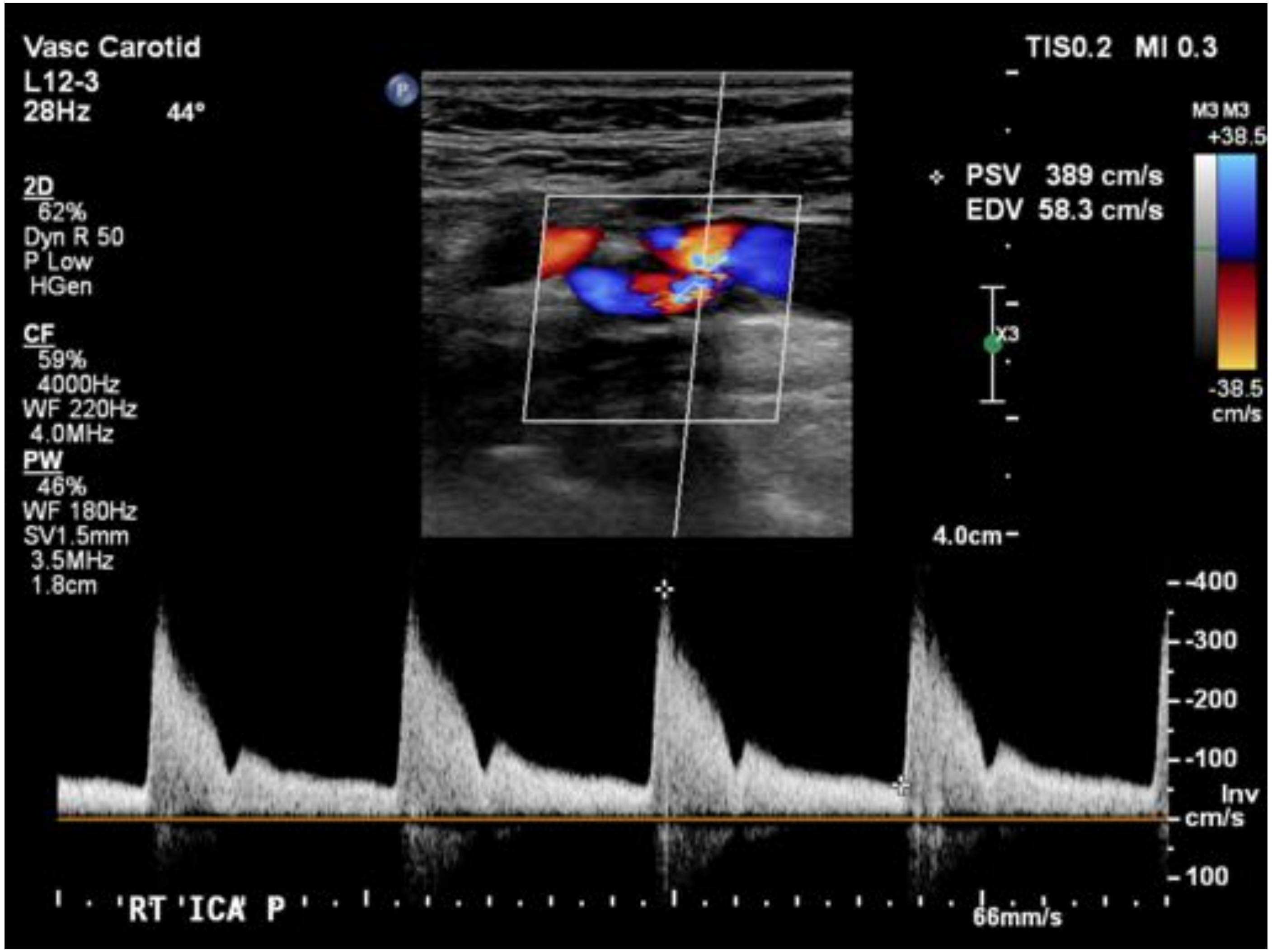



Image: J Chuen, Austin Health Vascular Laboratory

# Doppler Waveforms


Normal Triphasic Signals

**Narrow frequency band**

**Steep systolic increase**

**Forward systolic flow**

**Rapid drop**

**Reverse flow in late systole / early diastole (may not see in low resistance beds)**

**Short forward flow in late diastole**

Image: J Chuen, Austin Health Vascular Laboratory

# Doppler Waveforms

Biphasic Signals

**Slower systolic upstroke**

**Late systolic peak**

**Reverse diastolic flow may be preserved**

**steady positive flow in the diastole, or**

**forward flow in systole**

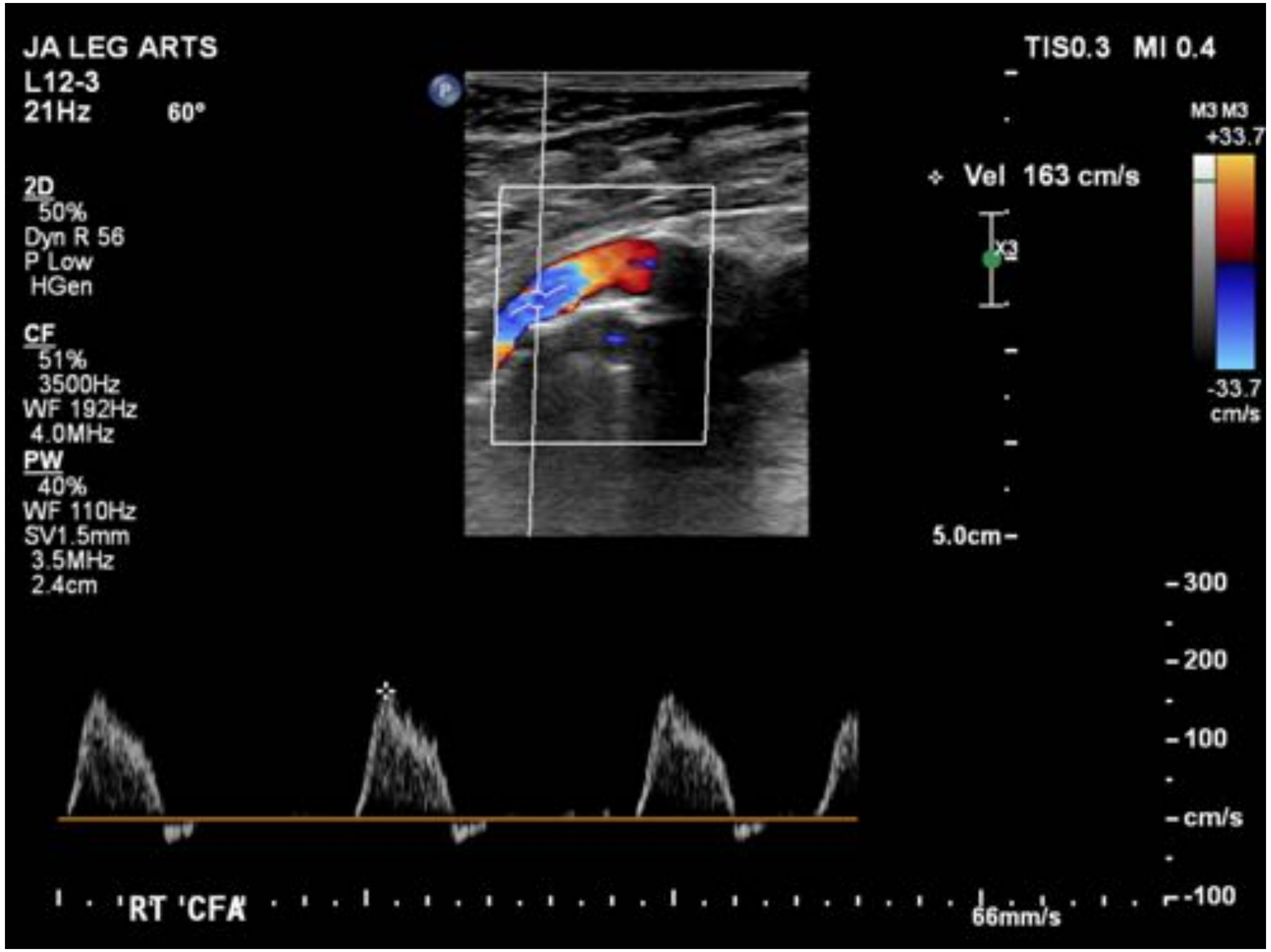



Image: J Chuen, Austin Health Vascular Laboratory

# Doppler Waveforms

Monophasic Signals

**Single phase with slow acceleration / deceleration**

**Due to inflow restriction or hyperaemia with low outflow resistance**

**Can be high or low velocity**

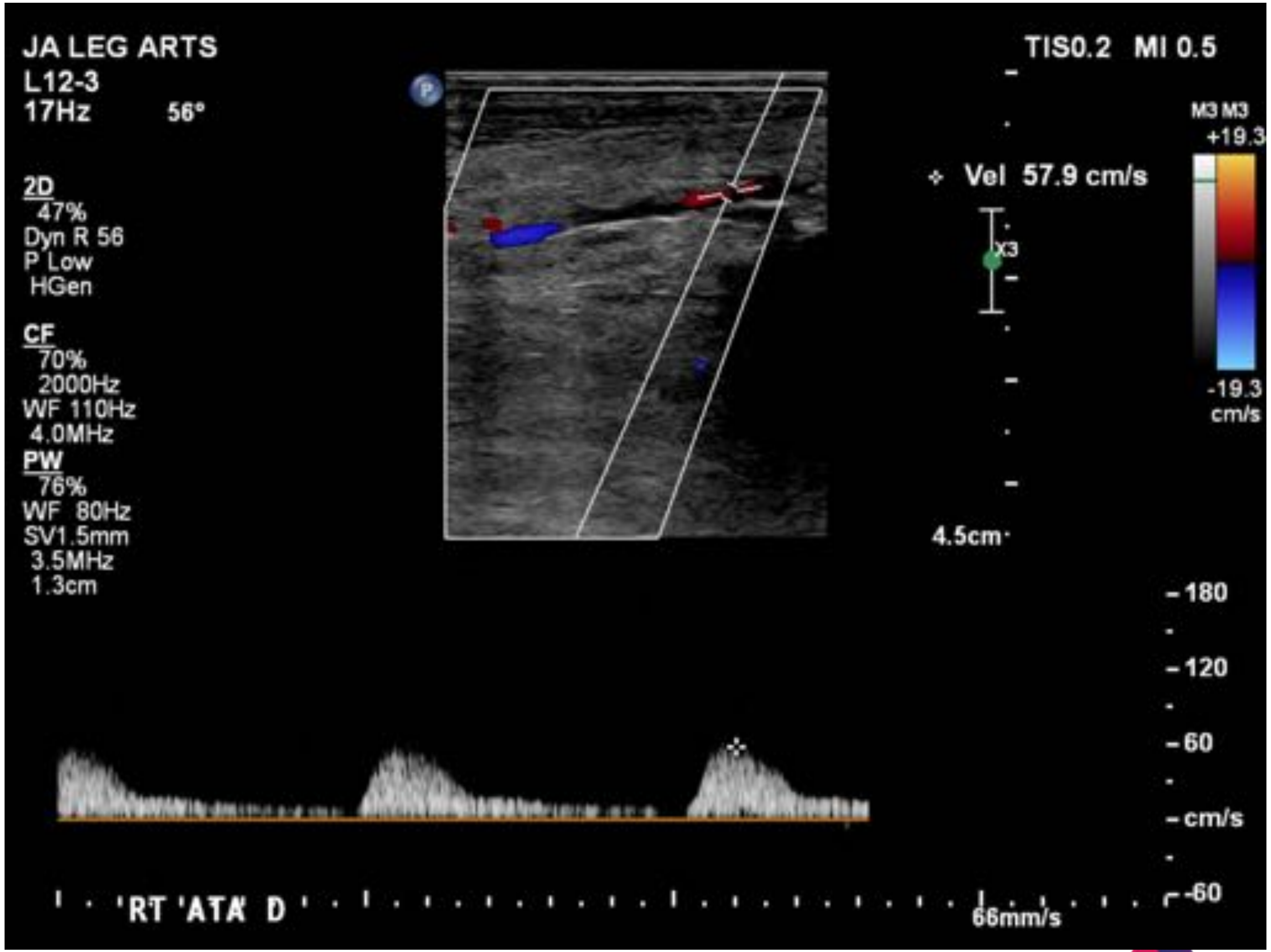



Image: J Chuen, Austin Health Vascular Laboratory

# Treatment Options

# Treatment Options

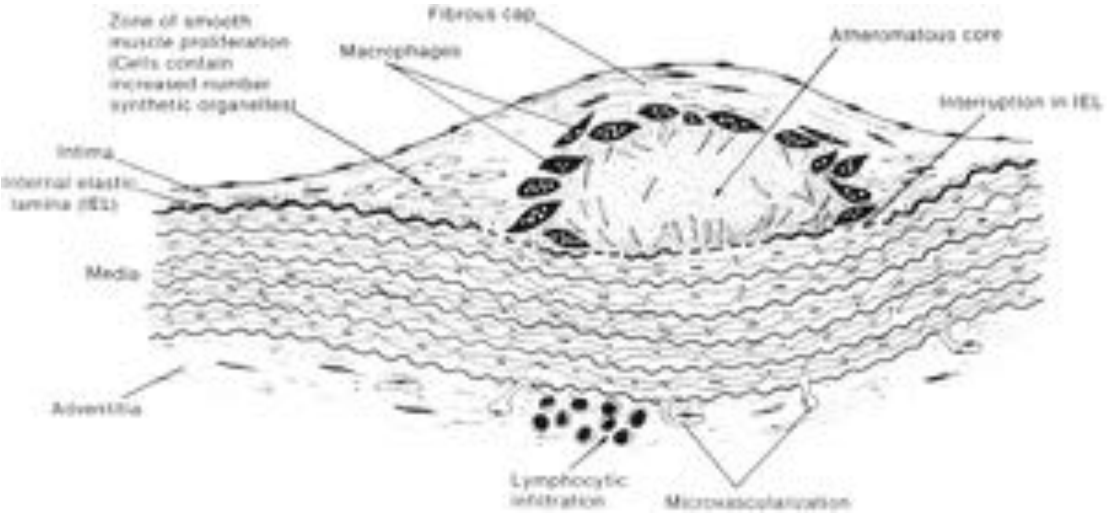
- Treat the cause
  - Limit disease progression
  - Improve arterial inflow
  - Reduce metabolic demand
- Treat the symptoms / sequelae

# Plaque Stabilisation

- Risk Factor Control
  - Smoking
  - Diabetes
  - Hypertension
  - Hyperlipidaemia

- Induction of collateralisation
  - Exercise therapy

- Pharmacotherapy
- “Vasodilator” therapy (Antivasospastic)
- Antiplatelet therapy



# Revascularisation Options

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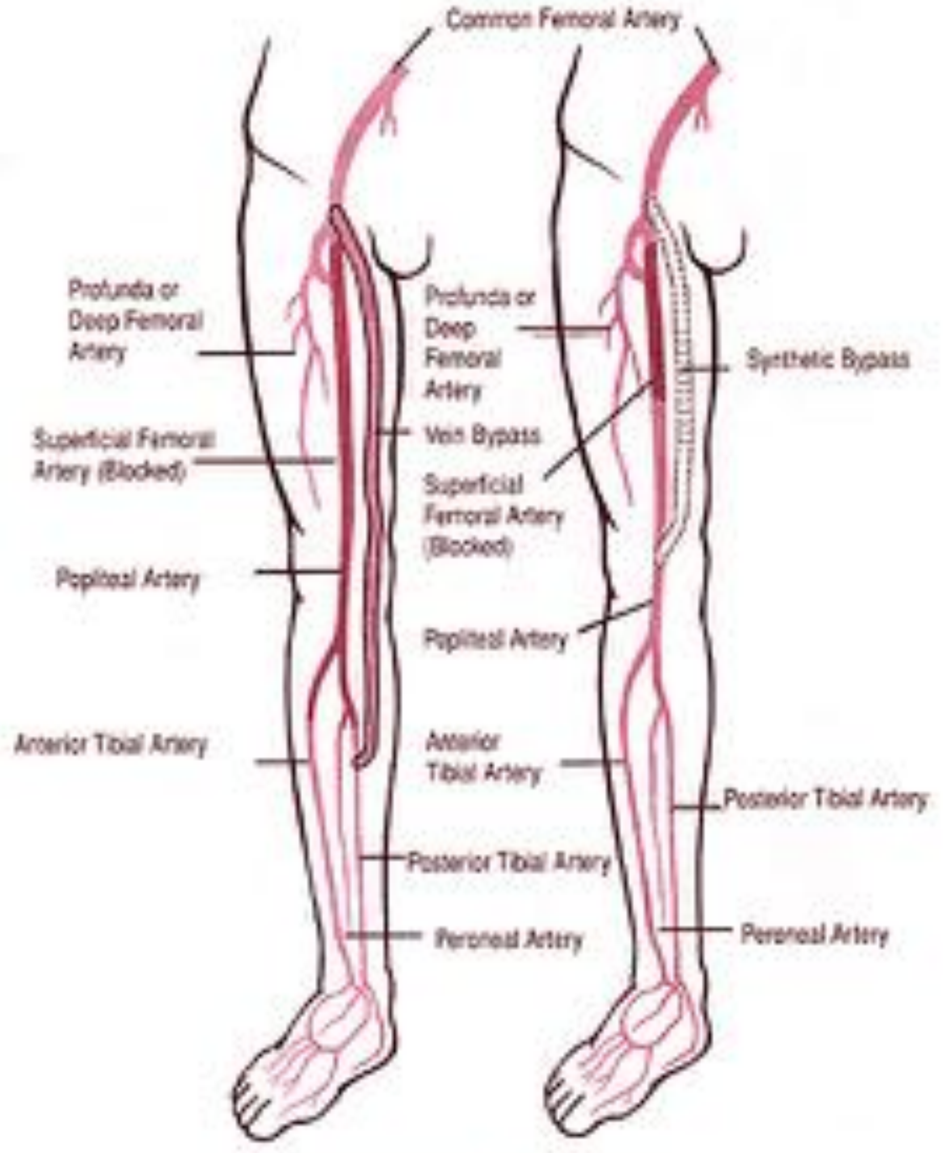
# Bypass Surgery

- **Inflow Vessel**
- **Nature of Conduit**
  - Vein > 3.5mm
  - Vein < 3.5mm
  - Prosthetic
- **Length of Conduit**
  - Above Knee
  - Below Knee
- **Tunelling**
- **Runoff vessels**

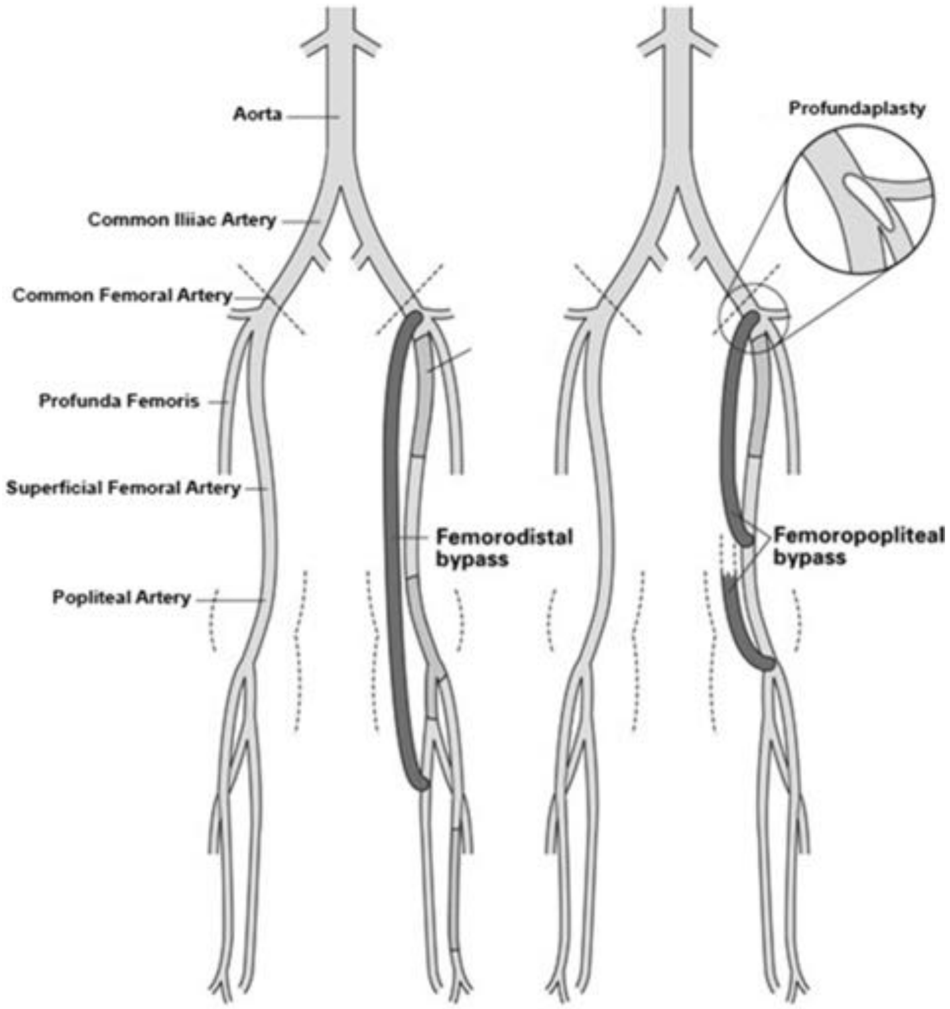


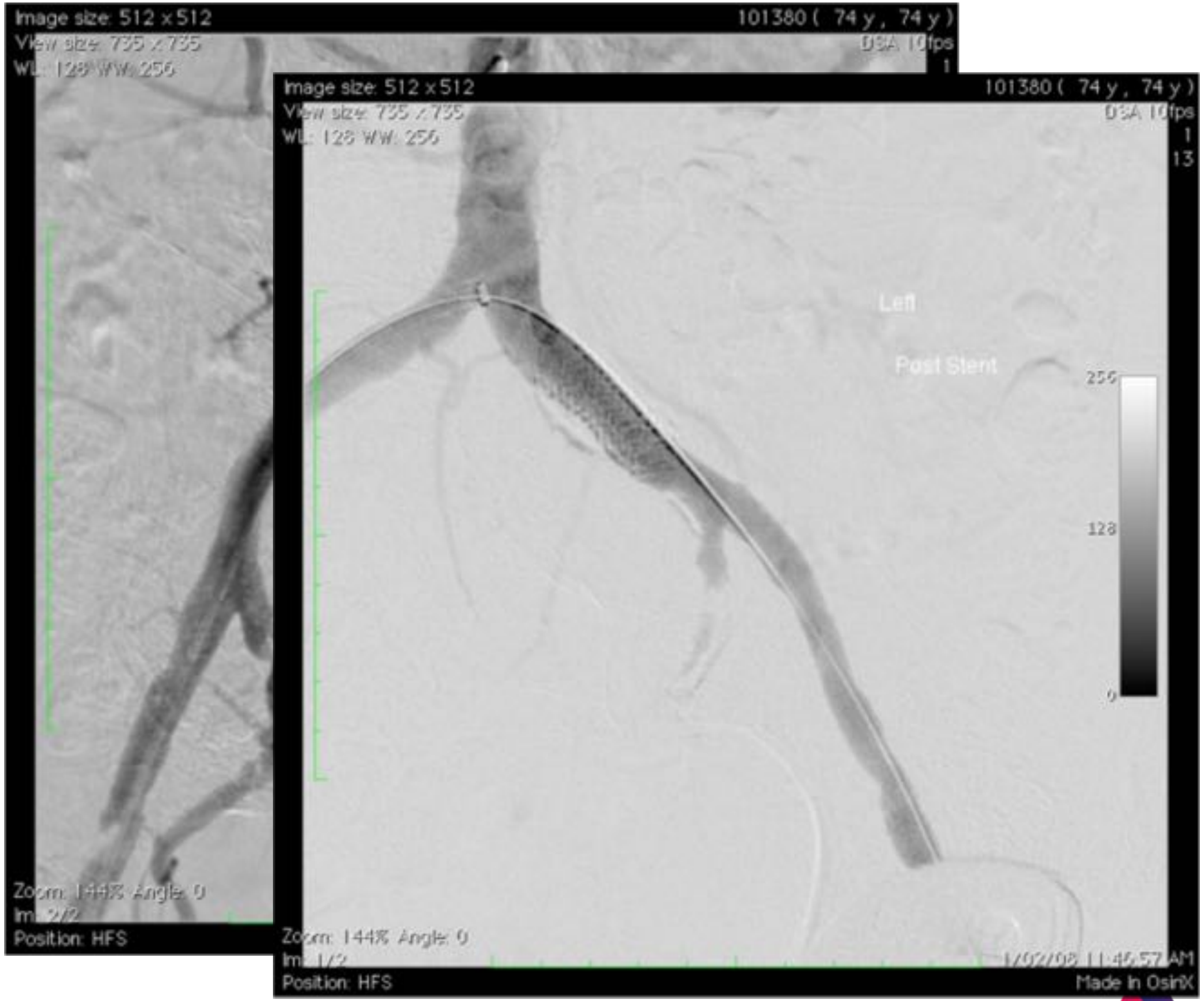

*Two Examples of Types of Bypasses*

**Table 20.** Vascular Surgical Procedures for Outflow Improvement

| Outflow Procedure | Operative Mortality (%) | Expected Patency Rate (%) |
|---|---|---|
| Fem-AK popliteal vein | 1.3–6.3 | 66 (5 yrs) |
| Fem-AK popliteal prosthetic | 1.3–6.3 | 47 (5 yrs) |
| Fem-BK popliteal vein | 1.3–6.3 | 66 (5 yrs) |
| Fem-BK popliteal prosthetic | 1.3–6.3 | 33 (5 yrs) |
| Fem-Tib vein | 1.3–6.3 | 74–80 (5 yrs) |
| Fem-Tib prosthetic | 1.3–6.3 | 25 (3 yrs) |
| Composite sequential bypass | 0–4 | 28–40 (5 yrs) |
| Fem-Tib blind segment bypass | 2.7–3.2 | 64–67 (2 yrs) |
| Profundaplasty | 0–3 | 49–50 (3 yrs) |

AK = above the knee; BK = below the knee; Fem = femoral; Tib = tibial.


Aorta
Common Iliiac Artery
Common Femoral Artery
Profunda Femoris
Superficial Femoral Artery
Popliteal Artery
Femorodistal bypass
Profundaplasty
Femoropopliteal bypass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101380 ( 74 y , 74 y )
Position: HFS
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101380 ( 74 y , 74 y )
View size: 735 x 735
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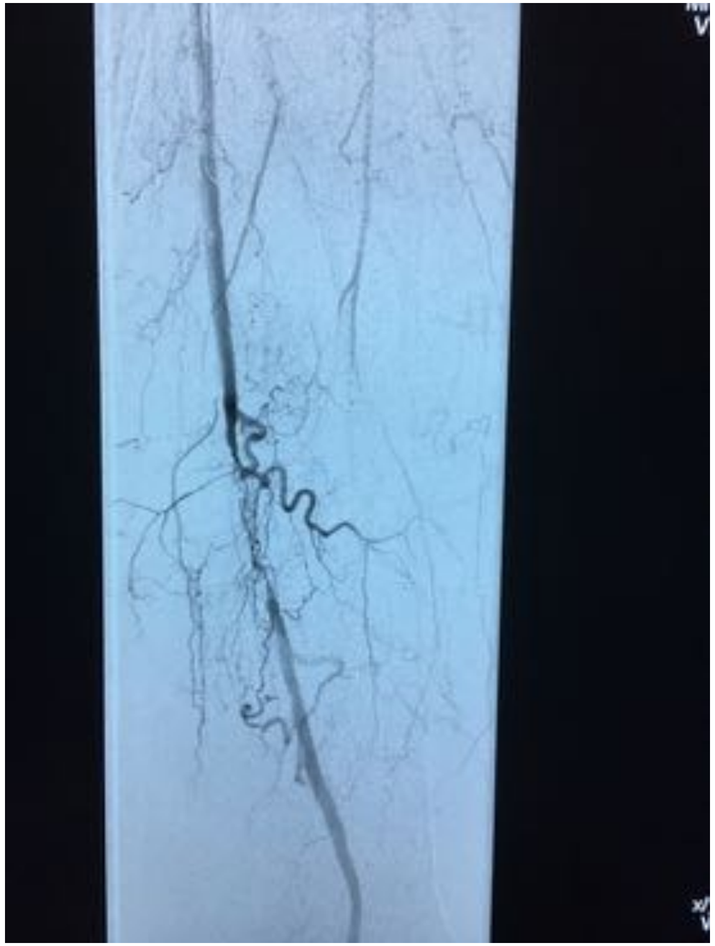

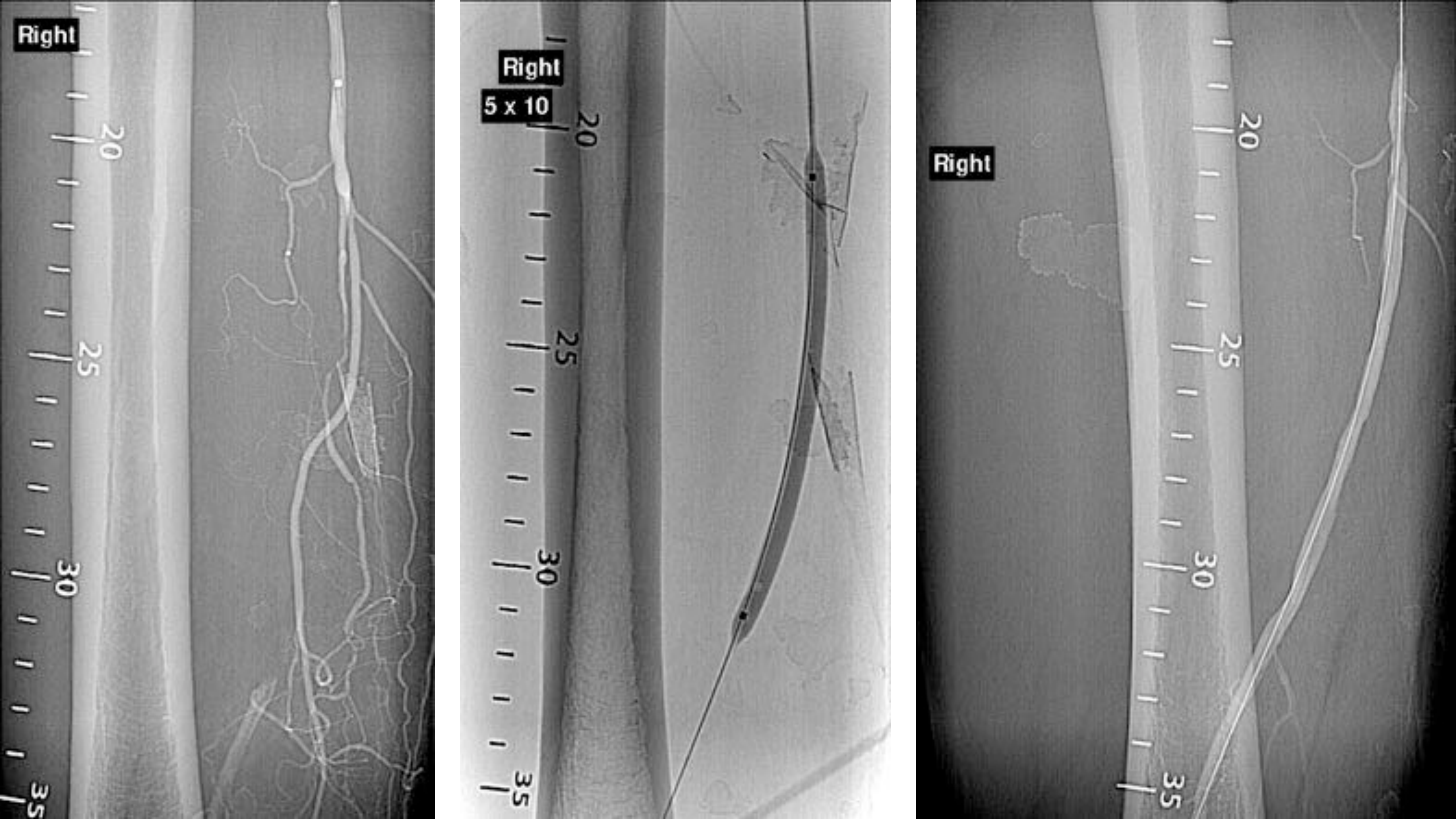
Right
20
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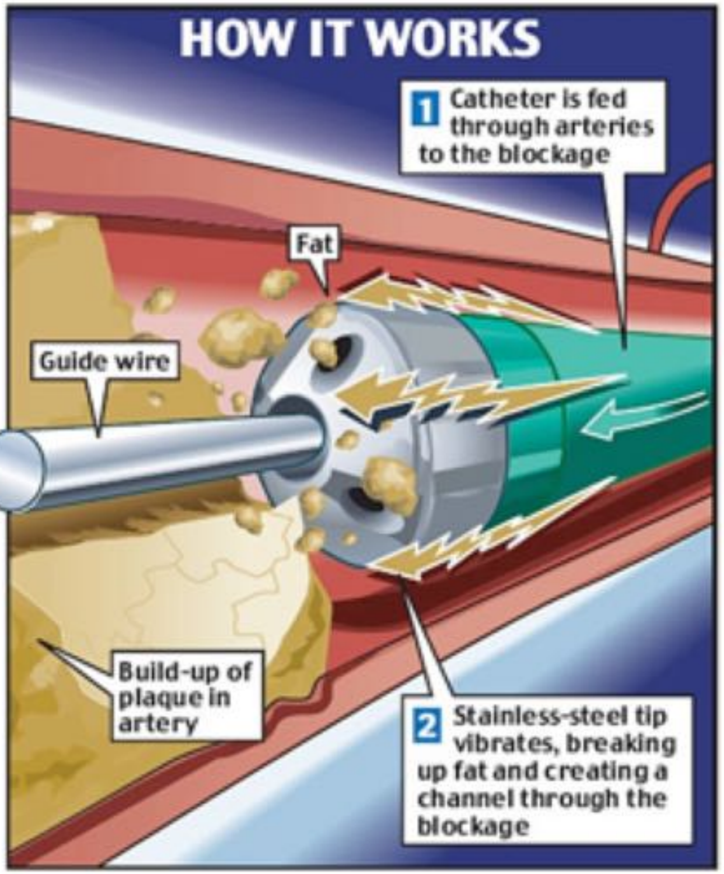
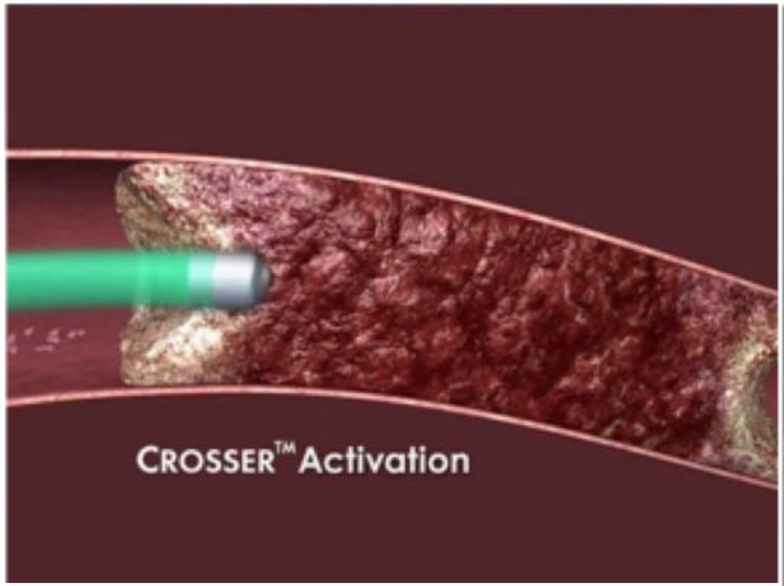
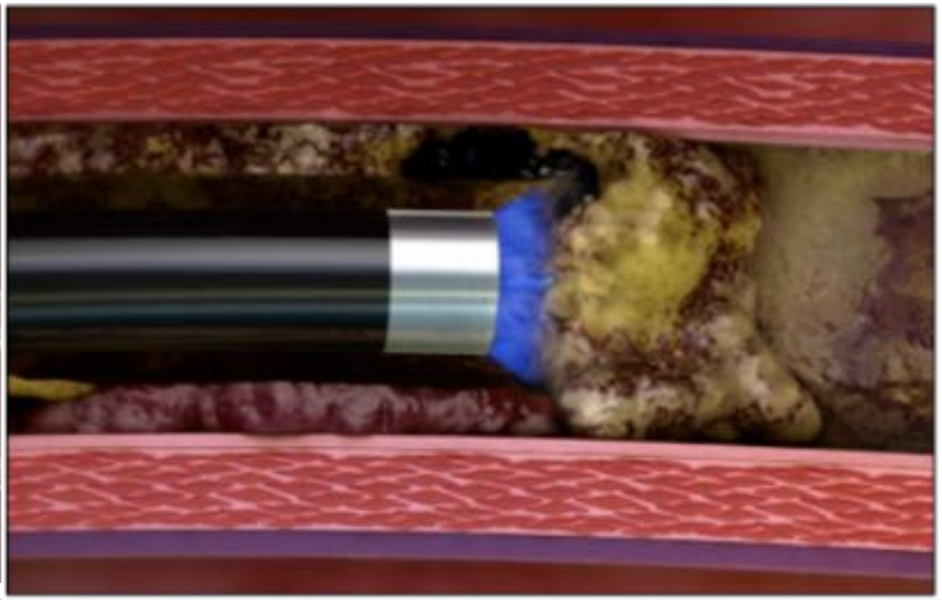
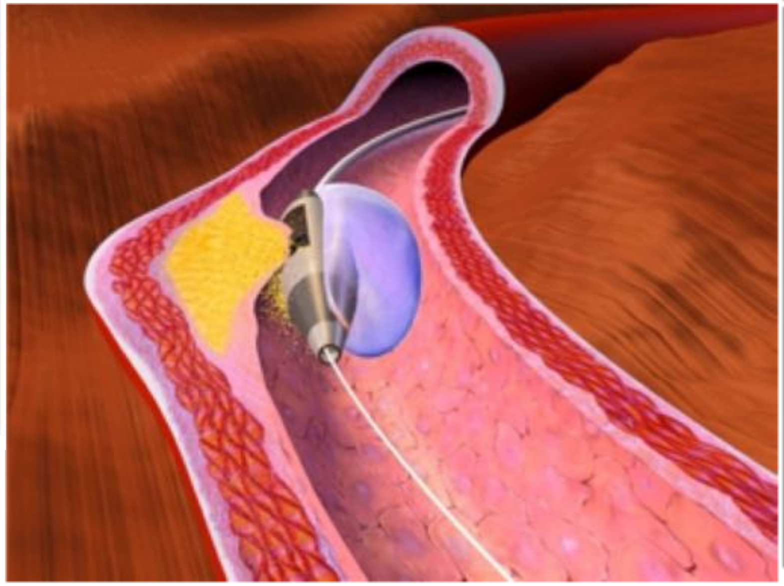
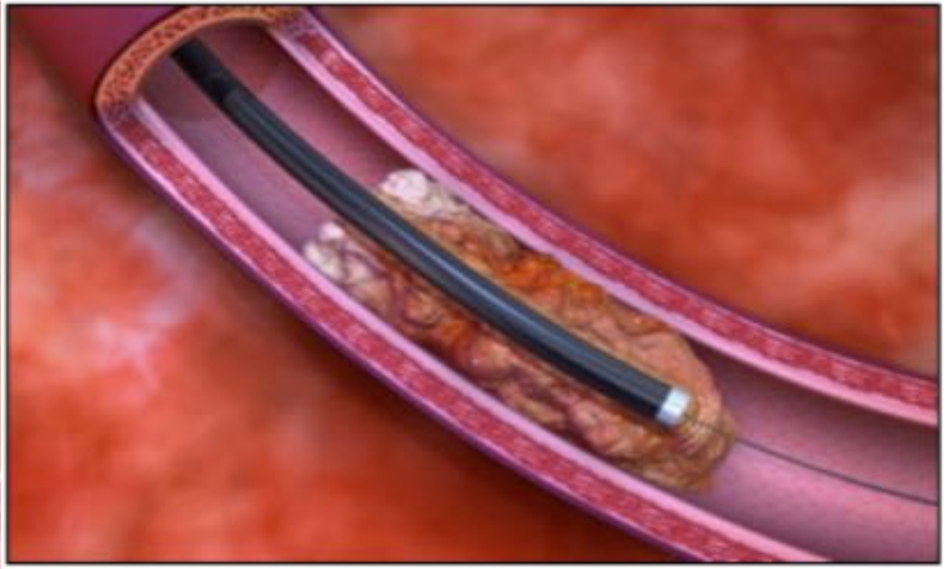
# Atherectomy Devices



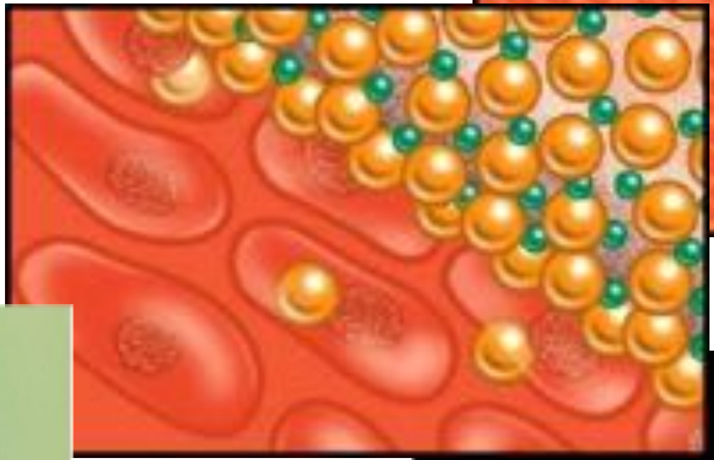



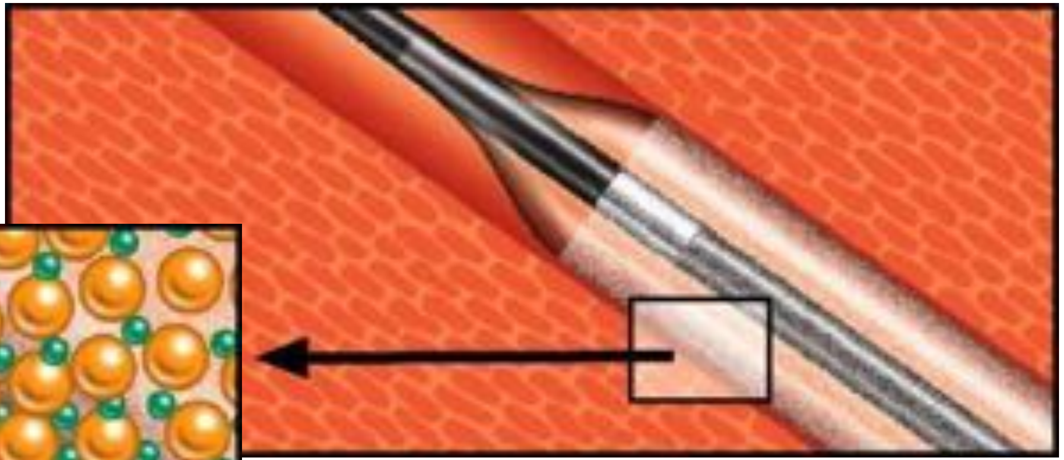



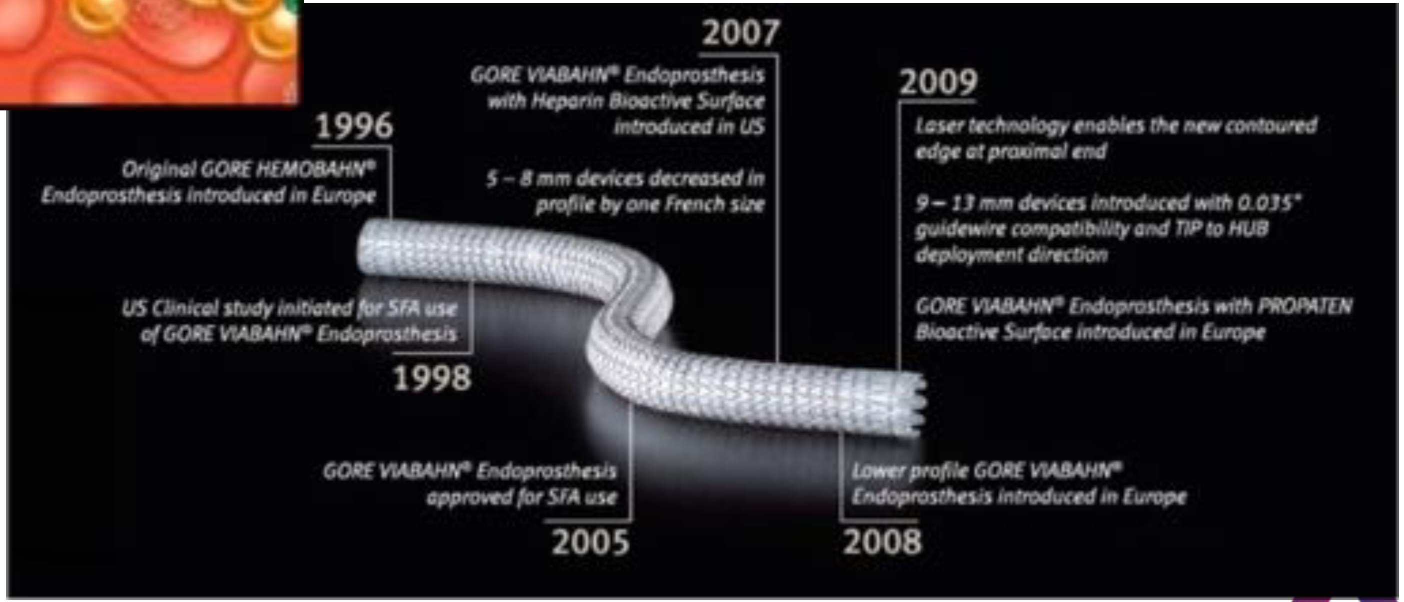




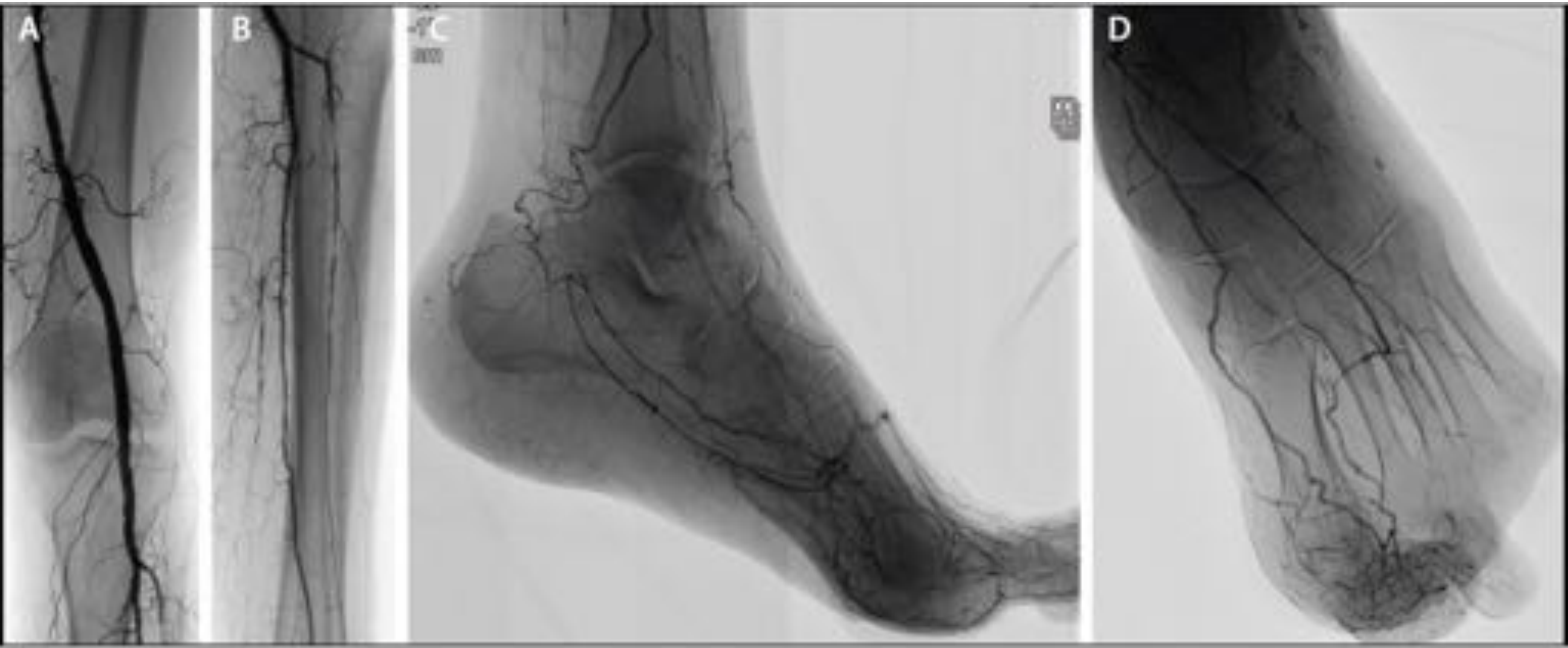
# Drug elution



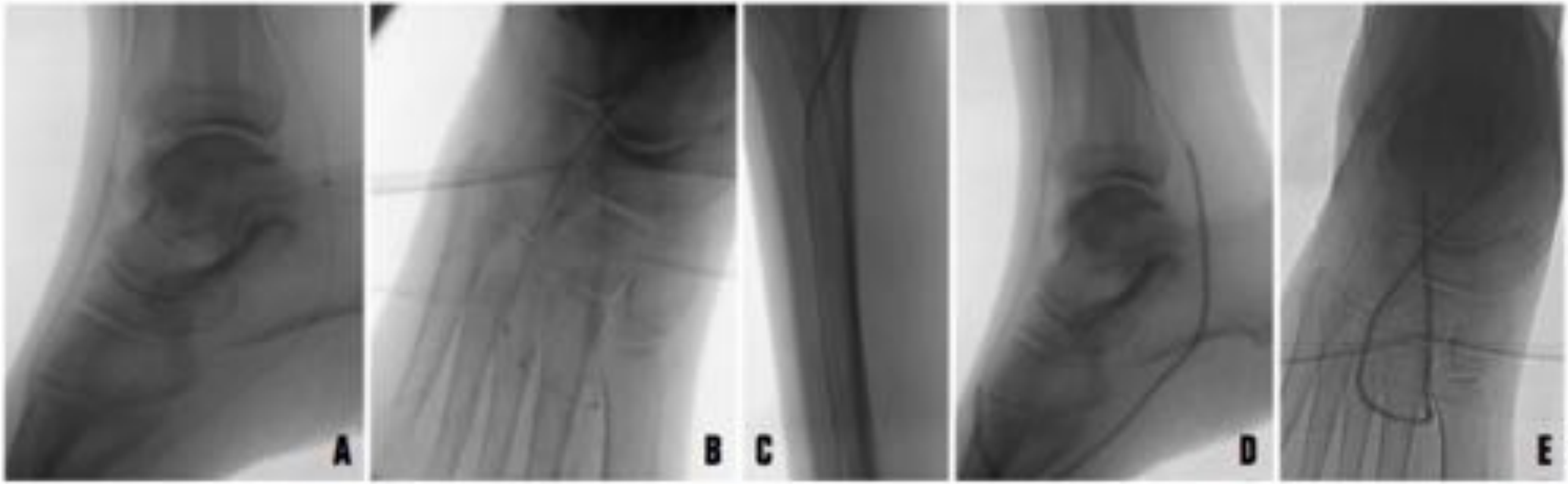




# Tibial and Pedal disease

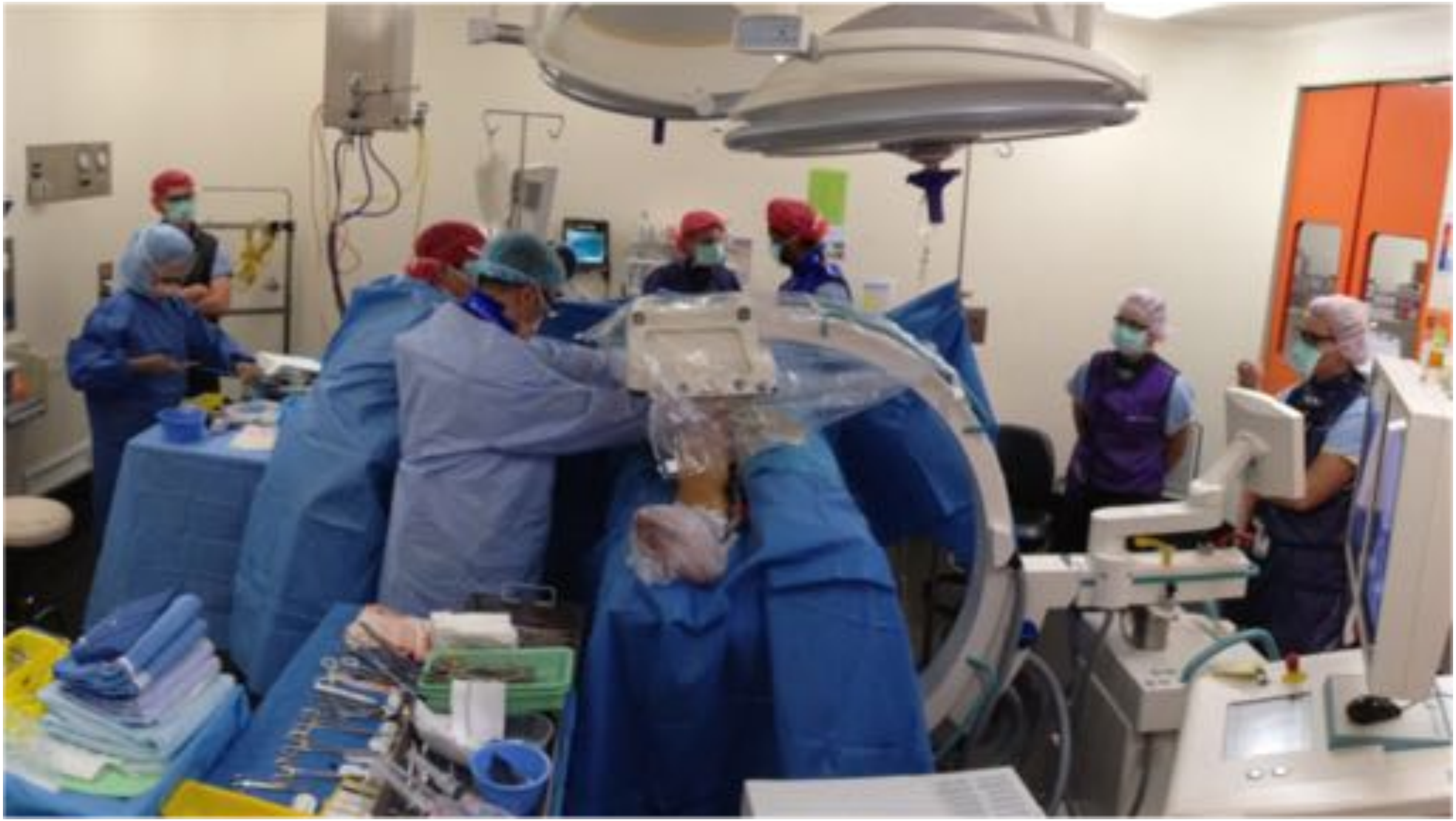


# Pedal angioplasty






MAQUET
數位複合式手術室
Hybrid operating Room



# Management of Tissue Loss

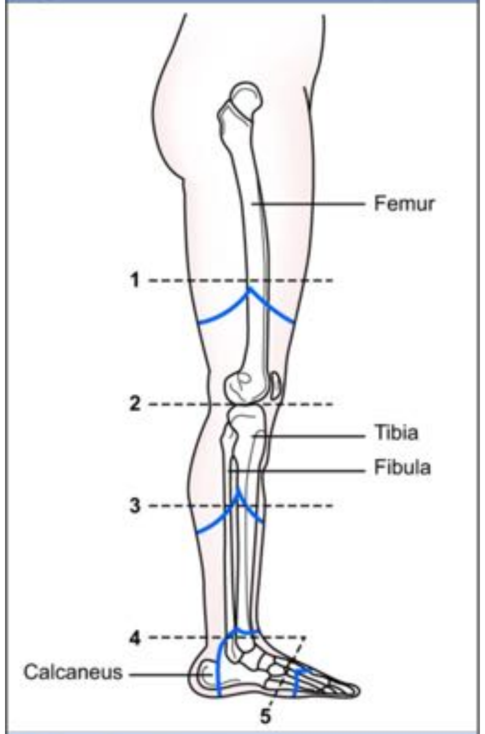
# Tissue Loss

- Treat or control superinfection
- Salvage tissue by improving vascularity
- Remove non-viable tissue (if safe to do so)
- Be prepared to sacrifice the limb
- Some patients cannot be salvaged

# Long Term Management

- Followup is paramount
- Risk factors require lifelong control
- Disease progression is inevitable
- Re-presentation with further ischaemia is likely
- Bypass Grafts and Stents have a limited life expectancy

Figure 1. Common levels of lower limb amputation




1 Above knee (transfemoral)
2 Through knee (knee disarticulation – Gritti Stokes)
3 Below knee (transtibial)
4 Ankle (ankle disarticulation – Symes)
5 Forefoot (transmetatarsal)

# Issues arising from change

- New treatment paradigms require a redesign of hospital organisational, physical and financial infrastructure. How do we do this?
- Can or should we push surveillance duties onto GPs, other specialties or a Vascular Surveillance Clinic?
- Does having a safer procedure mean that we can expand treatment indications?
- What happens if vascular surgeons become de-skilled in open surgery?
- Is early, high-cost intervention sustainable for our healthcare system?