بسم الله الرحمن الرحيم

Doppler Basics

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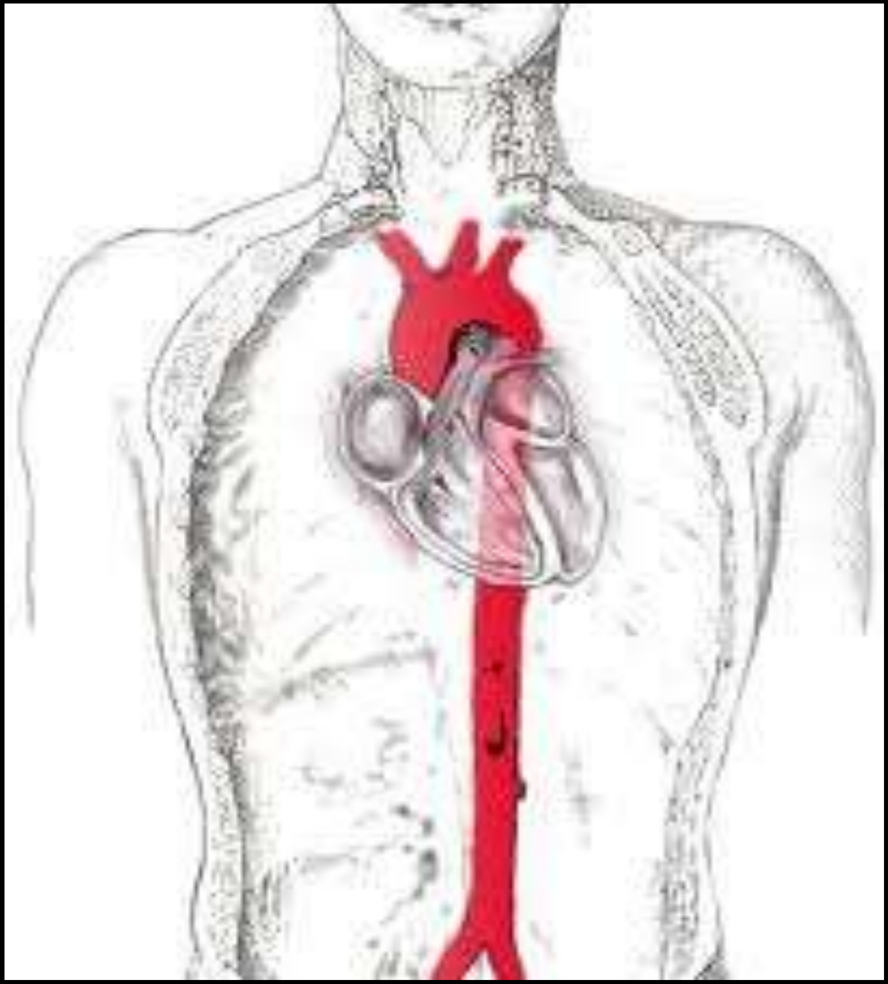
Surface Anatomy

Surface Anatomy

<u>Abd Aorta</u> :
- 2cm wide vertical band
- median plane
- To: 1cm below & Lt to Umb



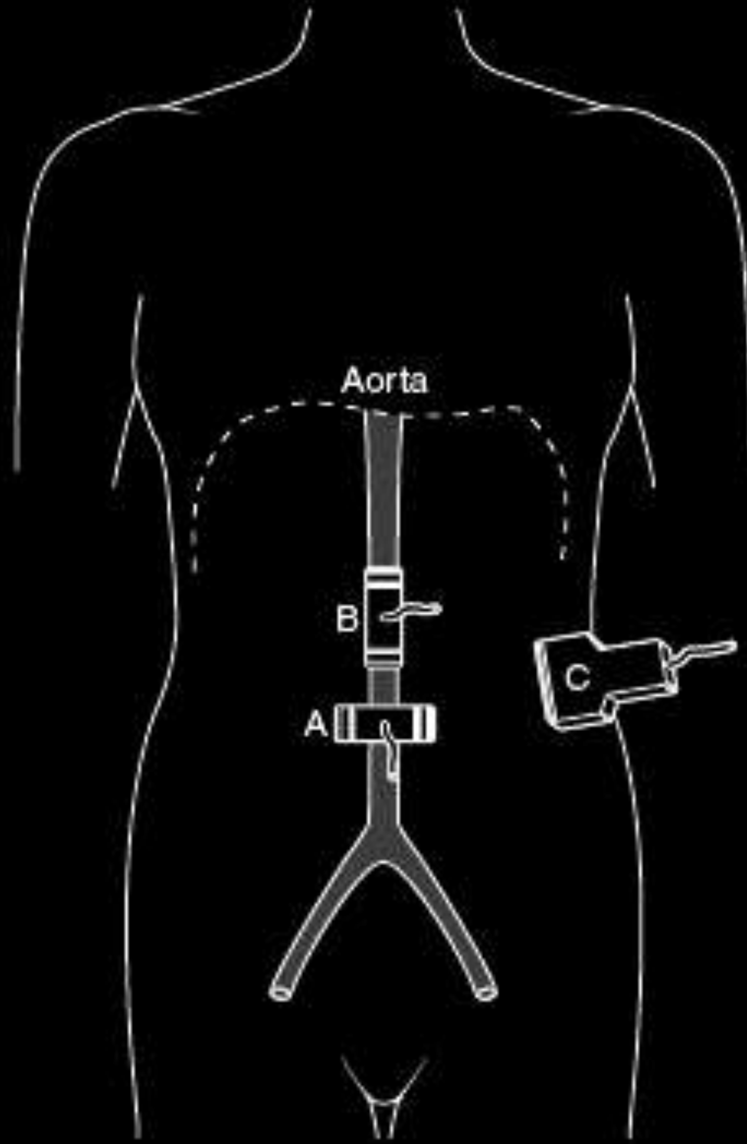
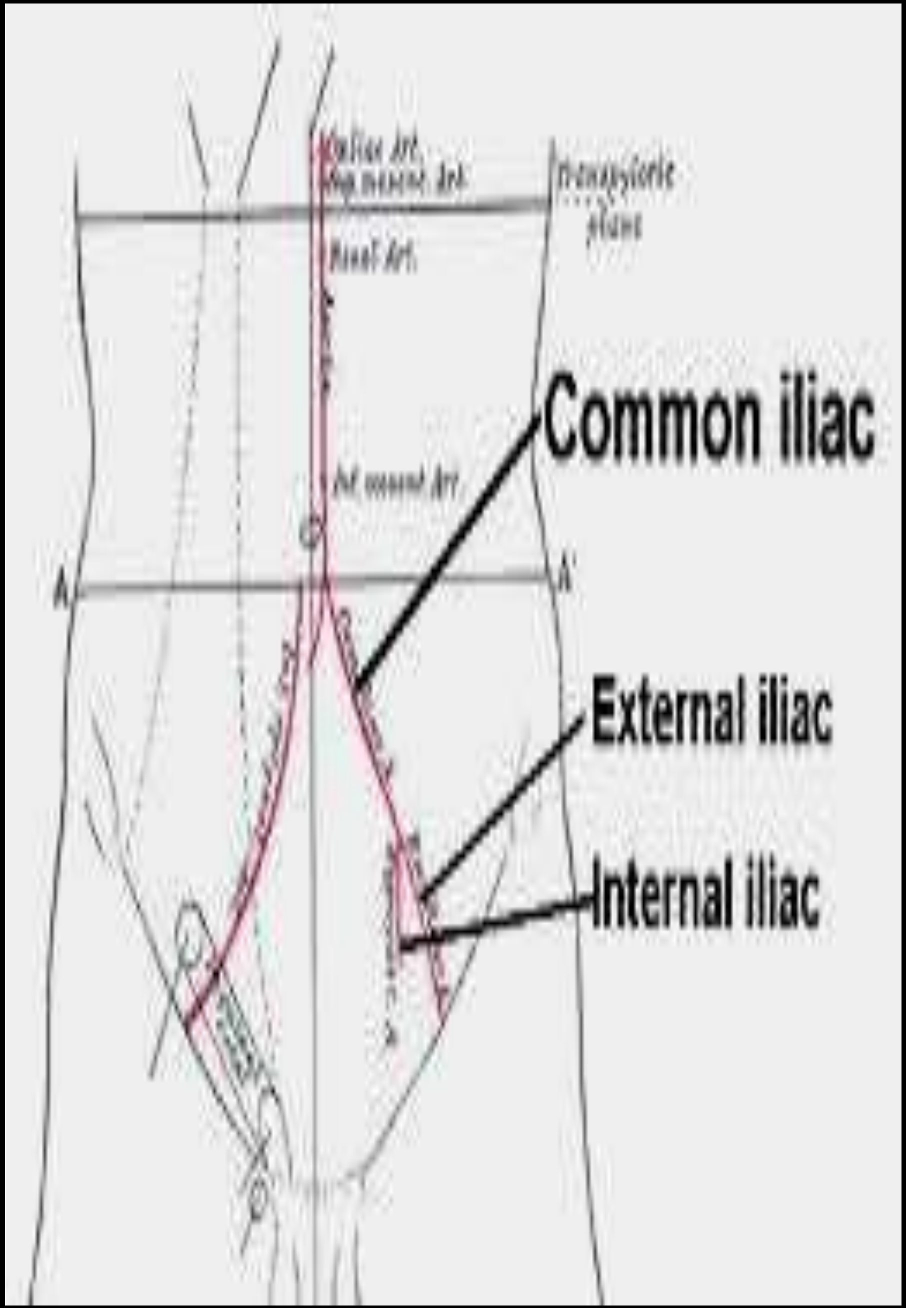


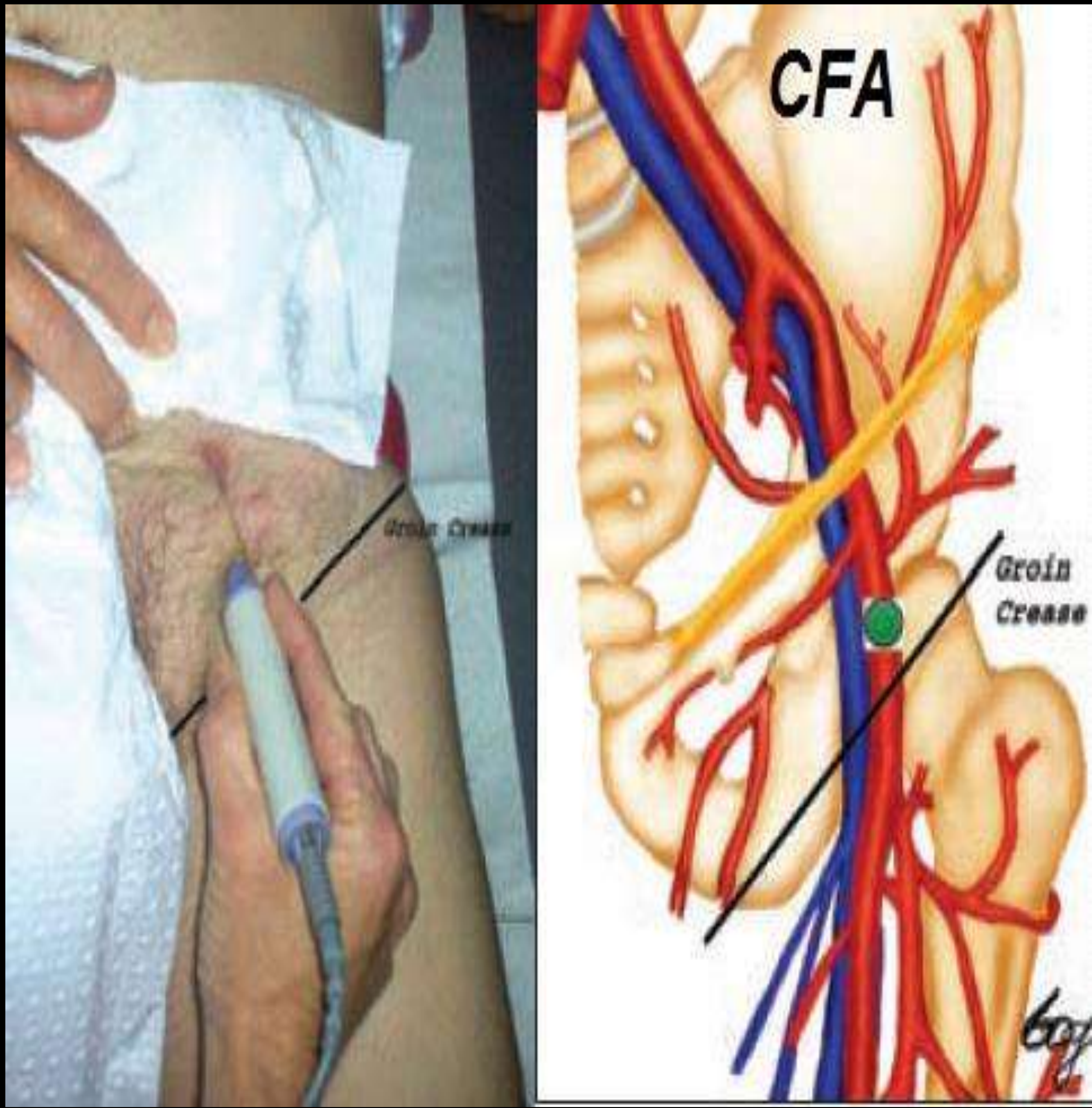
Figure 11.5 Transducer positions for scanning the abdominal aorta. A: Transverse. B: Sagittal or longitudinal. C: Coronal. The coronal view is used for measuring the lateral diameter of the aorta (i.e., side to side).

- CIA & EIA :
  - from: Point of Aortic Bifurcation.
  - To: point midway of "A.S.iliac spine & symph.pubis"
- Prox 1/3 CIA
- Dist 2/3 EIA



CFA & SFA :

Upper 2/3 of a line
" midinguinal point → Adductor Tubrcle"

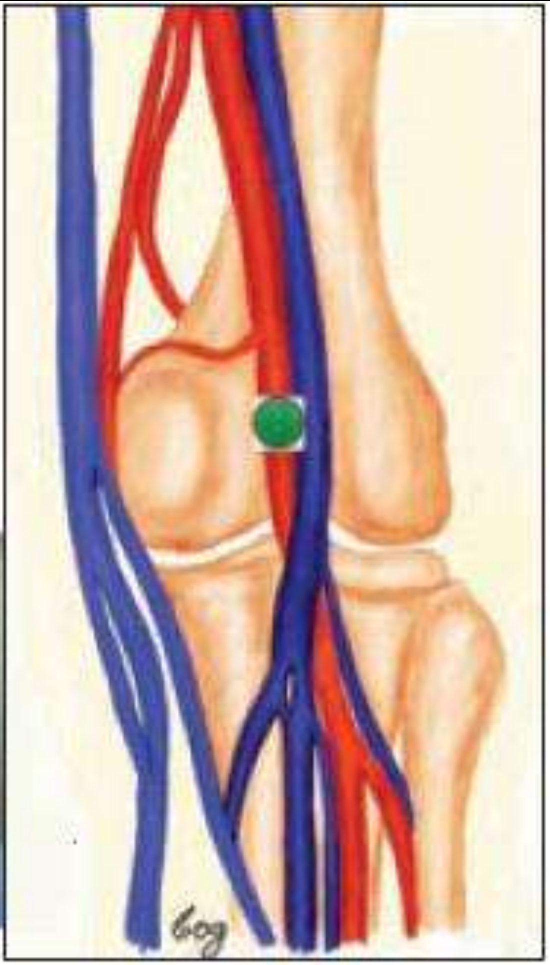


- *<u>***Popleteal A :***</u>
- ٢.٥ cm medial to midline
- - From: Level of junction Middle & Lower

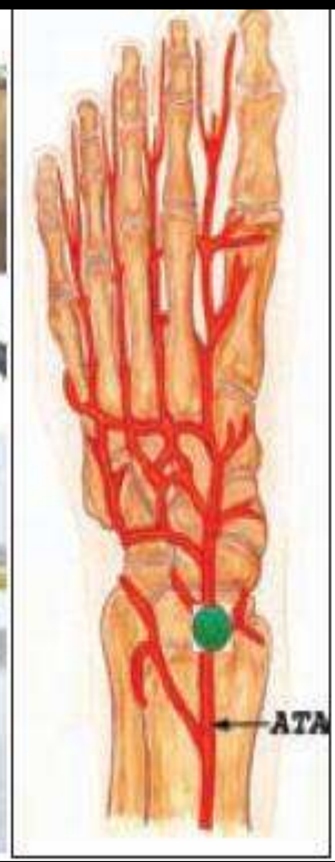
٣/١ of thigh

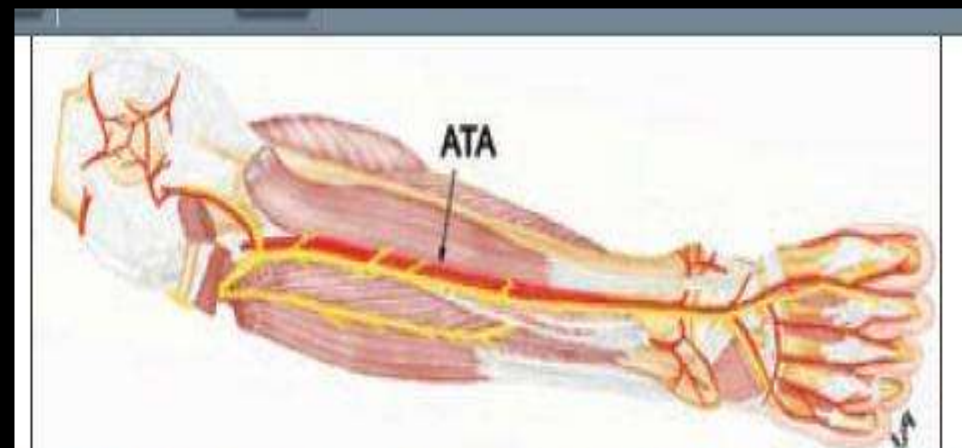
- - To: Midway of Femoral Condyles.
- - Then to tibial tubrusity "medial to Fibular neck"

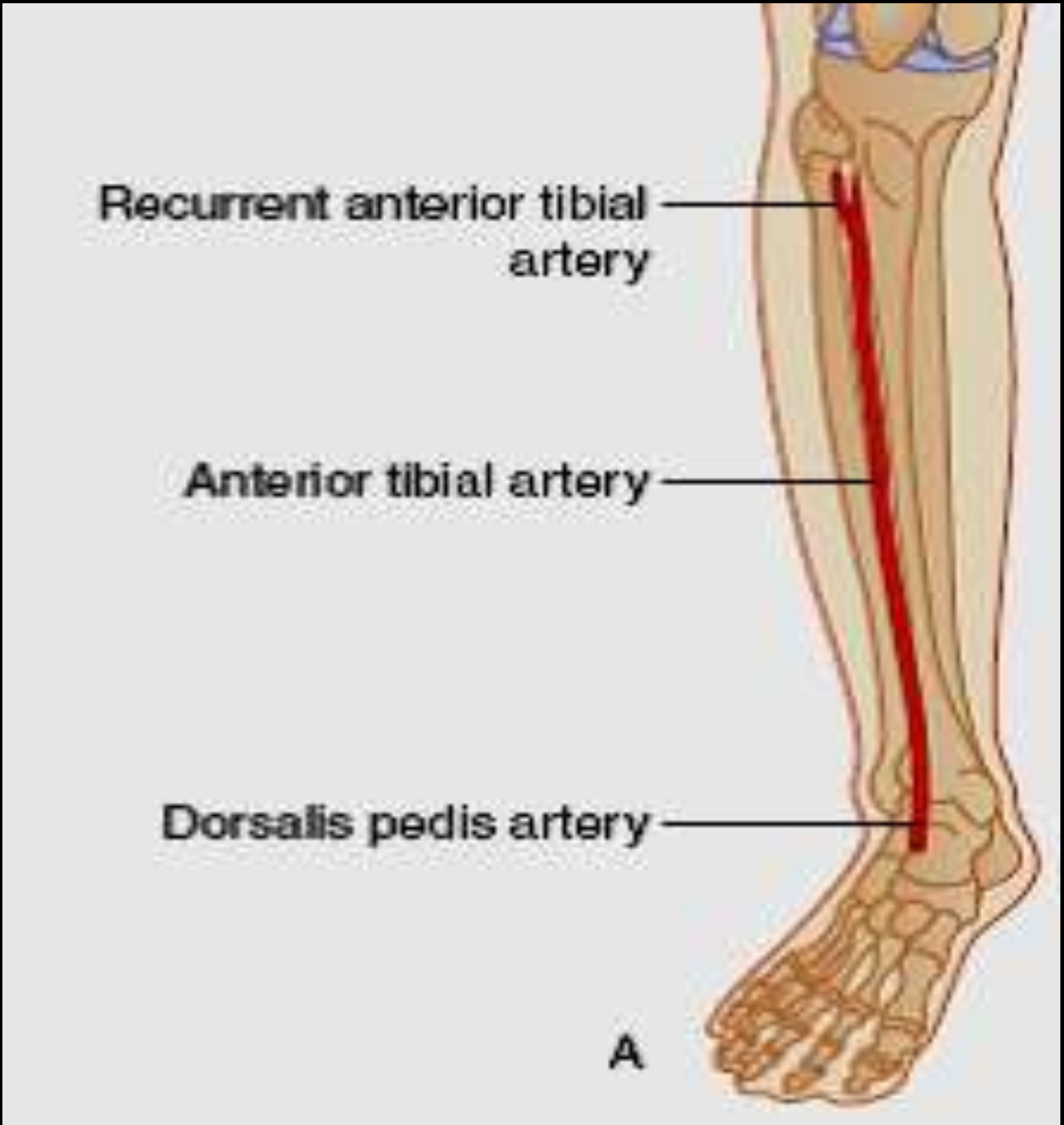
popleteal



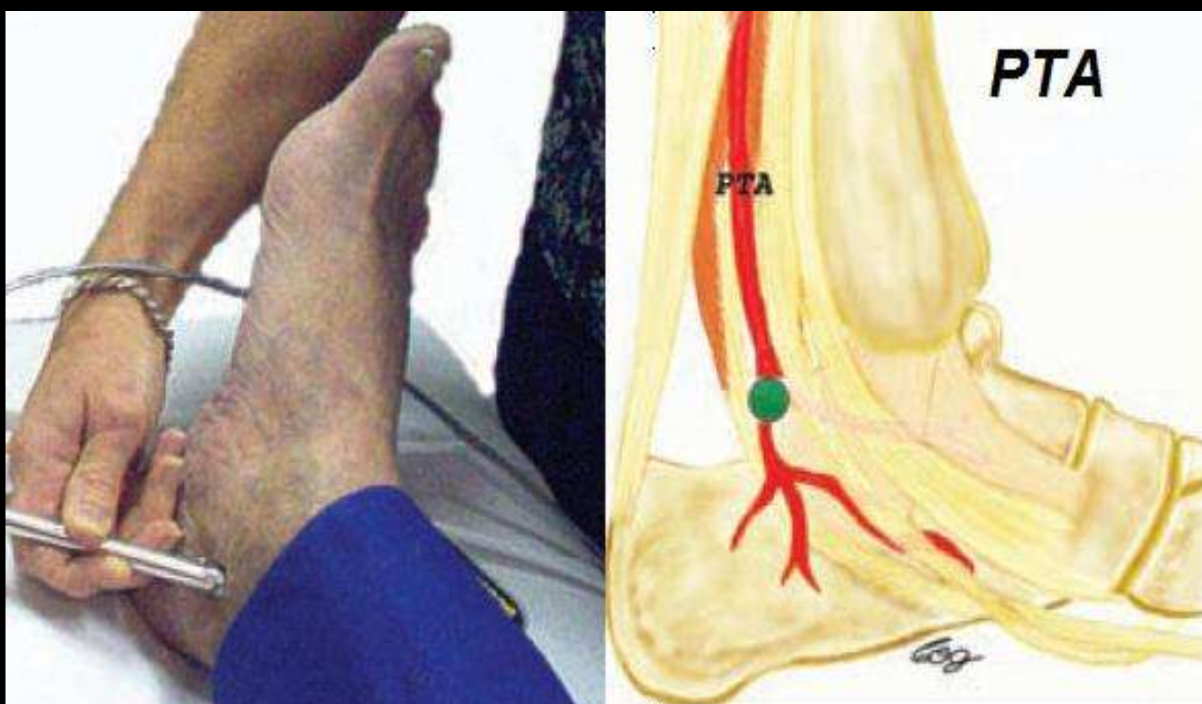
- ***Anterior Tibial A :***
- *٢.٥ cm* below & medial to Fibular Head
- To: Midaw med & Lat Maleoli "Front of Ankle"

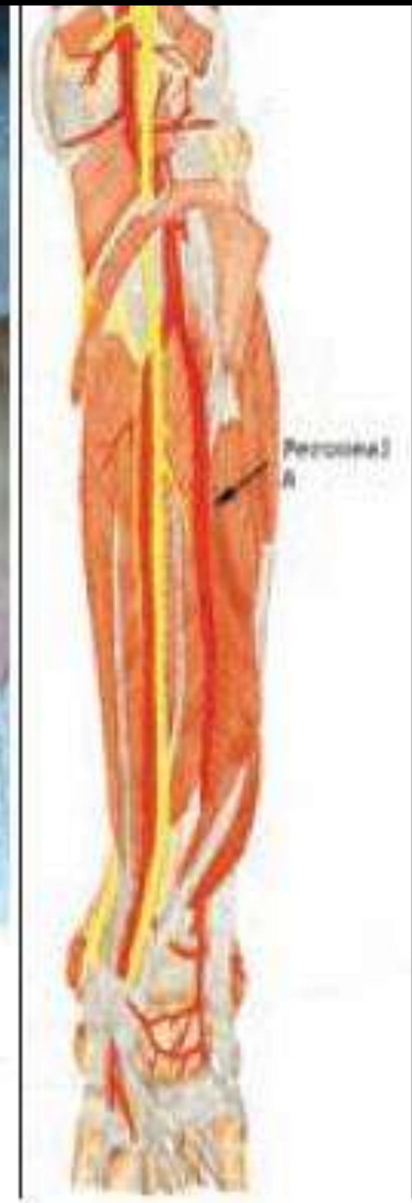





Recurrent anterior tibial artery
Anterior tibial artery
Dorsalis pedis artery
A

- *<u>***Posterior Tibial A :***</u>
- ١:٢- cm Lat to Calf Medline down & Medialy
- To: midway of Med maleolus & medial calcaneous Tubrcle.





peroneal A

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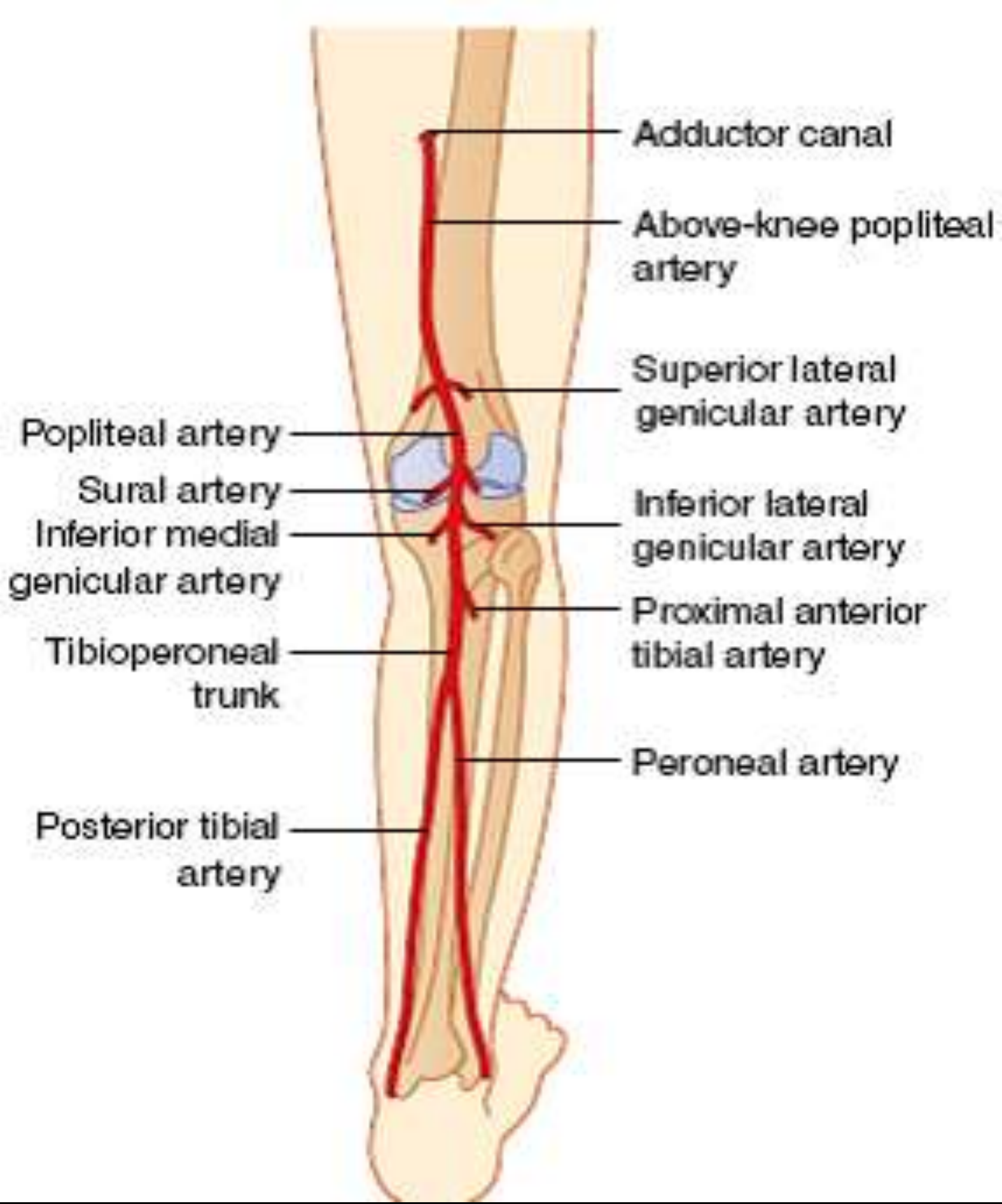
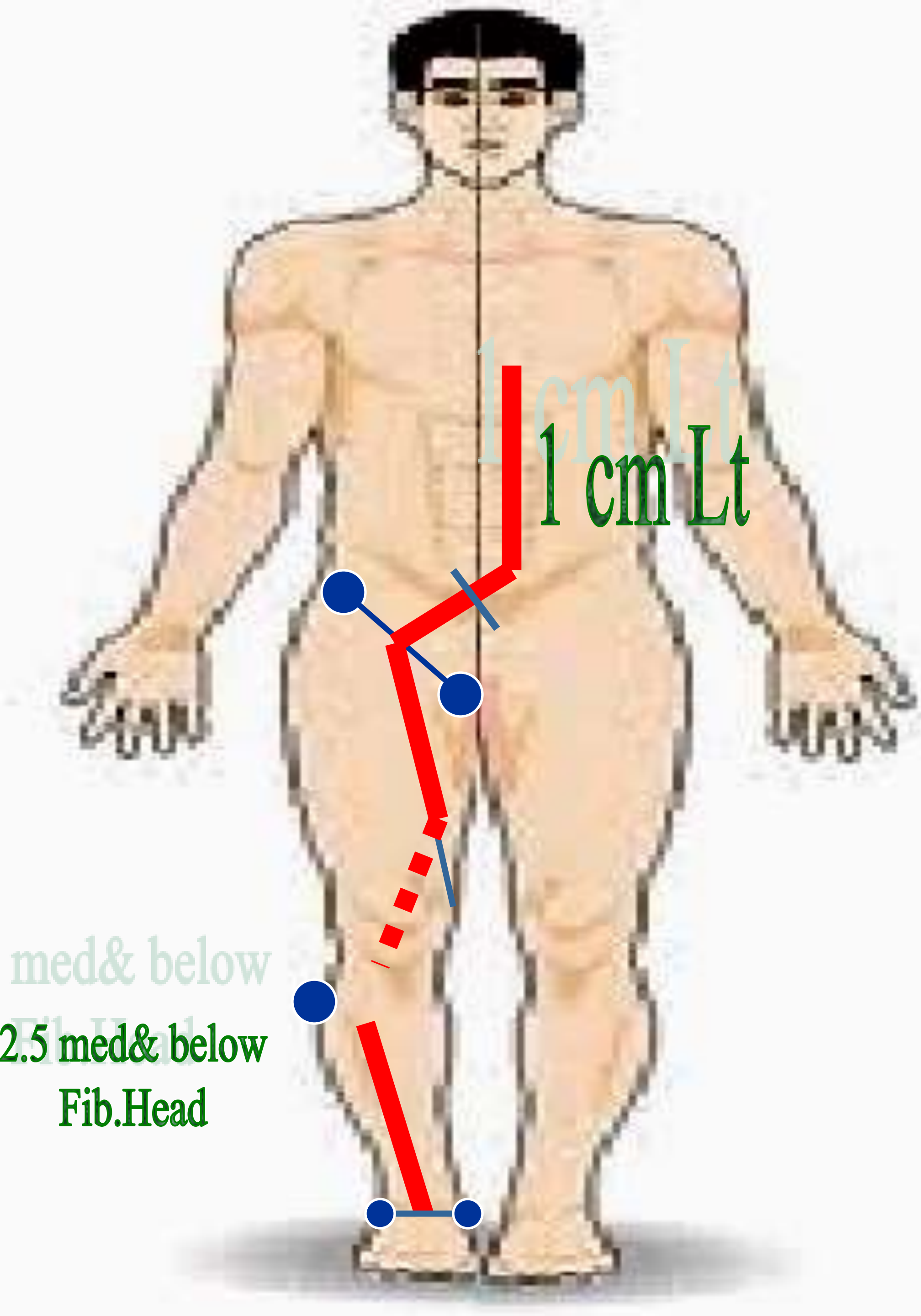
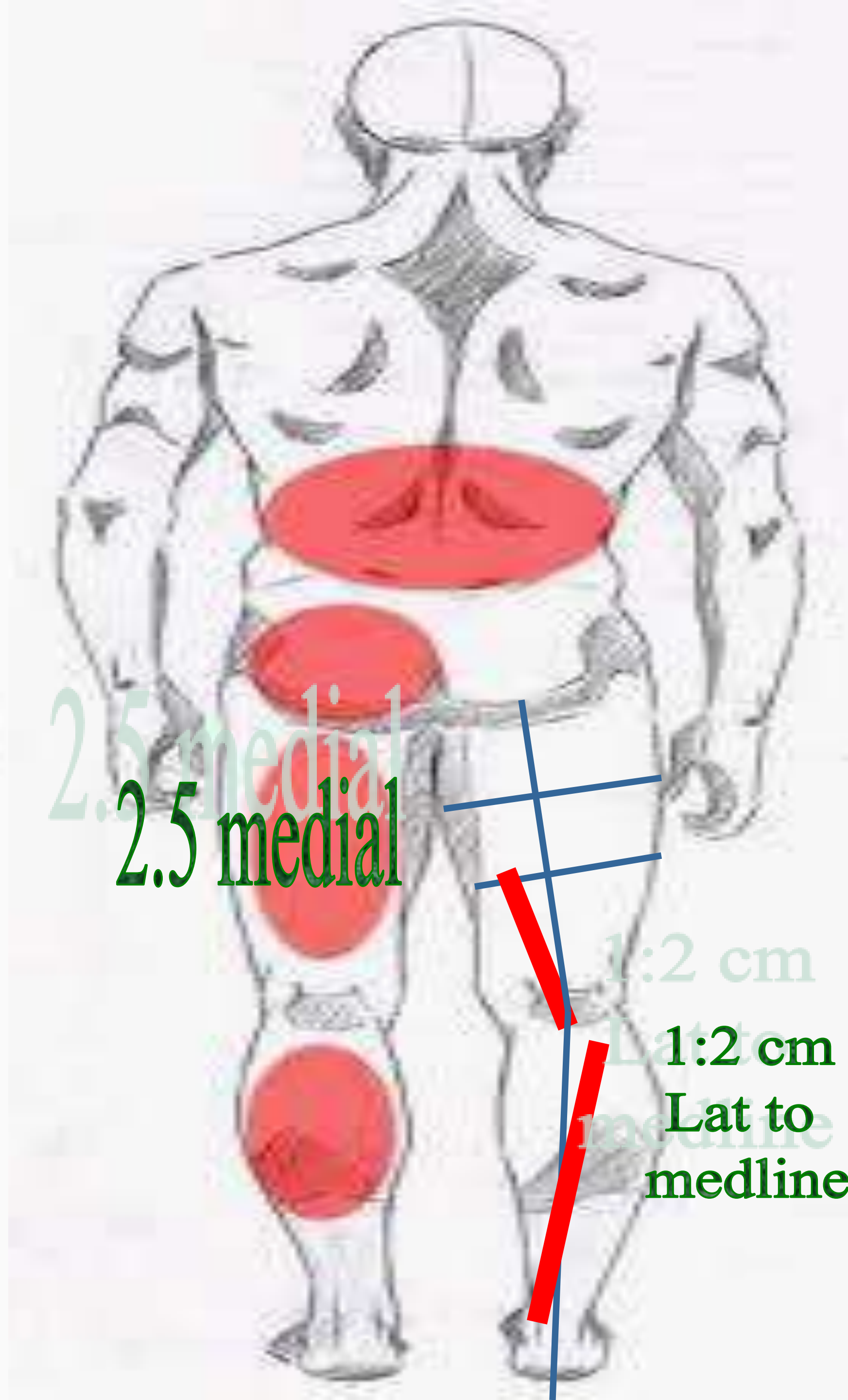

Adductor canal
Above-knee popliteal artery
Superior lateral genicular artery
Popliteal artery
Sural artery
Inferior medial genicular artery
Inferior lateral genicular artery
Proximal anterior tibial artery
Tibioperoneal trunk
Peroneal artery
Posterior tibial artery

- ****Dprsalis Pedis :****
- - Absent in 15 % of people.
- - From: Medway of Maleolai
- - To: Prox end of 1st


1 cm Lt
2.5 med& below
Fib.Head


2.5 medial
1:2 cm
Lat to
medline

Arterial and Venous Circulation of the Legs

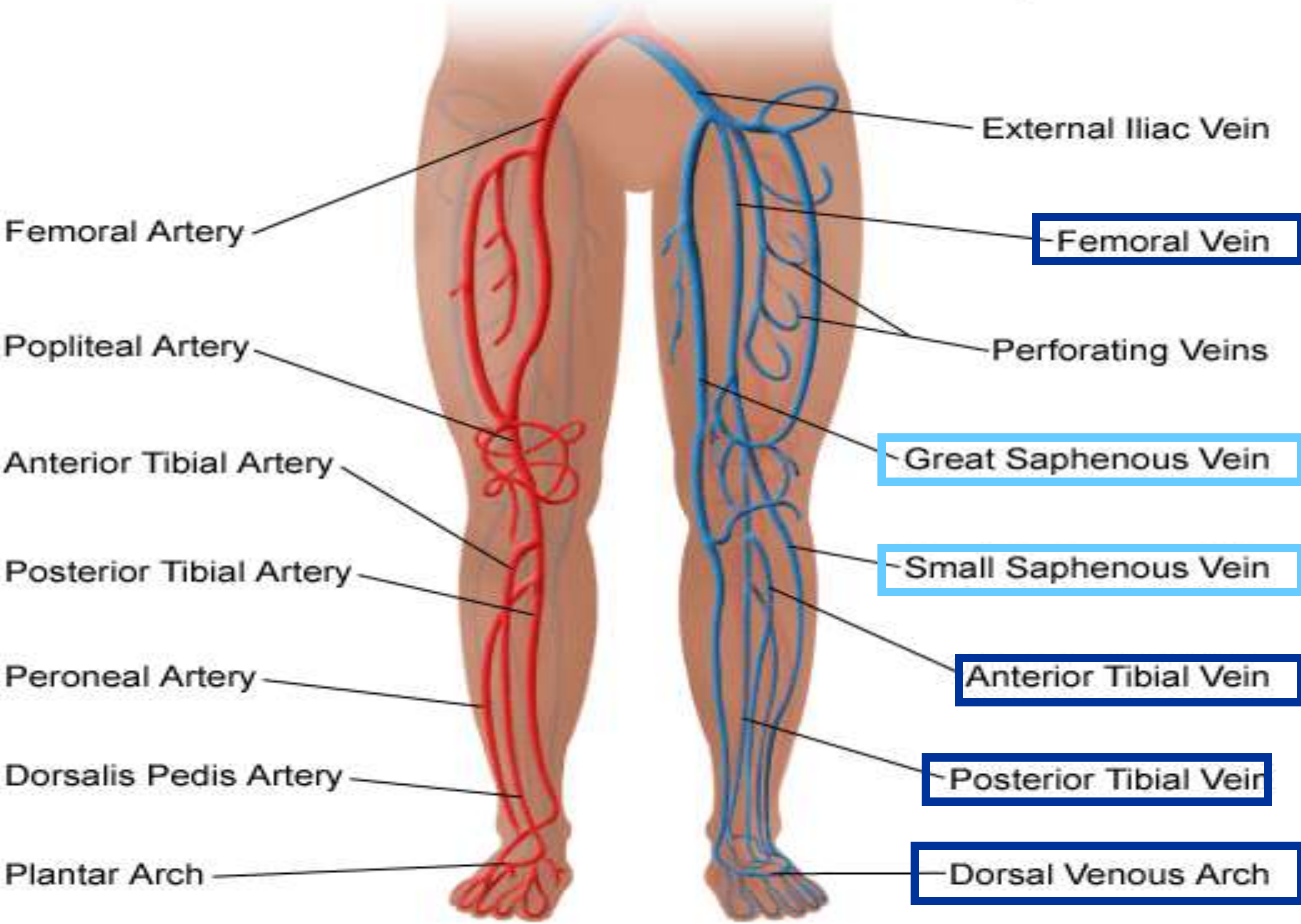
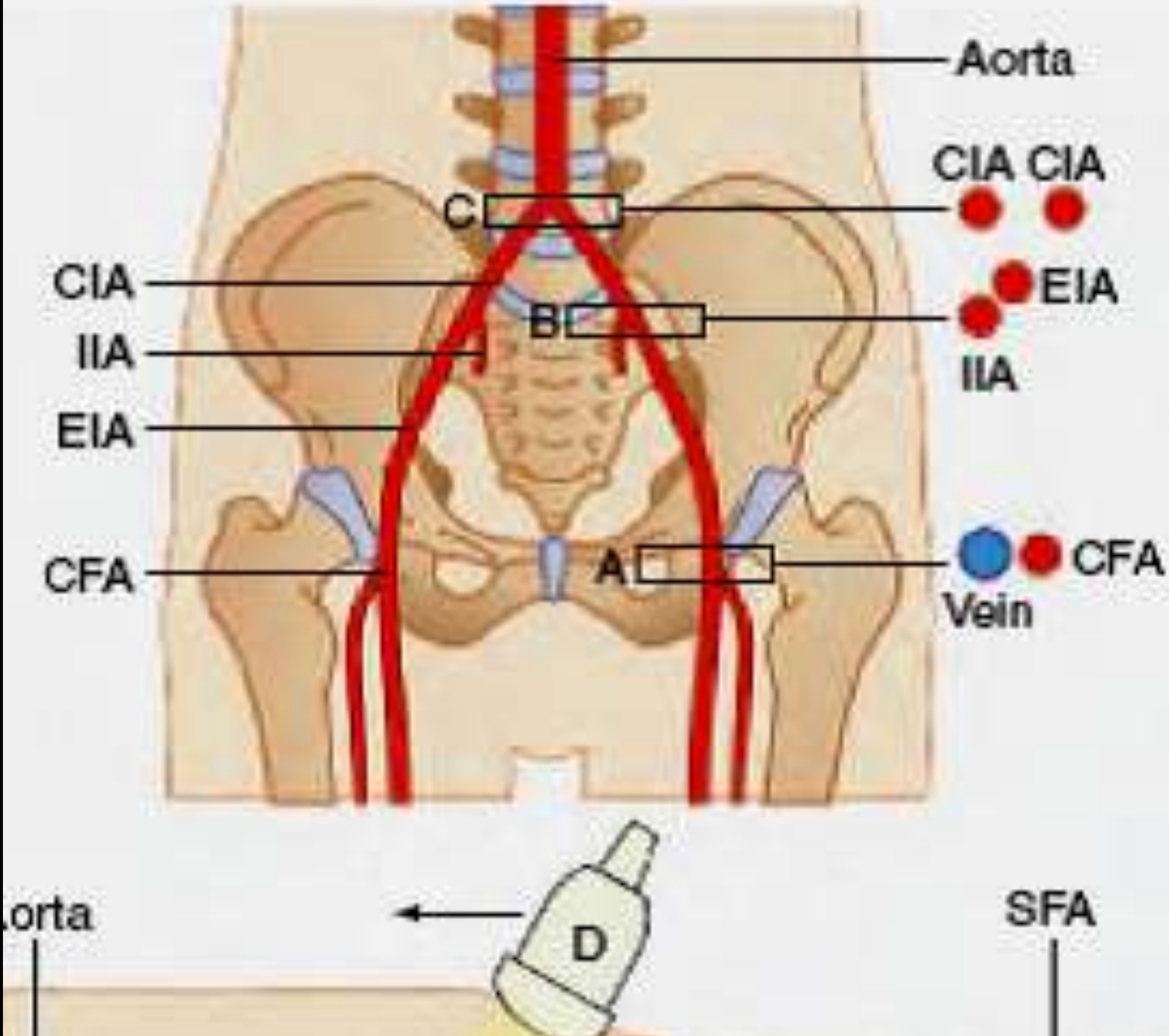


Table 9.1 Common collateral pathways of the lower limb arteries

Diseased artery	Distal normal artery	Common collateral pathway
Common iliac artery	External iliac artery	Lumbar arteries communicating with the iliolumbar arteries of the ipsilateral internal iliac artery, which supply the external iliac artery via retrograde flow; there can also be communication between the contralateral internal iliac artery and ipsilateral internal iliac artery
External iliac artery	Common femoral artery	Ipsilateral internal iliac artery via pelvic connections to the deep iliac circumflex artery or inferior epigastric artery
Common femoral artery	Femoral bifurcation	Ipsilateral pelvic arteries filling the profunda femoris artery via the femoral circumflex arteries, which supply the superficial femoral artery via retrograde flow
Superficial femoral artery	Above-knee popliteal artery	Flow via profunda femoris artery (or branches of the proximal superficial femoral artery if patent) to the descending or superior genicular arteries, depending on the length of the superficial femoral artery occlusion
Superficial femoral artery	Below-knee popliteal artery	Profunda femoris artery branches to inferior genicular branches of the popliteal artery
Popliteal artery	Distal popliteal artery	Flow via the superior genicular arteries to inferior genicular arteries, depending on the level of the occlusion
Proximal tibial arteries	Distal tibial arteries	There are numerous arterial collateral connections in the calf, but they may not be large enough to carry sufficient flow to the foot


Aorta
CIA CIA
C
CIA
EIA
B
IIA
IIA
EIA
CFA
A
CFA
Vein
orta
D
SFA

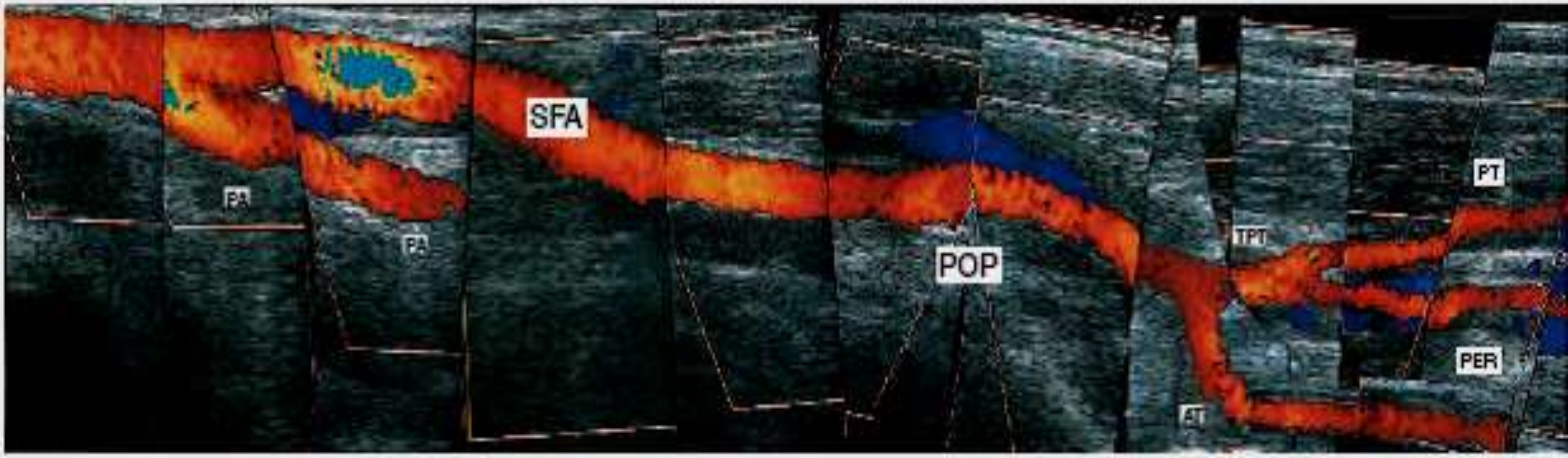
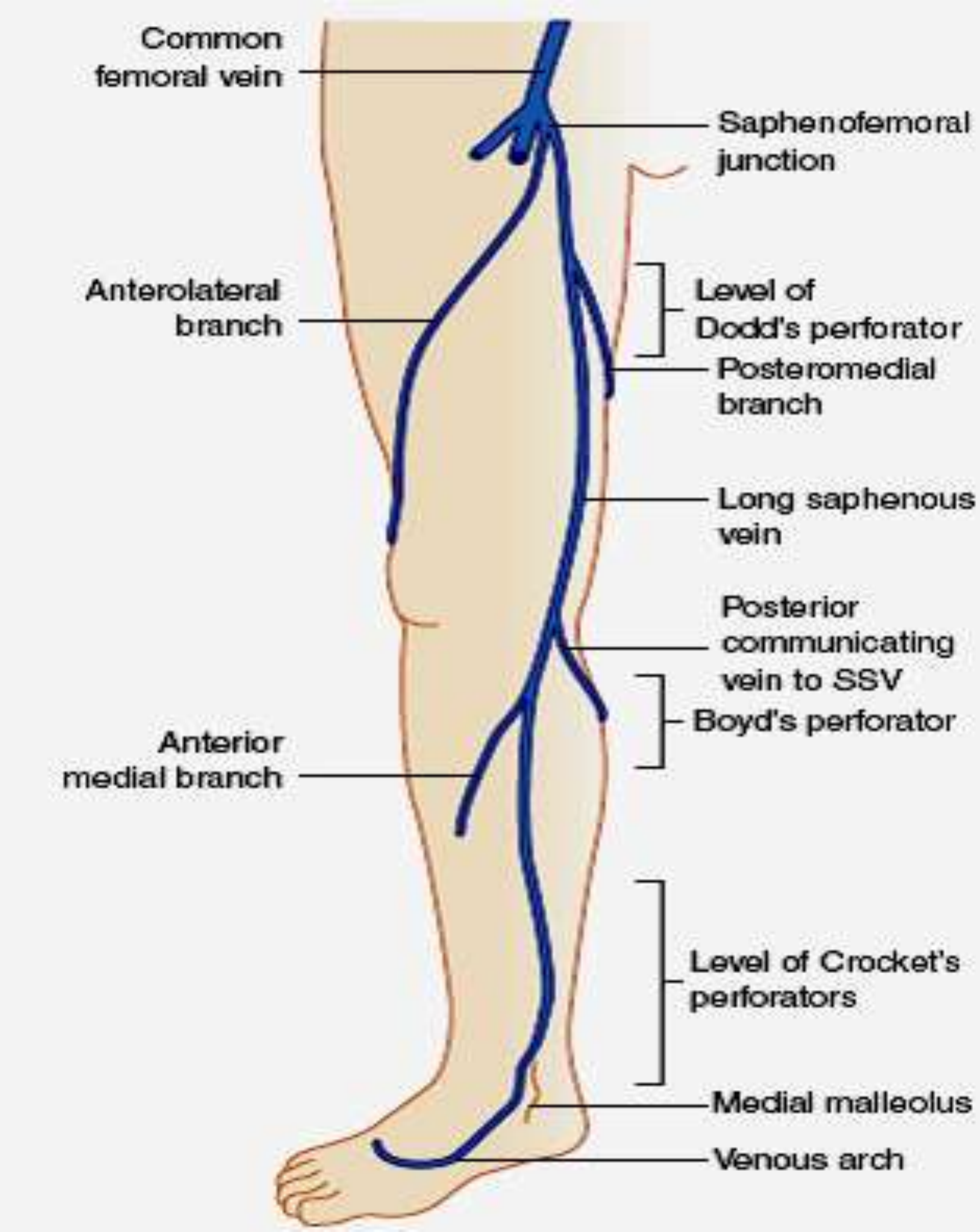
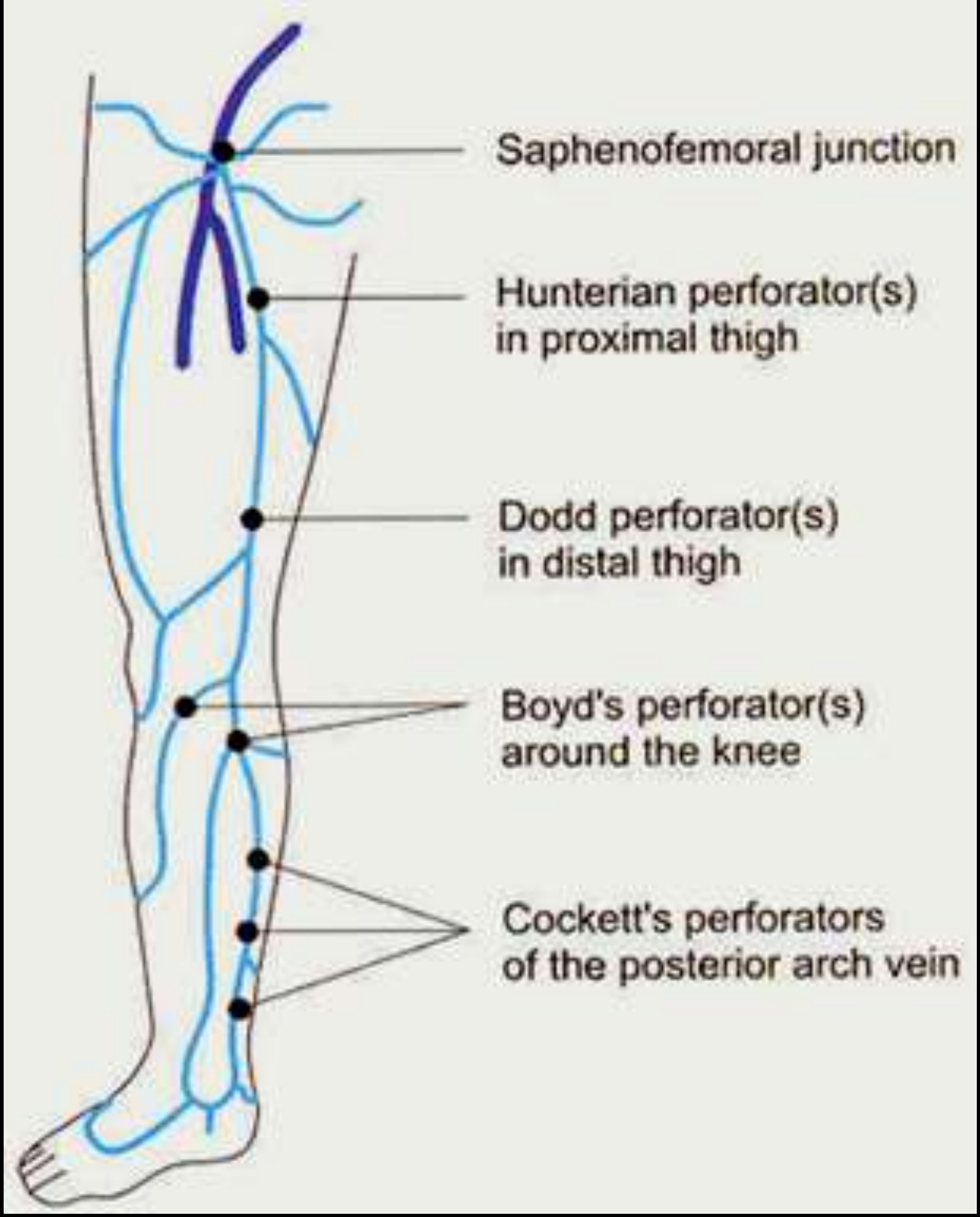


Figure 9.9 A color montage of the femoropopliteal and calf arteries. The image shows the profunda femoris artery (PA), SFA, popliteal artery (POP), tibial peroneal trunk (TPT), PT, AT and peroneal artery (PER).


Common femoral vein
Saphenofemoral junction
Anterolateral branch
Level of Dodd's perforator
Posteromedial branch
Long saphenous vein
Posterior communicating vein to SSV
Boyd's perforator
Anterior medial branch
Level of Crocket's perforators
Medial malleolus
Venous arch


Saphenofemoral junction
Hunterian perforator(s)
in proximal thigh
Dodd perforator(s)
in distal thigh
Boyd's perforator(s)
around the knee
Cockett's perforators
of the posterior arch vein

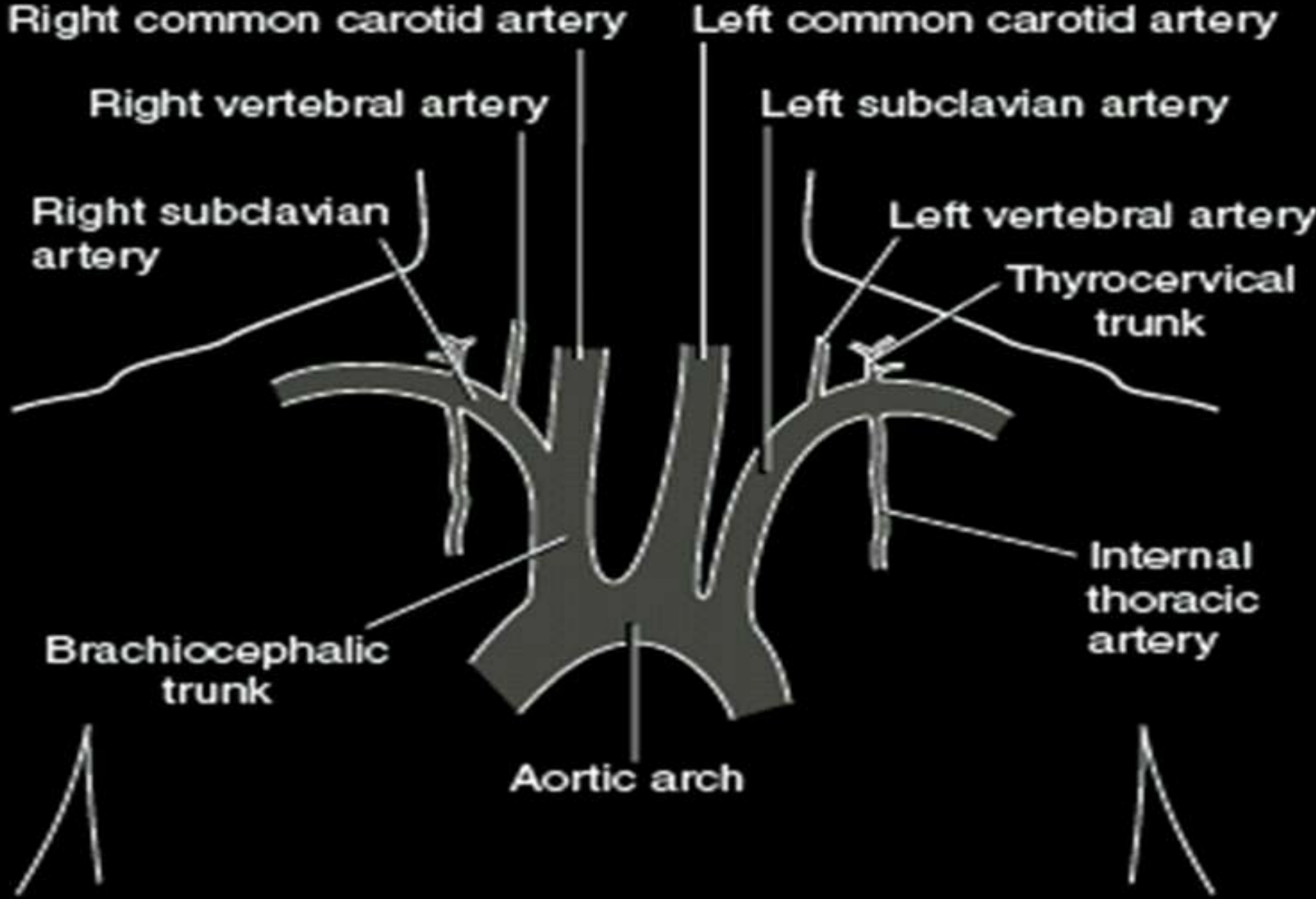


Figure 10.1 The arterial anatomy of the aortic arch and subclavian artery.

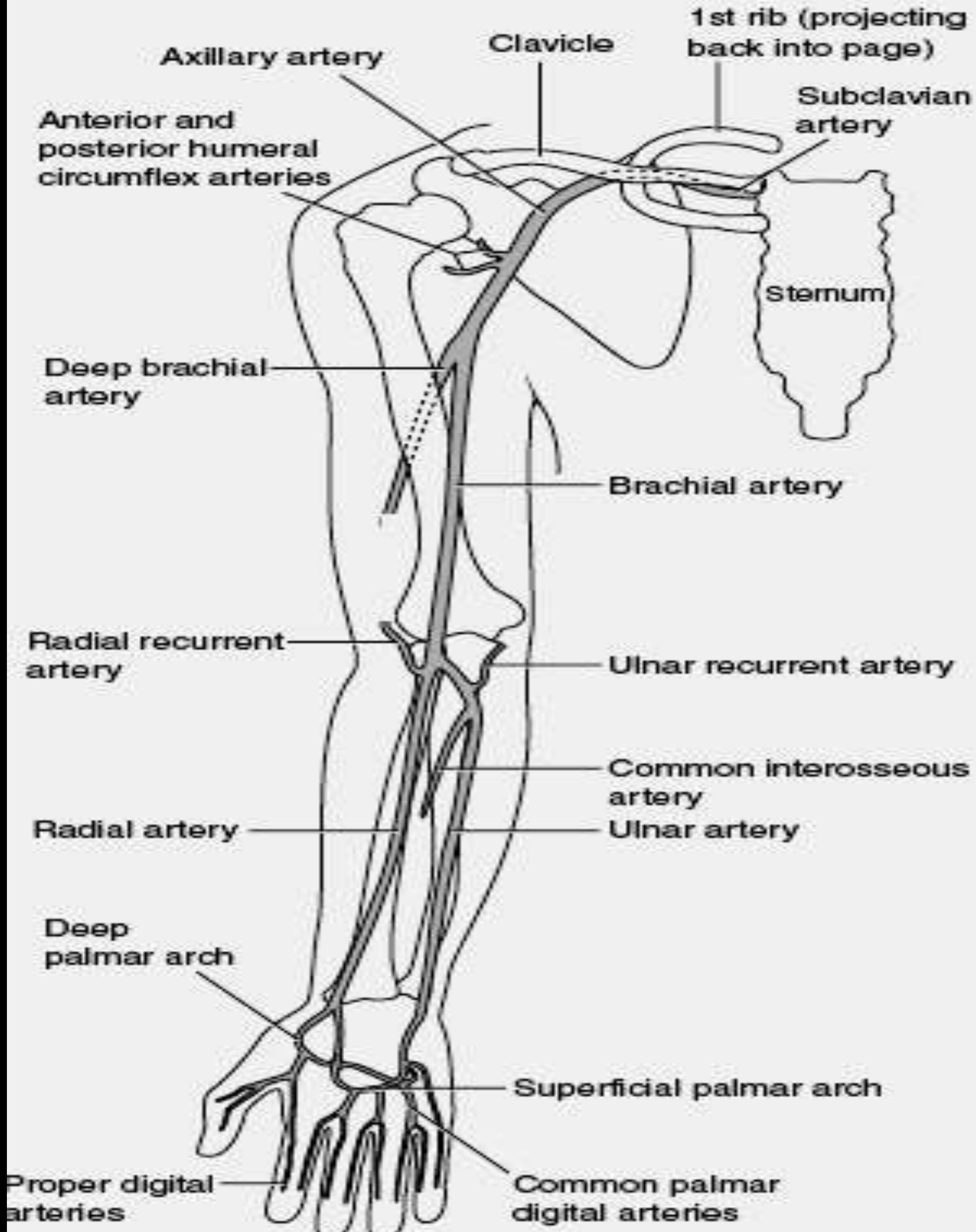


Figure 10.2 The arterial anatomy of the arm and hand.

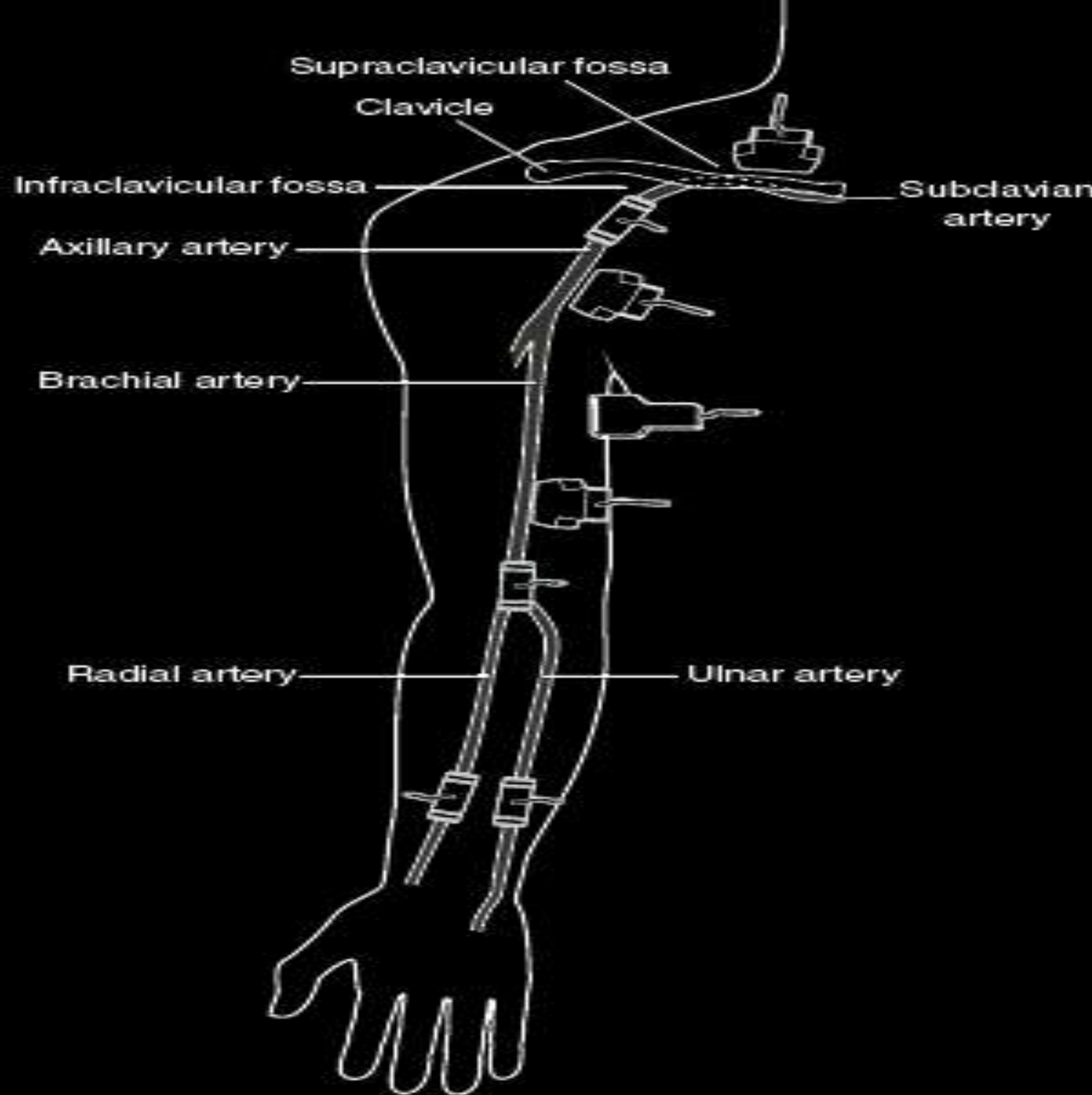
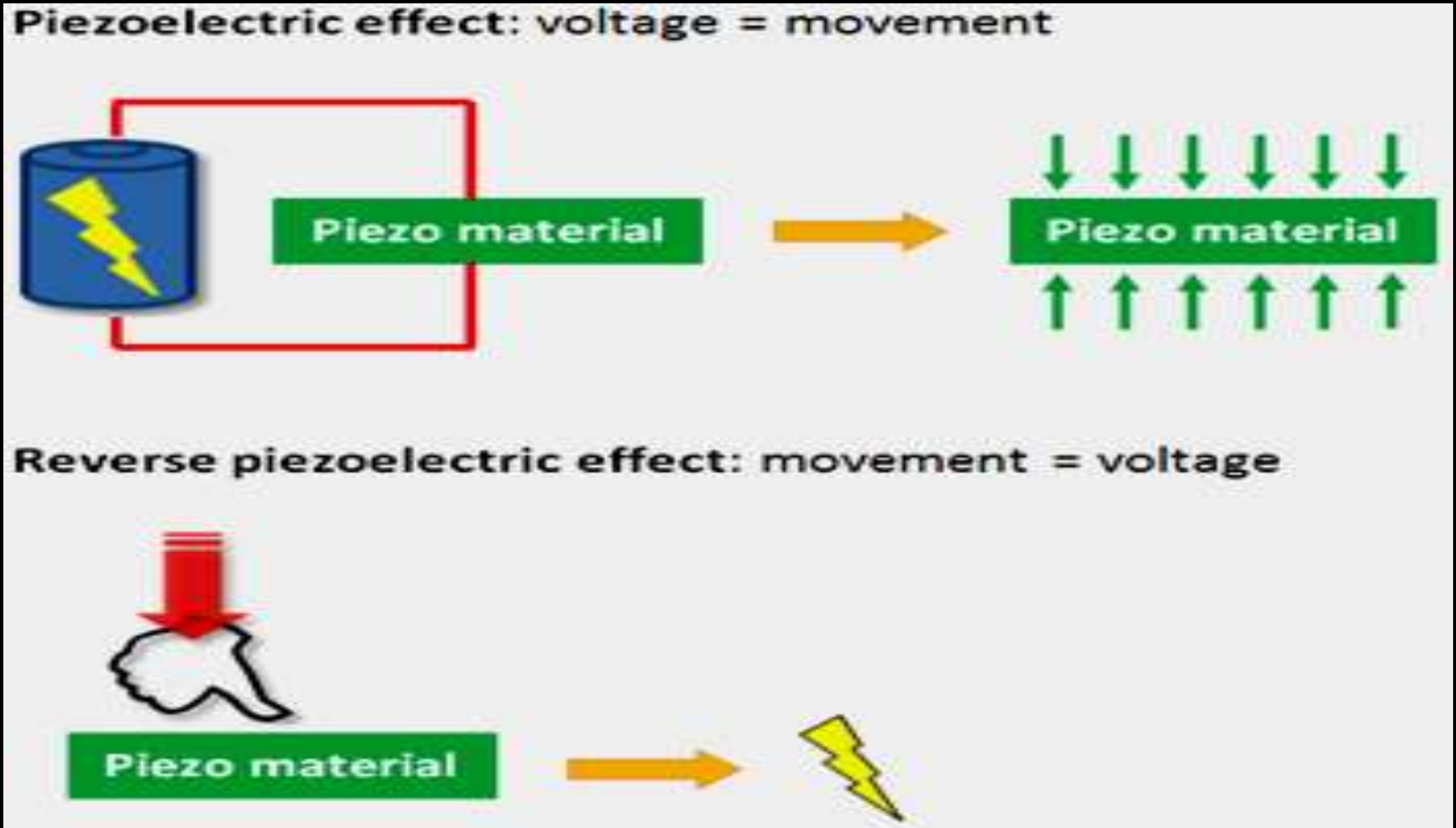


Figure 10.3 Transducer positions for scanning the upper extremity arteries.

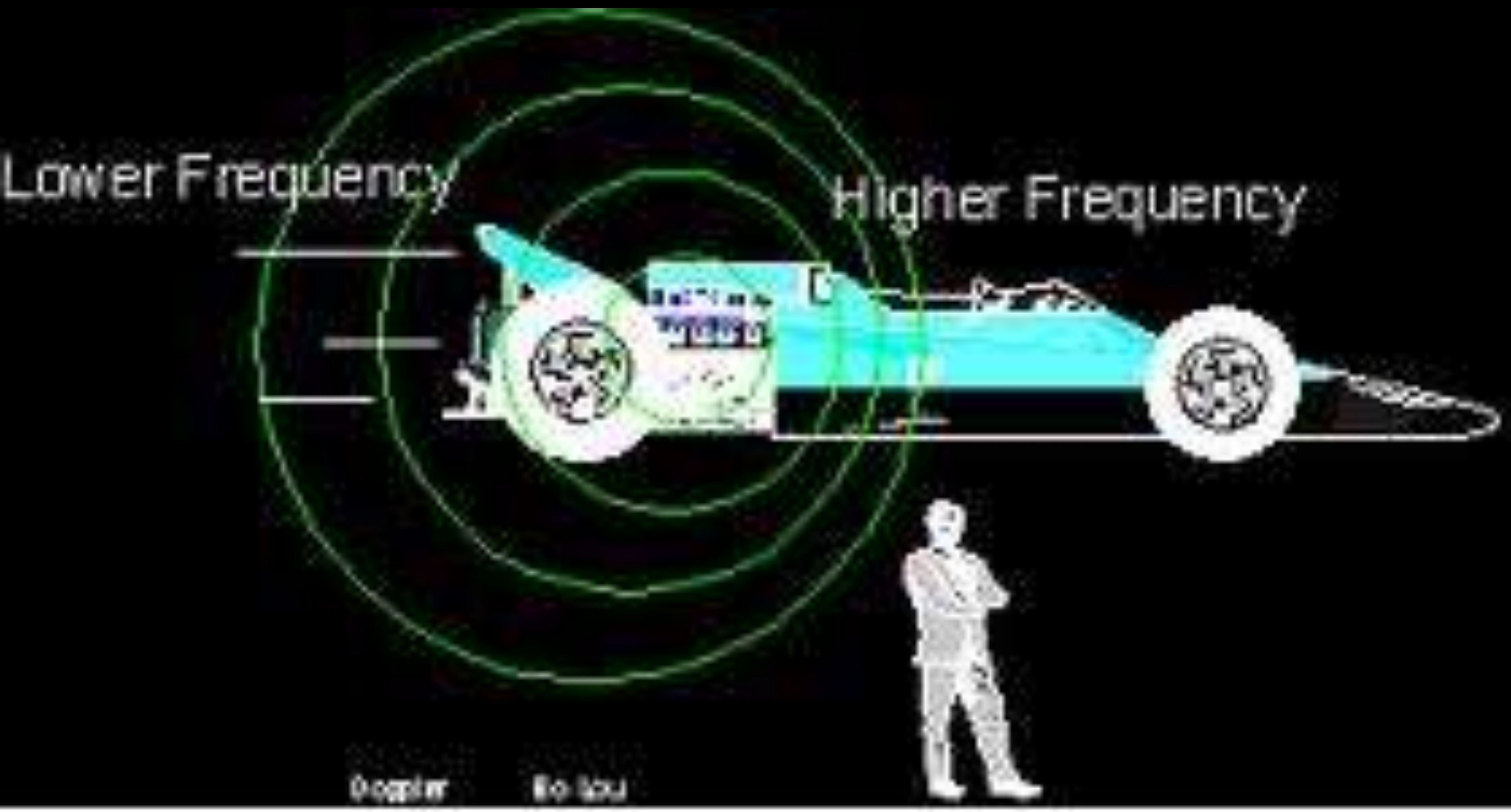
DOPPLER

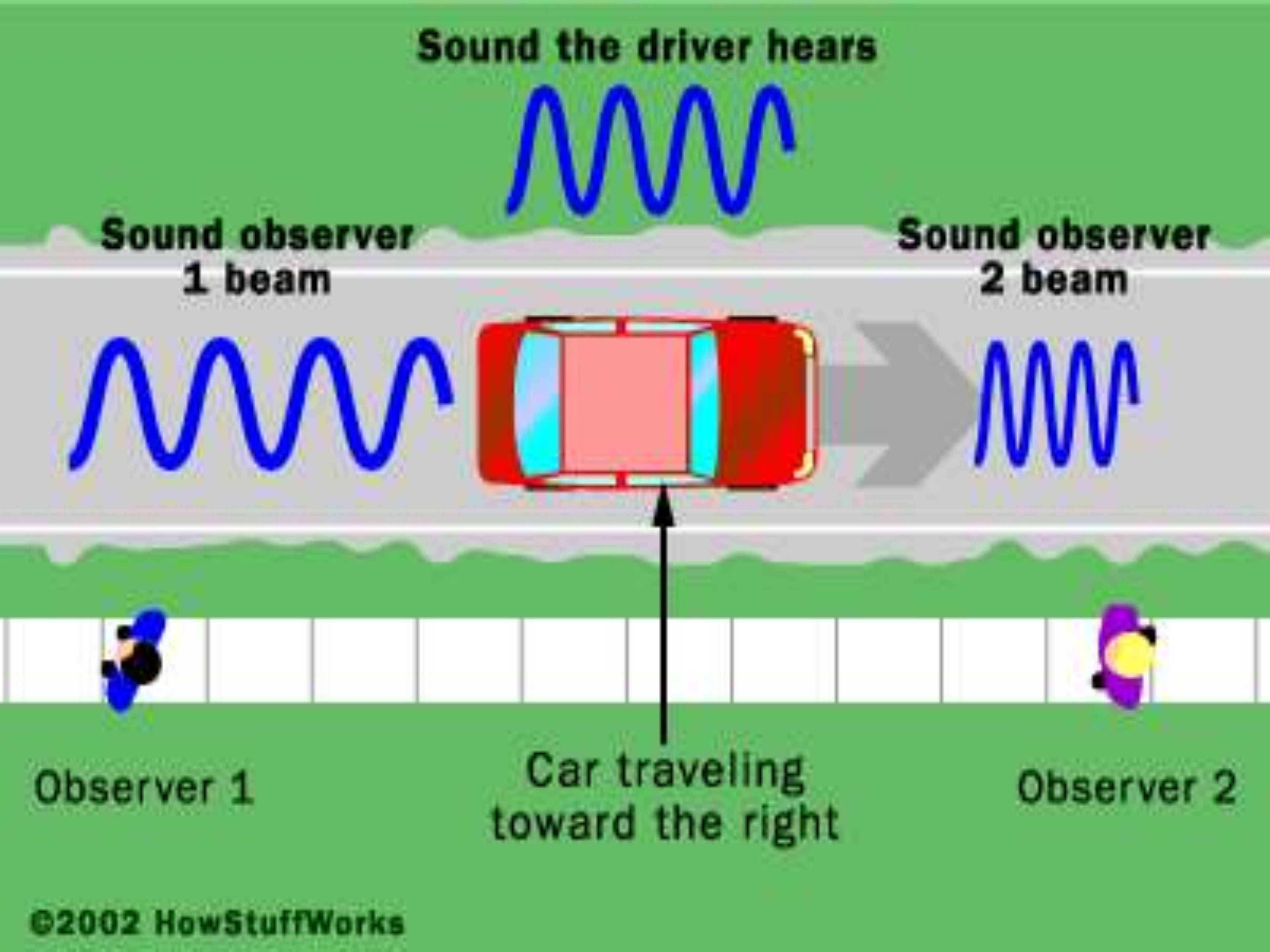
Piezoelectric effect



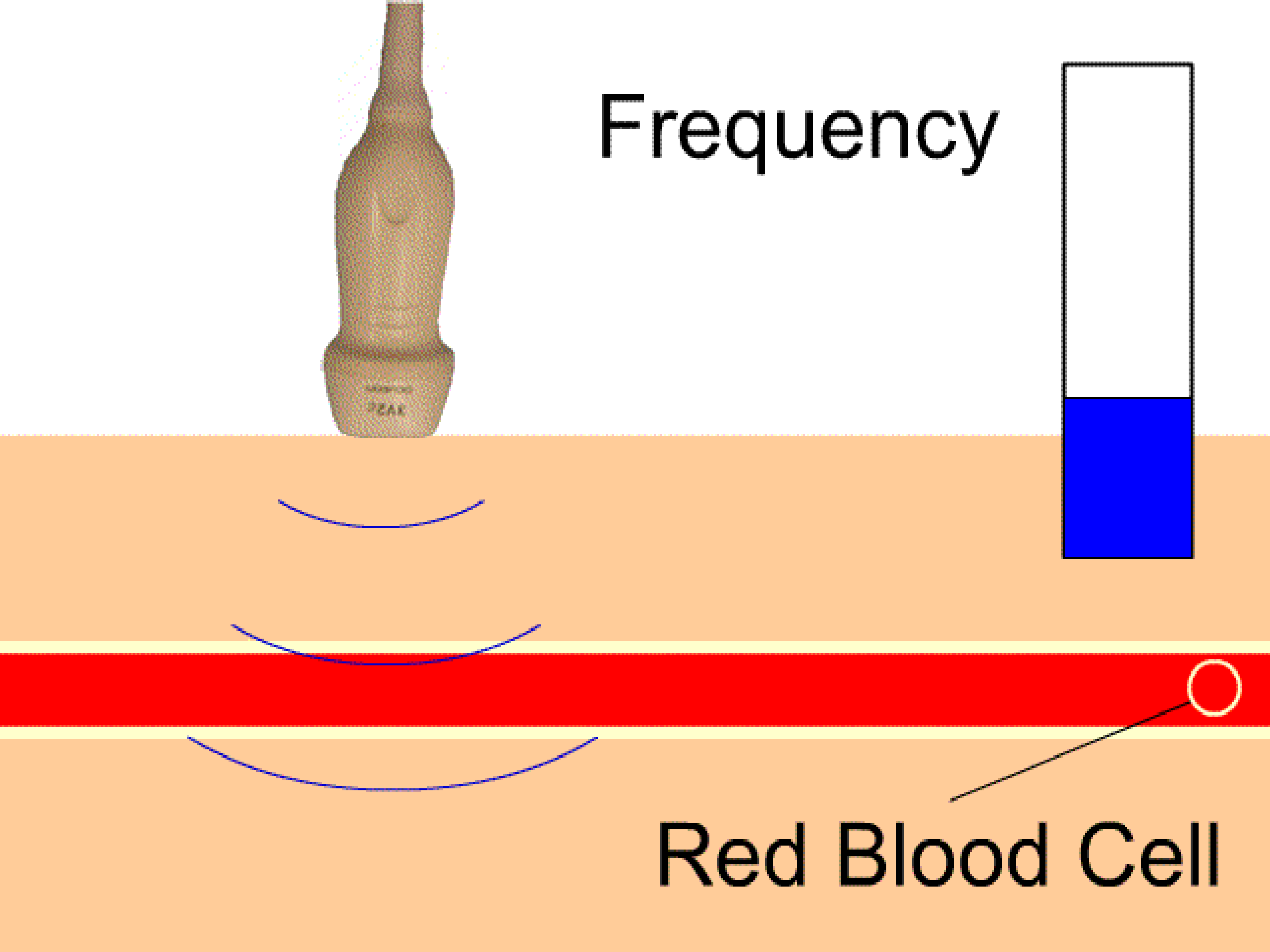
DOPPLER Effect

Reflected sounds from moving objects has different frequencies.


Lower Frequency
Higher Frequency



Sound the driver hears
Sound observer 1 beam
Sound observer 2 beam
Observer 1
Car traveling toward the right
Observer 2
©2002 HowStuffWorks



Frequency
Red Blood Cell

Table 2.1 Speed of sound in different tissues

Medium	Speed of sound (m/s)
Air	330
Water (20° C)	1480
Fat	1450
Blood	1570
Muscle	1580
Bone	3500
Soft tissue (average)	1540

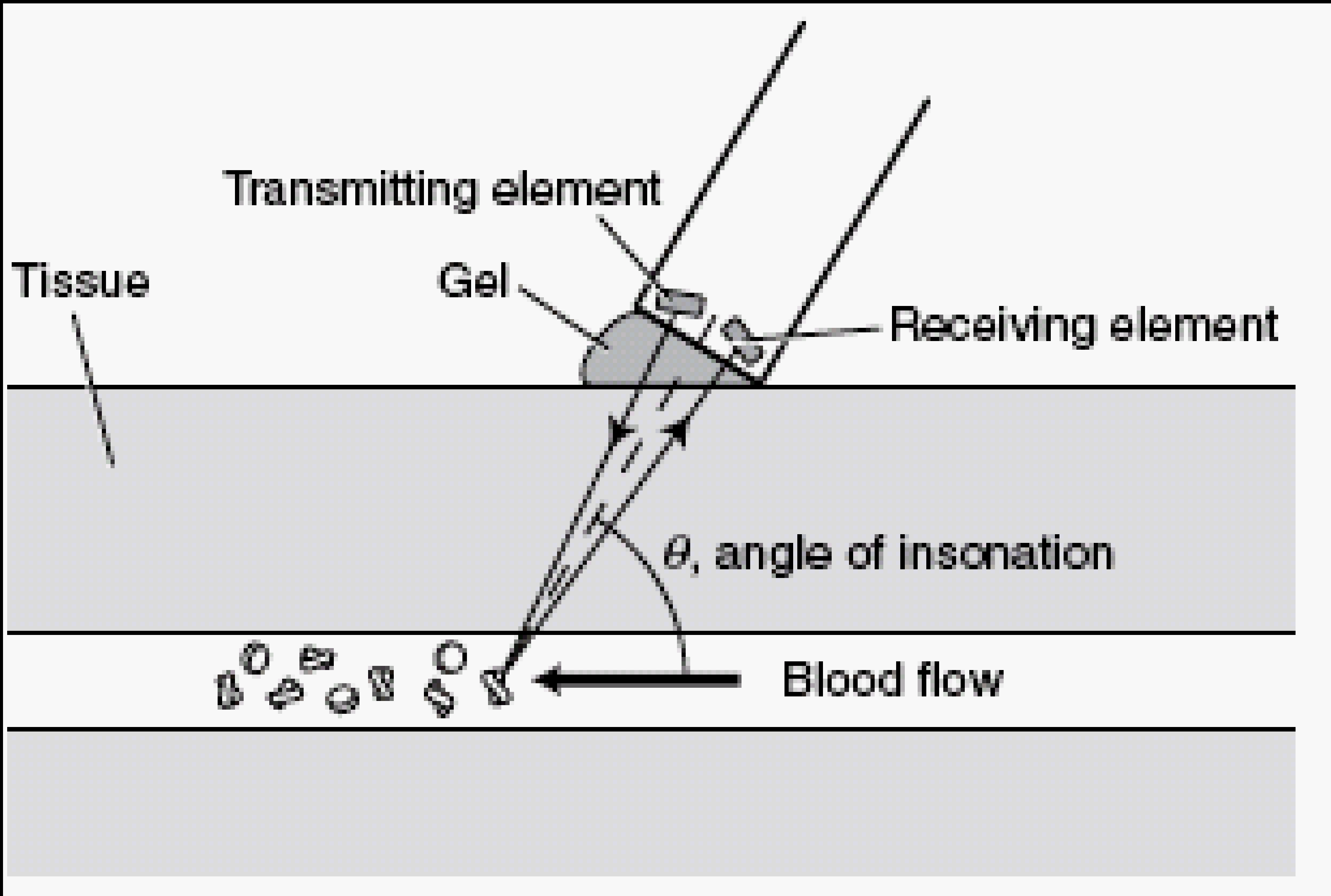
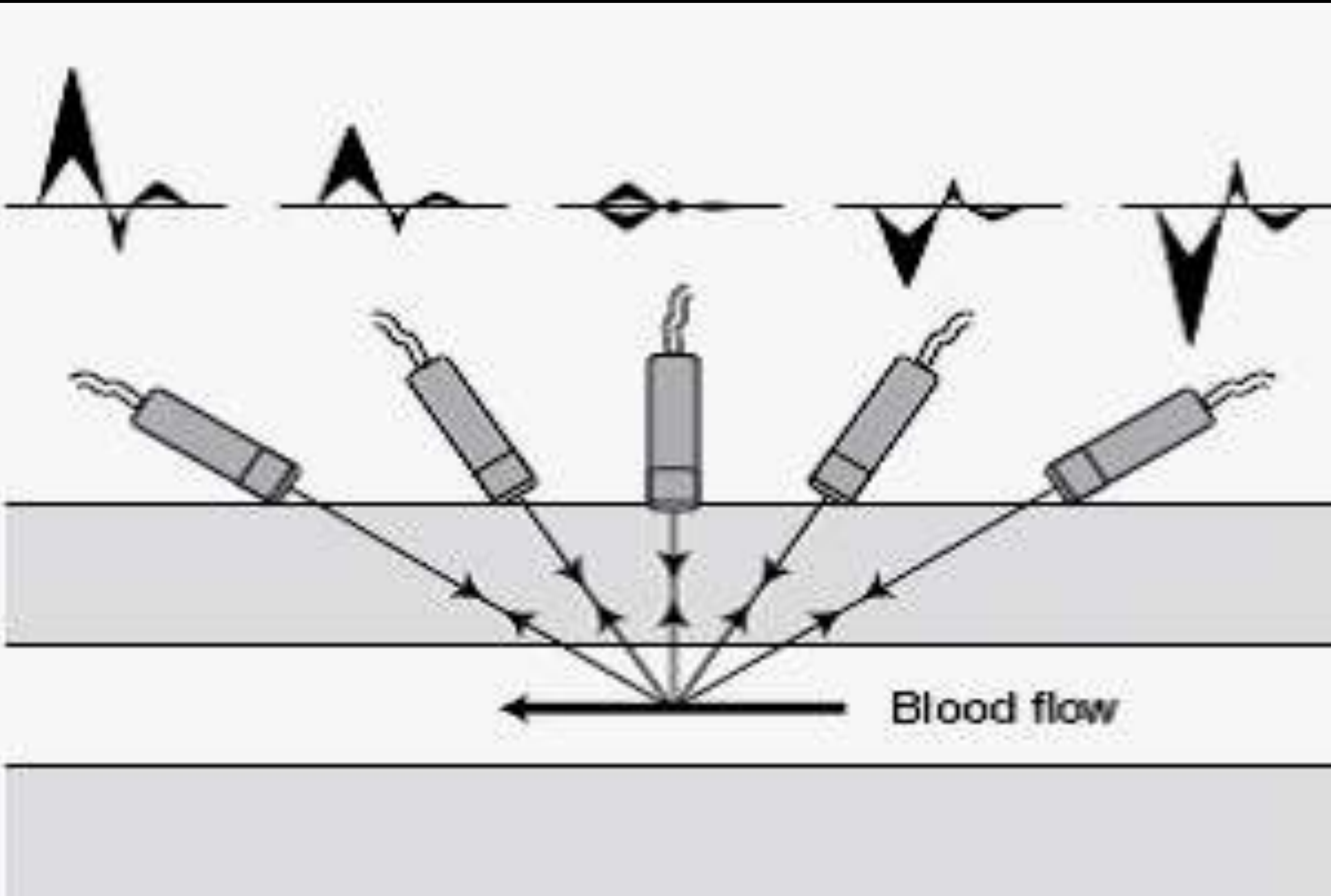
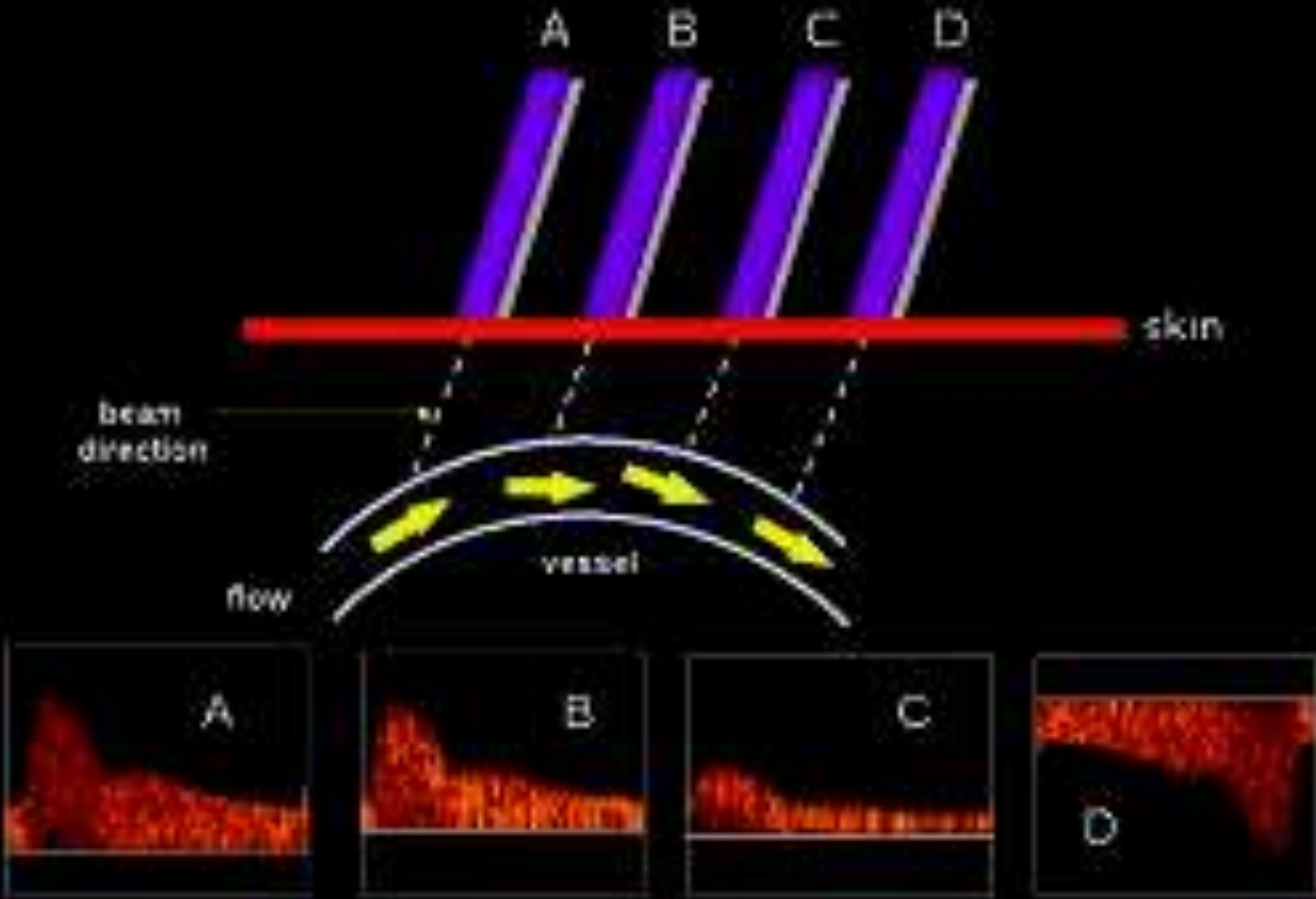

Transmitting element
Tissue
Gel
Receiving element
θ, angle of insonation
Blood flow

Table 3.1 Variation of the cos θ term of the Doppler equation with the angle of insonation

θ (°)	cos θ
0	1
30	0.87
45	0.71
60	0.5
75	0.26
90	0


Blood flow



Sonogram

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

- ***v*** = velocity of the blood,
- ***0*** *=* is the angle between the US beam and the direction of blood flow

(also known as the angle of insonation).

- **f** = Frequency
- * ***t*** = transmitted ,**r** = received ,
- ***c*** = speed of sound in tissue.

$$F_d = \frac{2F_t V \cos\theta}{C}$$

٢ X التردد X جتا الزاوية X سرعة الدم

ســـــرعــــــة الصــــــــوت

- Variables
- Fixed

- ***for example,***

- a ***5 MHz*** transducer used
- blood vessel with a flow velocity

of ***50 cm/s***

- an angle of insonation of ***60°.***

- speed of sound in tissue to be ***1540 m/s***,

the Doppler equation can be used to

estimate that the Doppler shift frequency produced will be

1.6 kHz.

$$\frac{2 \text{ X } 50 \text{ X } 5000 \text{ X } 0.5}{١٥٤٠}$$

=

1.6 KHz

Instrument Setting

- Examination sequences : by ***B-Mode*** , → ***color Flow*** image ,→ ***Doppler*** spectrum.

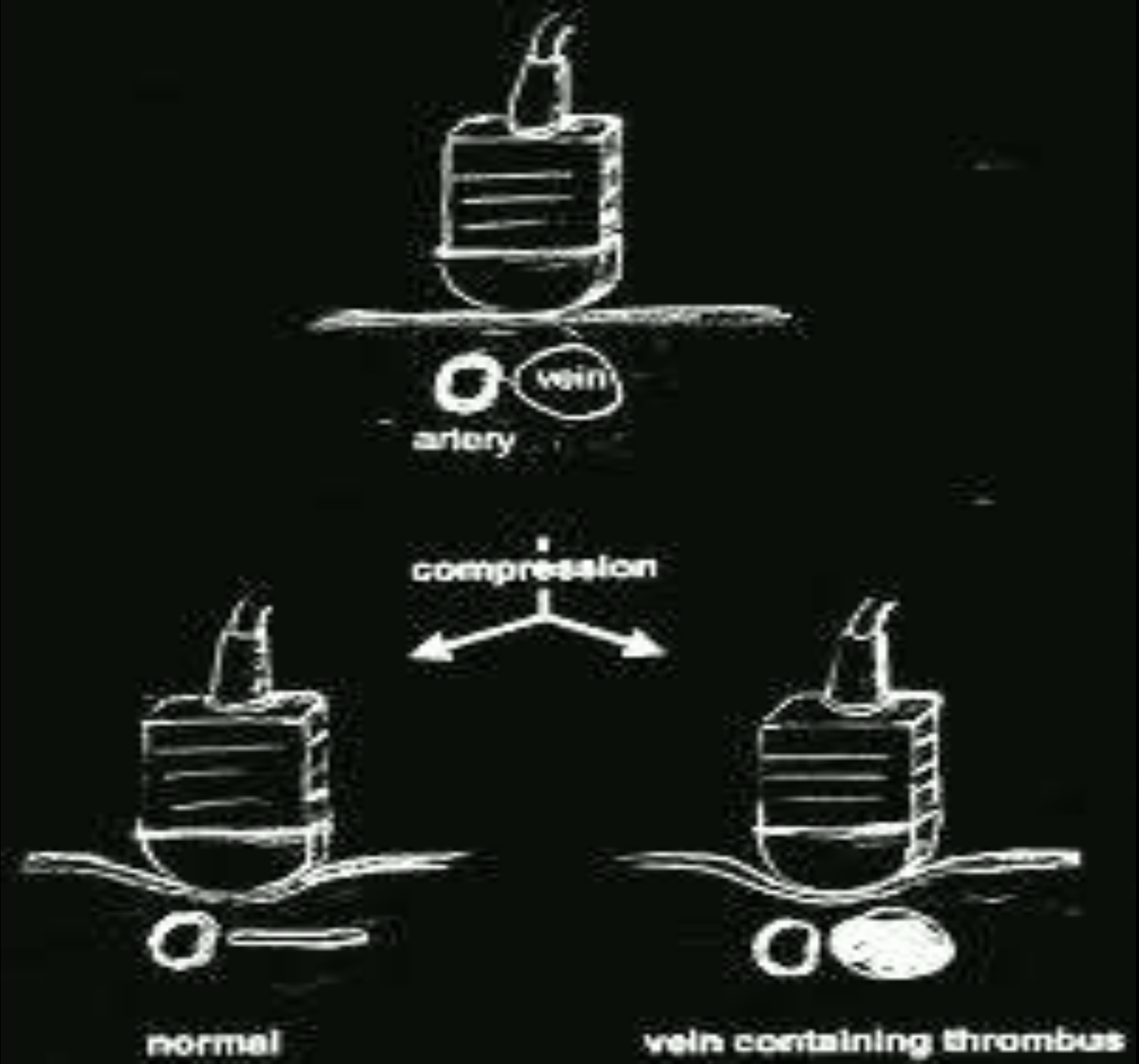
1. ***B – Mode:***
   1. ***Decrease gain*** → no echoes in lumen.
   2. Use ***single focal zone*** on the target vessel.

Sonography of Vessels

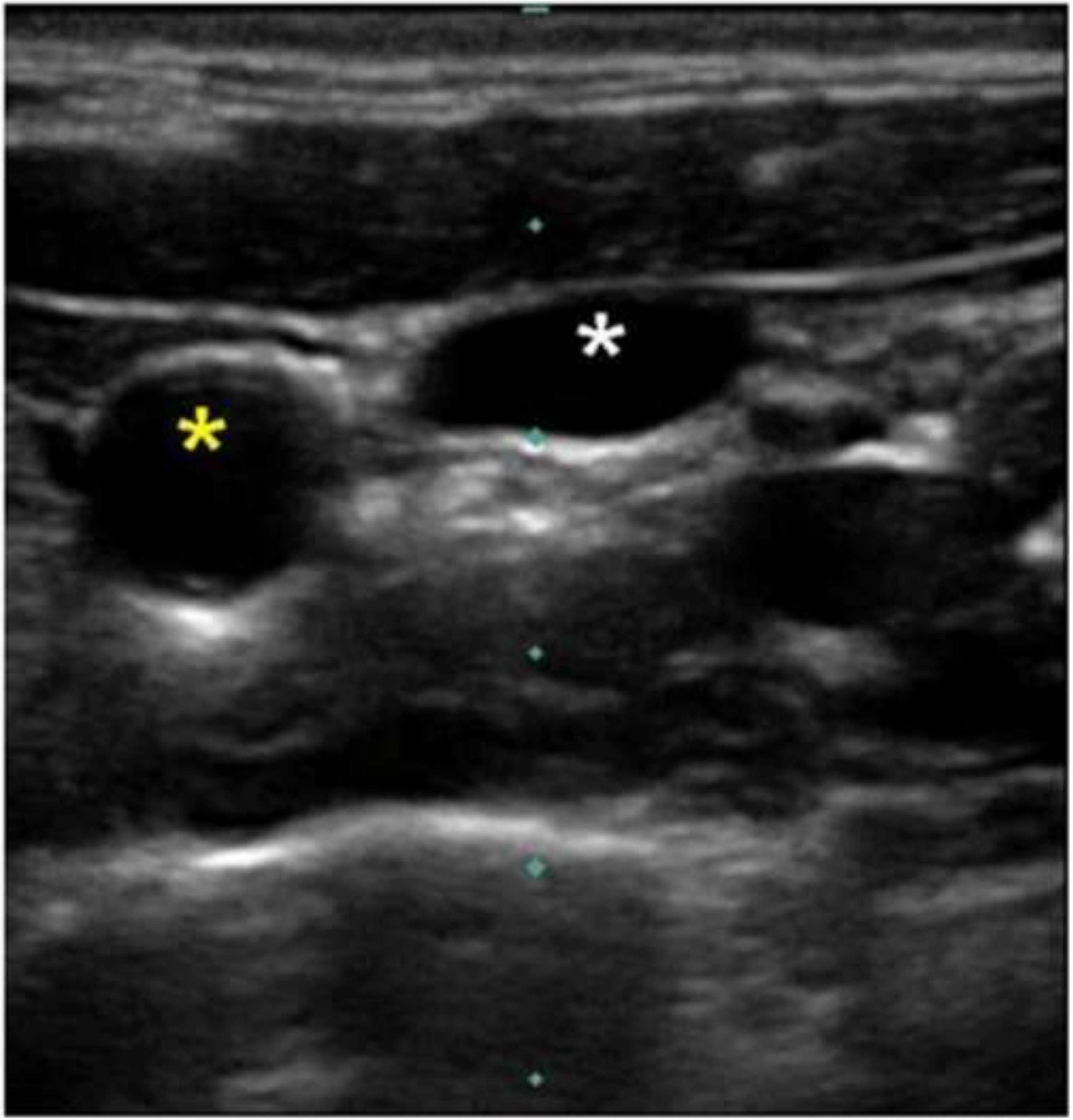
→ ***By B - Mode*** :

- Vein → Compressible.
- Artery → Anechoic structure e thick echogenic wall.

- Media is anechoic in between.



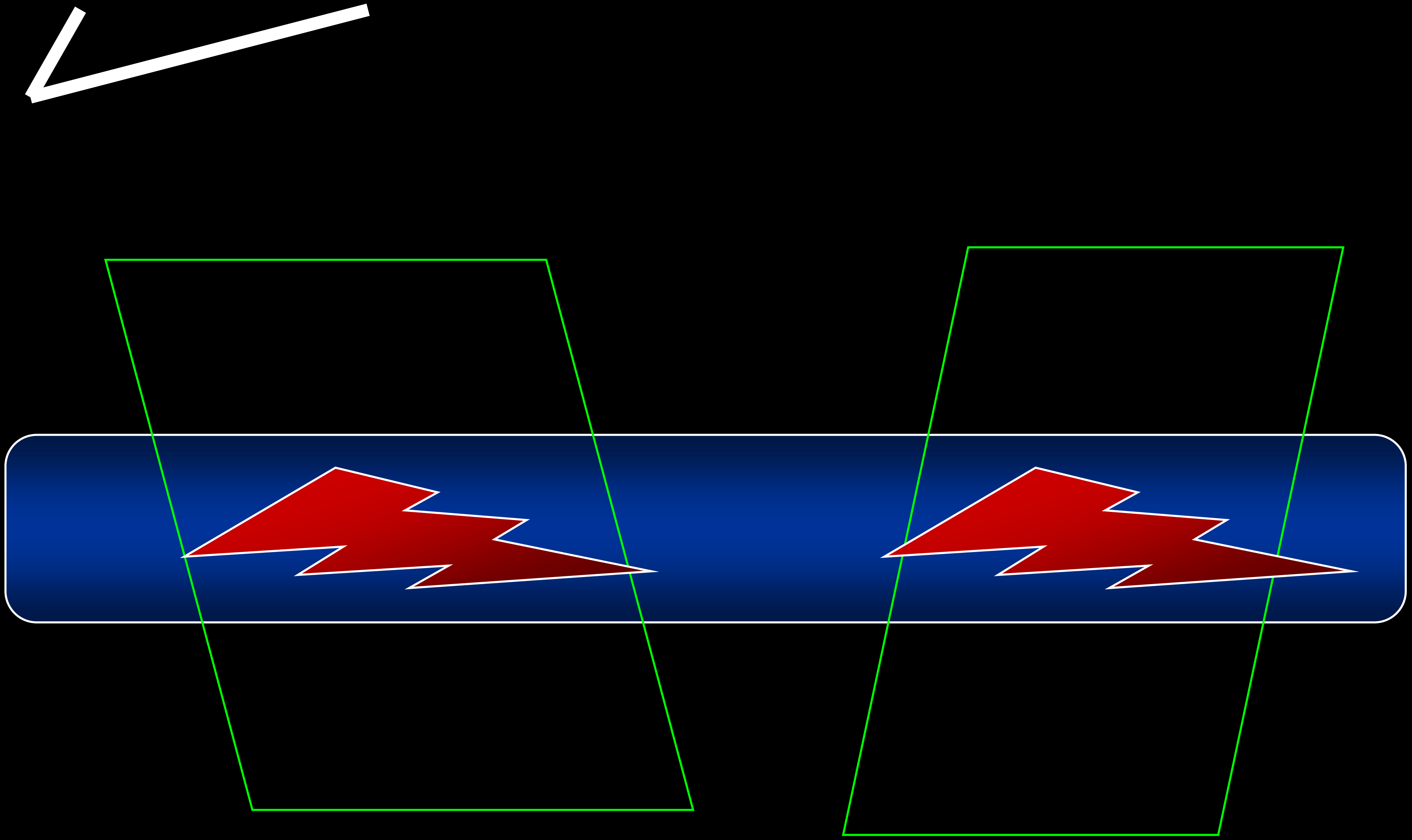
vein
artery
compression
normal
vein containing thrombus



2. ***Optimizing Color Flow:***

1. *Vessel* *Must Not be parallel* *to probe ← steering of color box.*
2. *First set color gain high until → color bleed*
3. *Then decrease it Gradually until fit walls.*

X



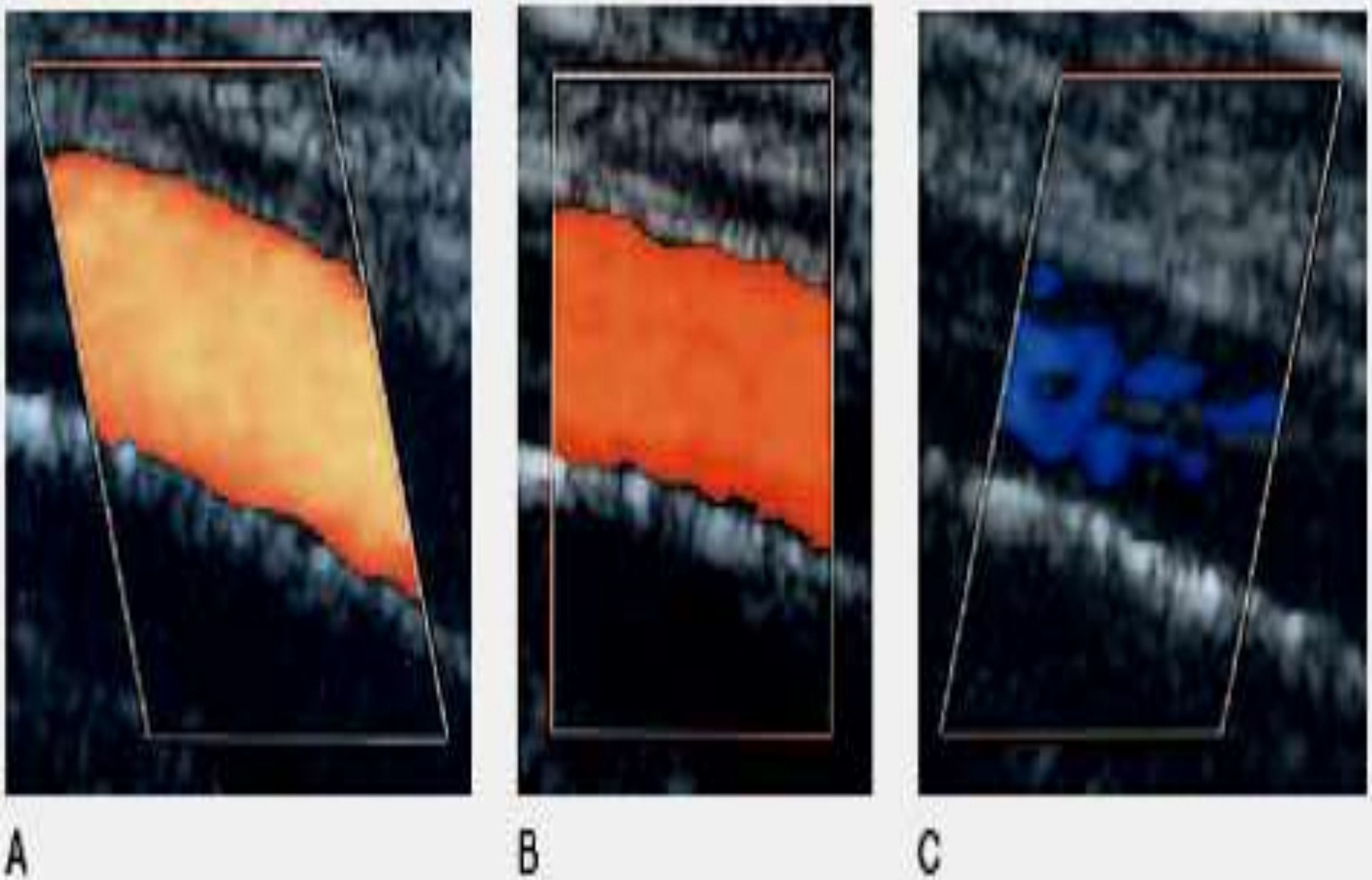


Figure 4.6 Effect of changing the angle of insonation (shown on the image), by steering the color box, on the image produced. A: A small angle gives a good image. B: A moderate angle displays flow but is not optimal. C: A large angle gives an unusable image.

➔Color Flow

- Complete color Filling e no filling defects.
- Color & Direction:
- ***To Transducer***

"red-Slow" &

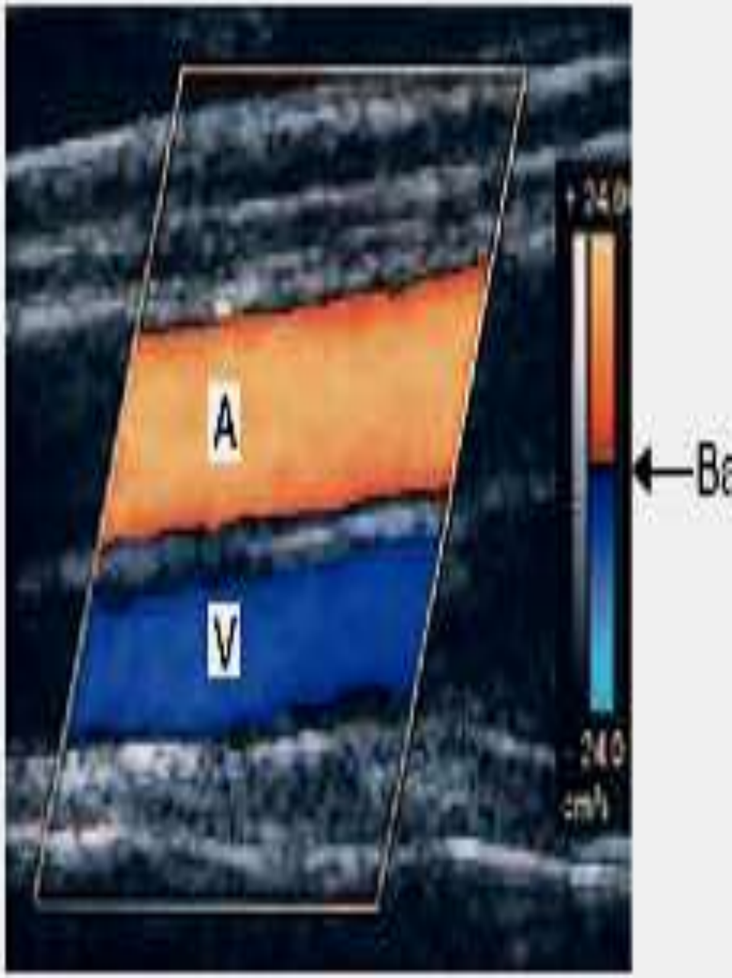
"Yellow Faster"

- ***Away*** :

"Dark Blow-Slow" &

"Light Blow Faster"

➔ (LIGHTER is FASTER)



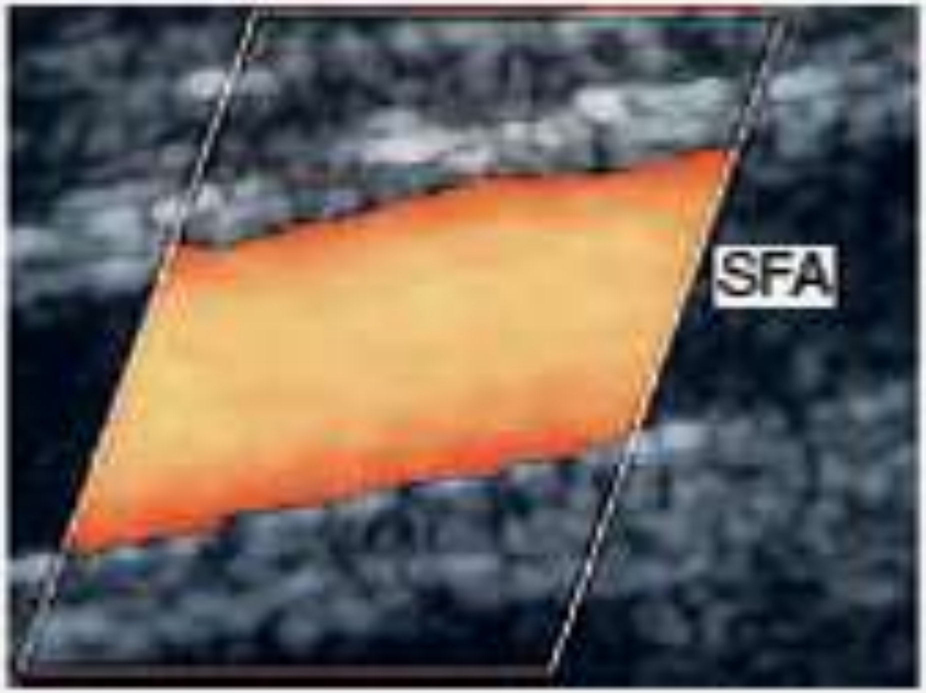


Figure 5.6 Color flow image showing high velocities (shown as yellow) in the center of a normal superficial femoral artery, with lower velocities (shown as red) nearer the vessel wall.

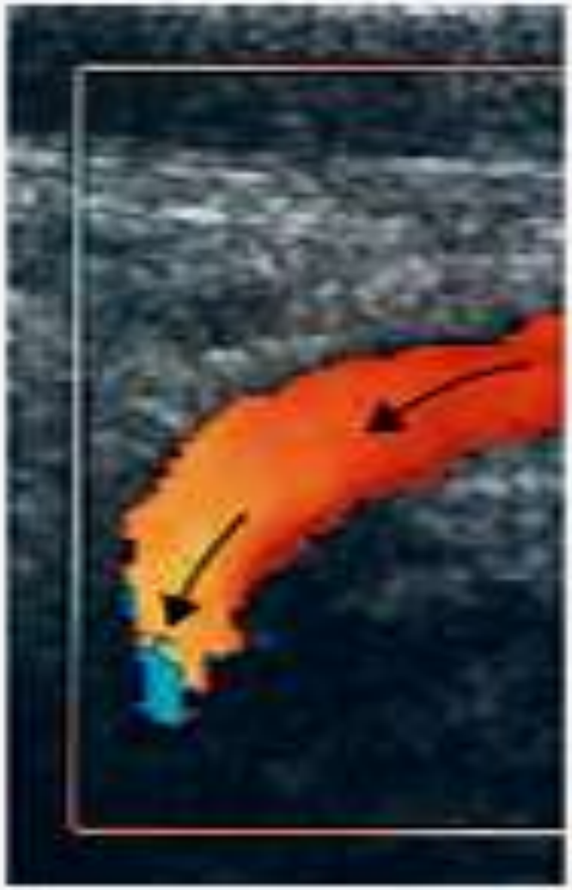


Figure 4.7 An internal carotid artery as it dips deep in the neck. As the path of the artery changes relative to the Doppler beam (shown by the arrow), the relative velocity (Doppler frequency) detected will alter, leading to a change in the color displayed, despite the fact that the velocity of the blood flow has not changed.

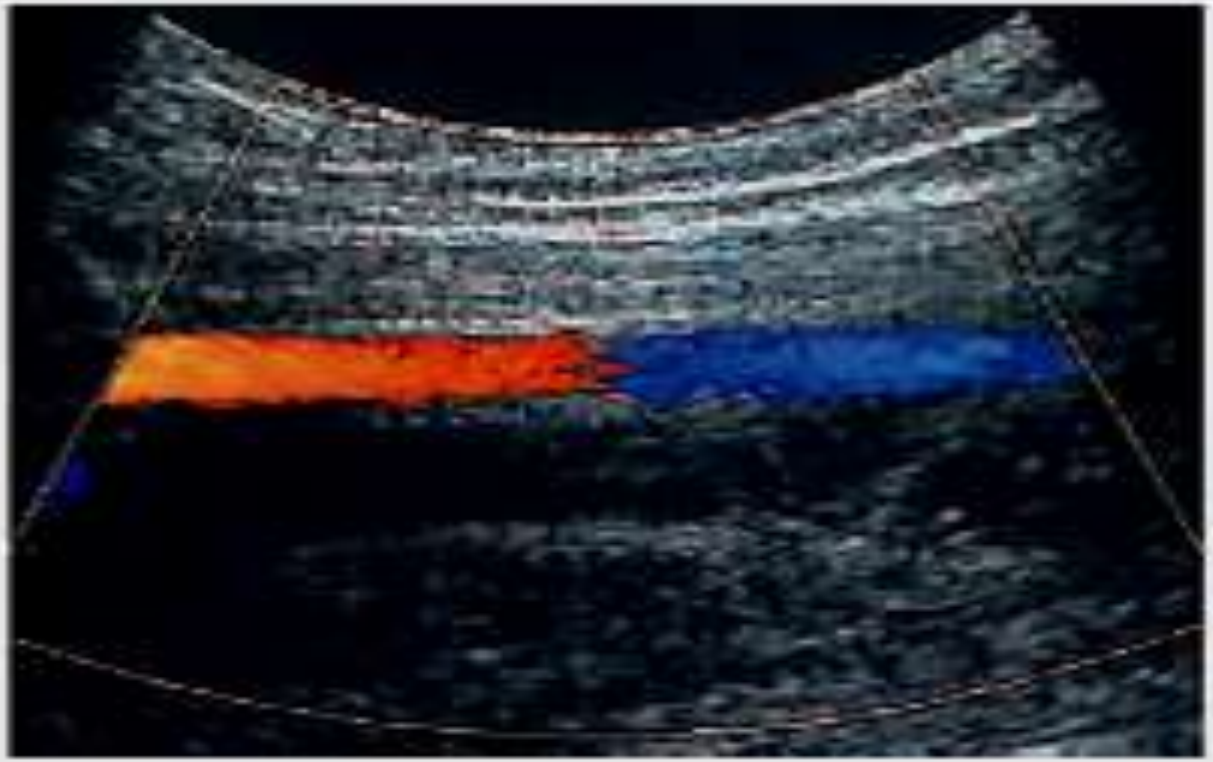


Figure 4.8 As the scan lines of a curvilinear transducer diverge, the angle between the straight vessel and the beam will change. This will lead to a change in the detected velocity relative to the ultrasound beam (Doppler frequency), altering the color displayed. No flow is displayed in the center of the image, where the flow is at right angles to the beam.

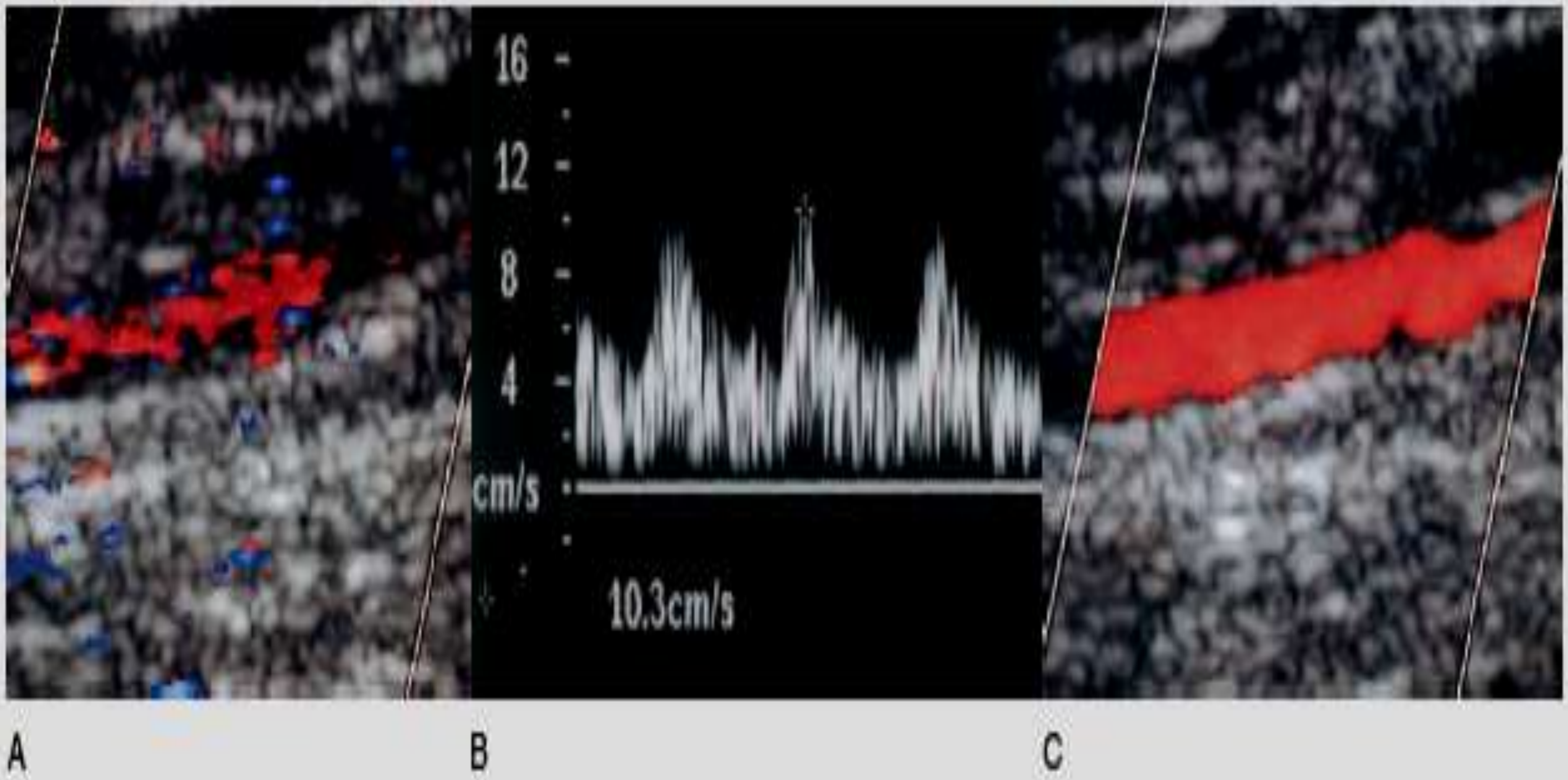
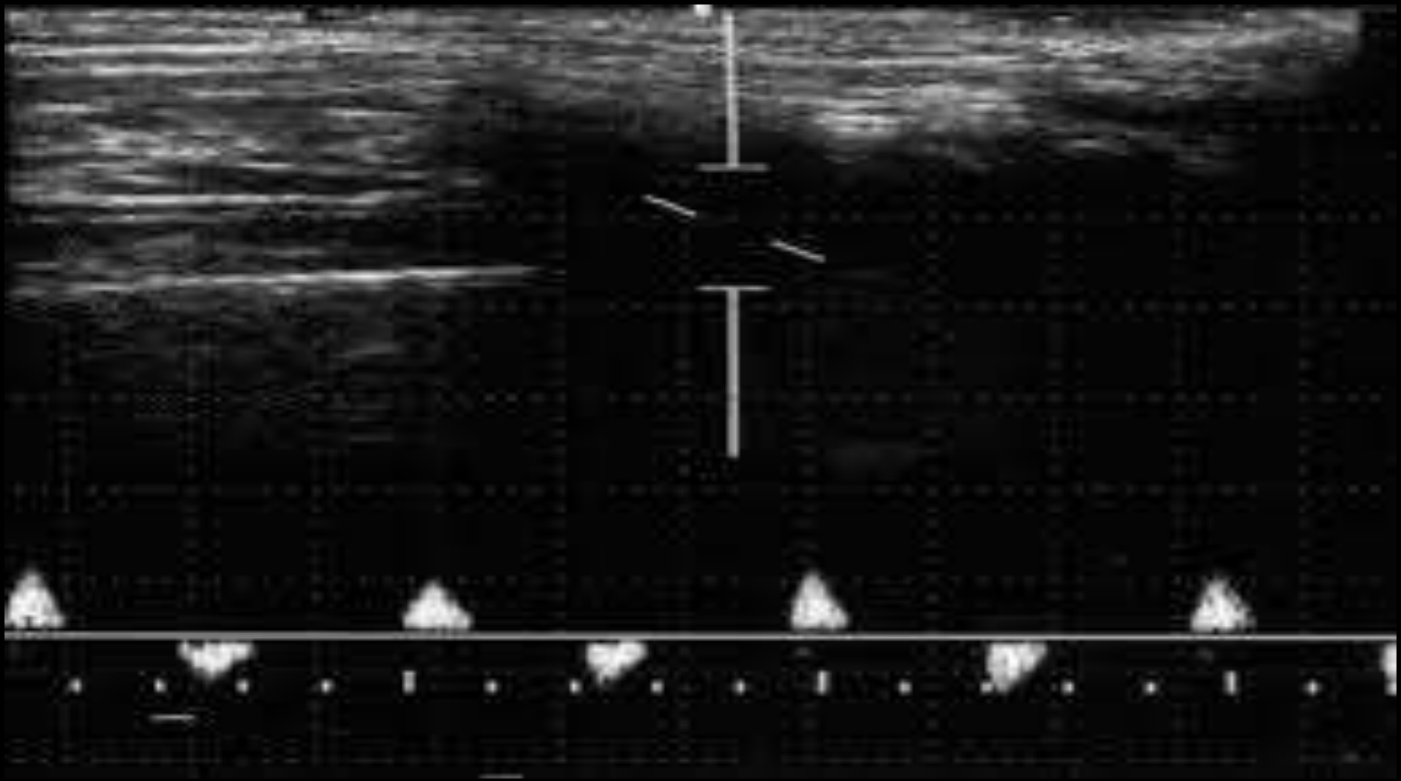


Figure 7.4 A: Poor color filling is seen in the posterior tibial artery distal to a long arterial occlusion because the PRF is set too high at 2500 Hz, and the color controls have not been optimized. B: The Doppler waveform confirms low-velocity damped flow with a peak systolic velocity of 10 cm/s. C: In order to improve the color flow display, the PRF has been lowered to 1000 Hz, the color write priority increased and the color sensitivity control increased. Note that only 79% color gain is needed in image C, compared to 85% in image A.

3. Optimizing Doppler spectrum:

1. Sample volume (=) must not > 2/3 of Artery diameter. *"If widened → involve slower flow near walls"*
2. *PRF setting according to velocity.*

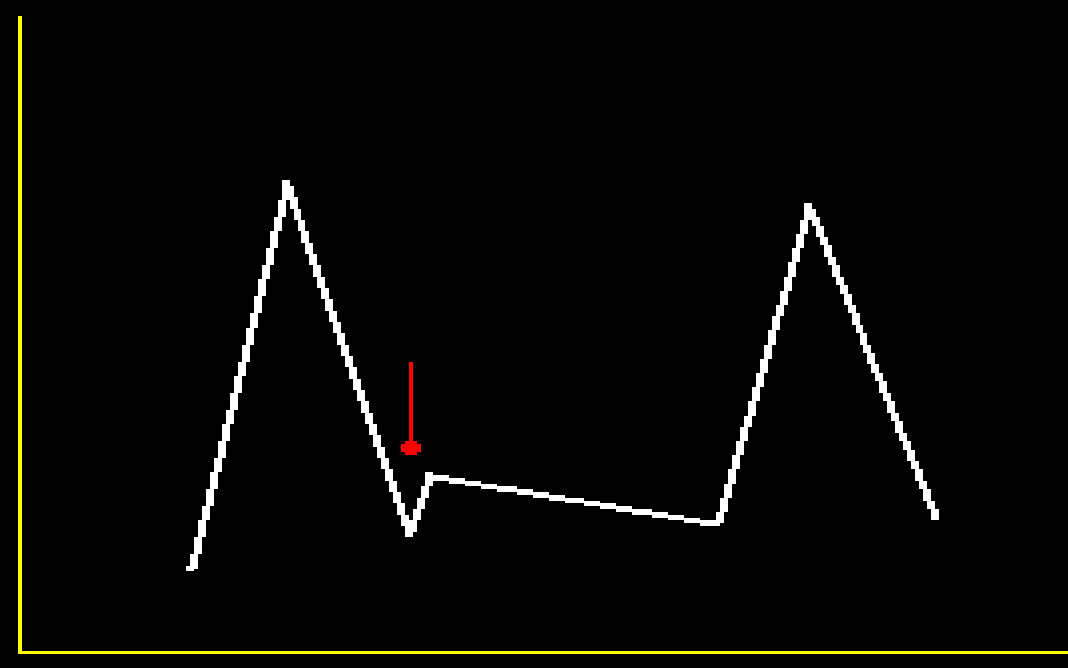


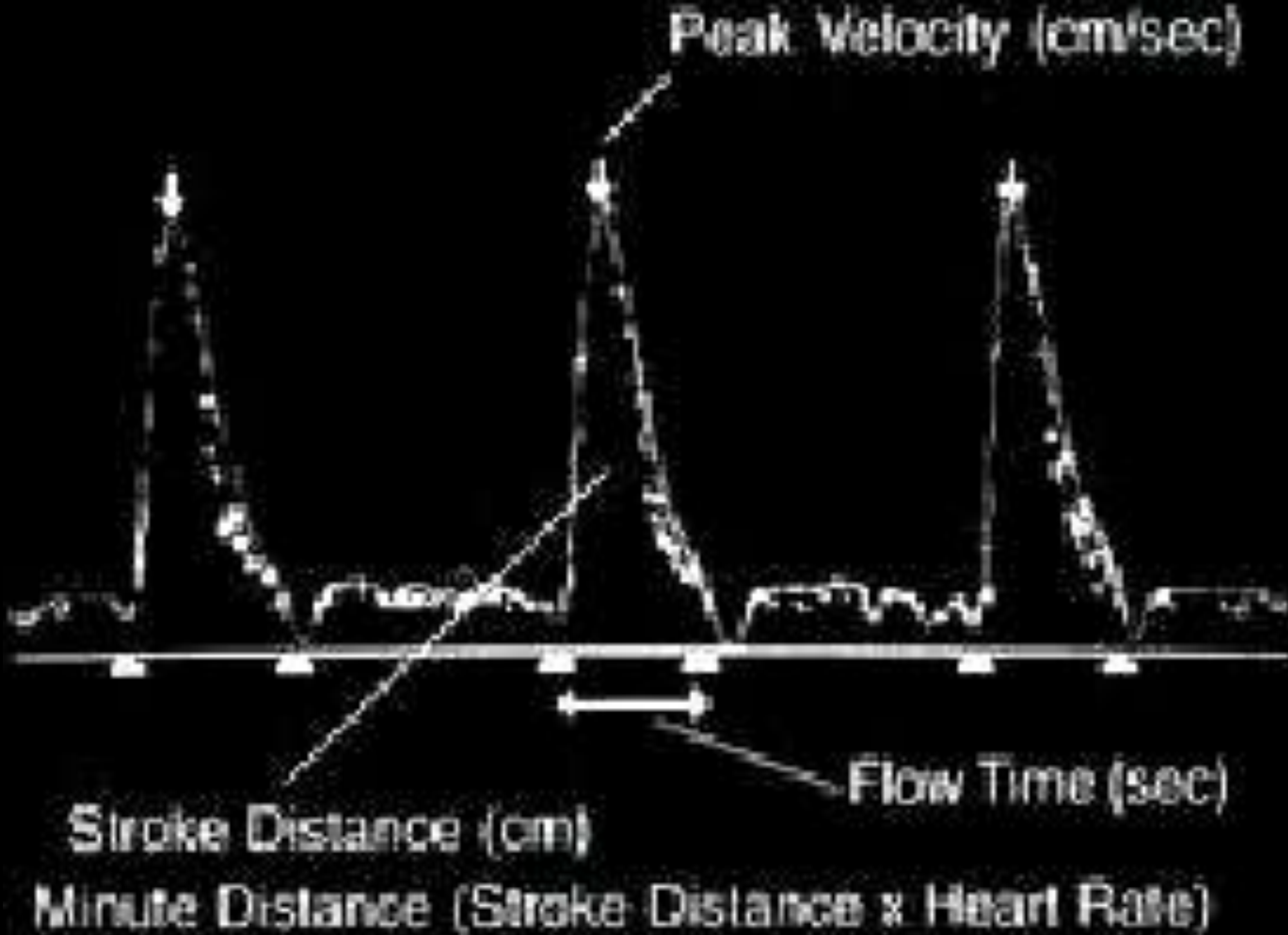
Doppler Spectra

- ***<u>Central Arteries :</u>***

Low resistance ، ***<u>Biphasic Flow</u>***

- Aortic Closure ، May → Notch at end of Systole.

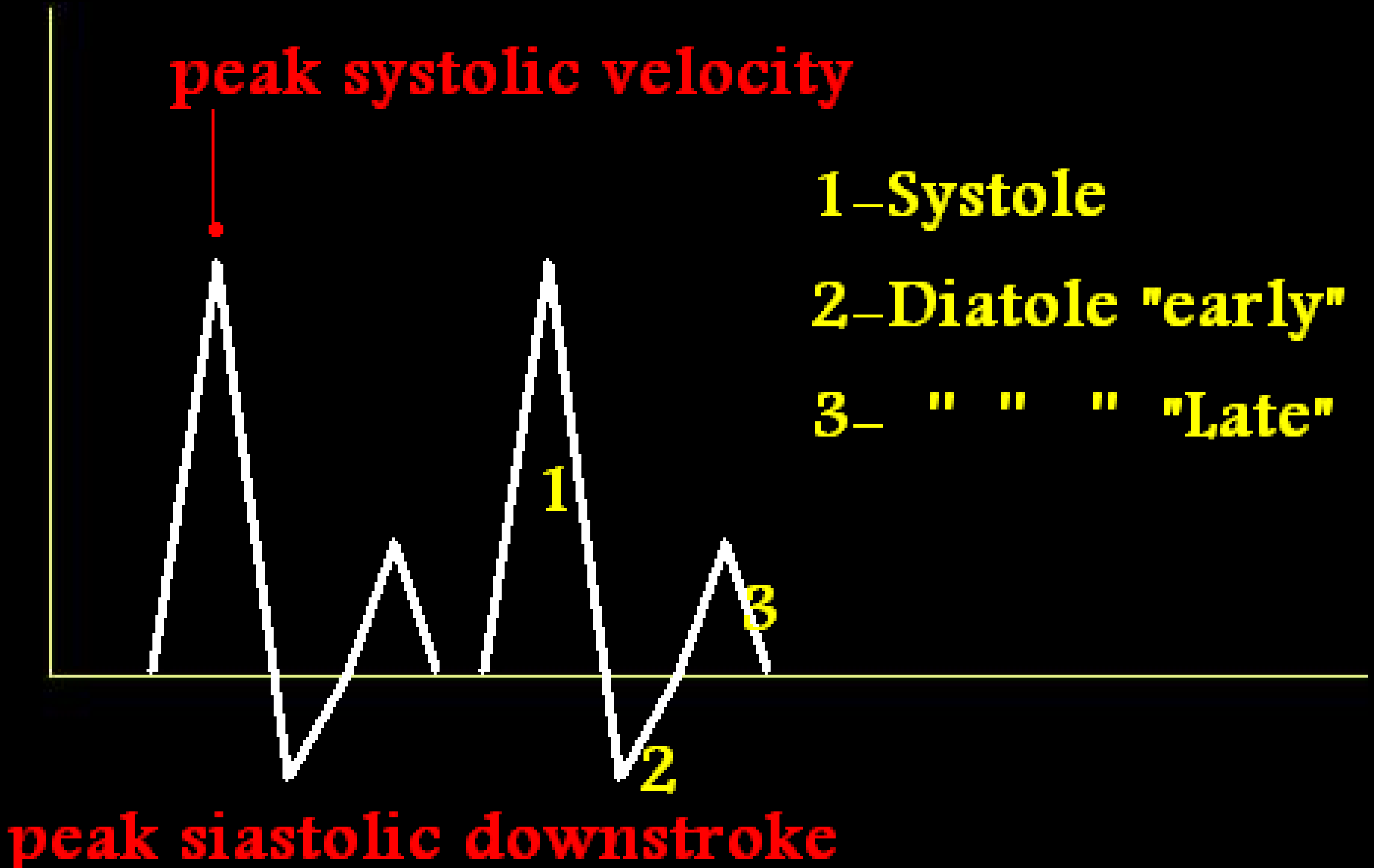




Peak Velocity (cm/sec)
Flow Time (sec)
Stroke Distance (cm)
Minute Distance (Stroke Distance x Heart Rate)

- Peripheral Arteries:

High resistance ‹ ***Triphasic Flow***

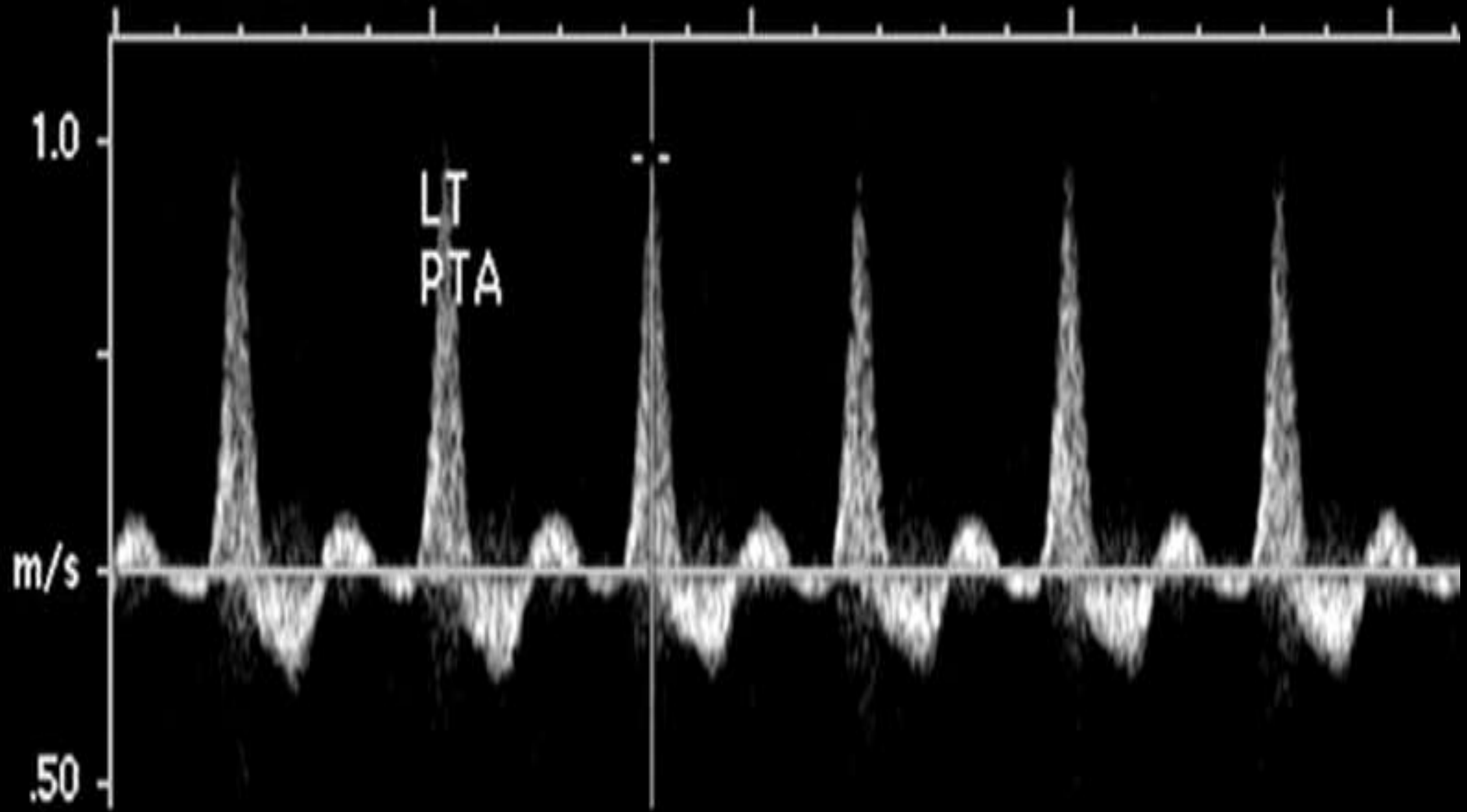


- ***Triphasic :***

-Systole: Hi Forward

-Distole *Early*: Brief Reverse

- "   *Late* : Low Forward



1.0
LT
PTA
m/s
.50

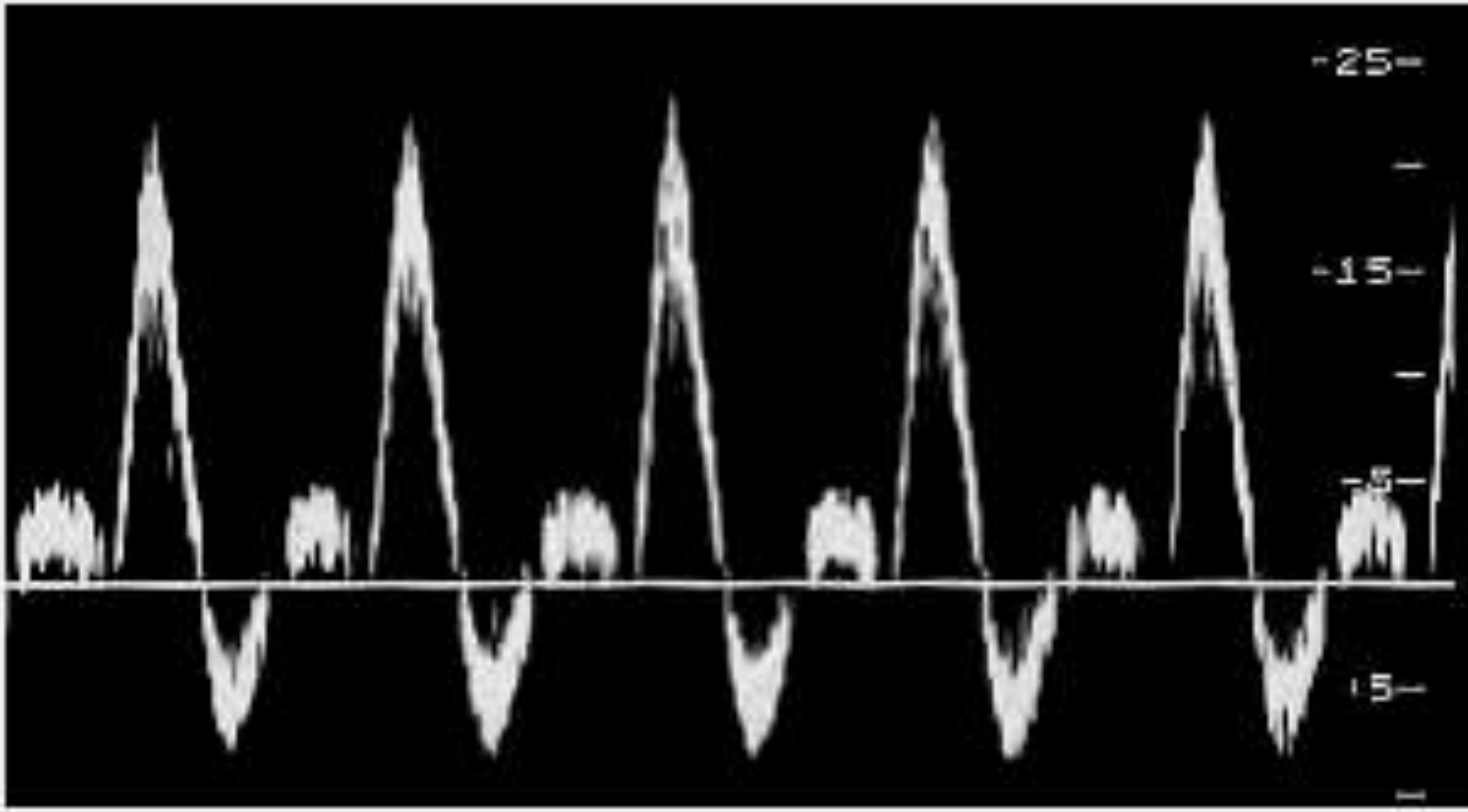
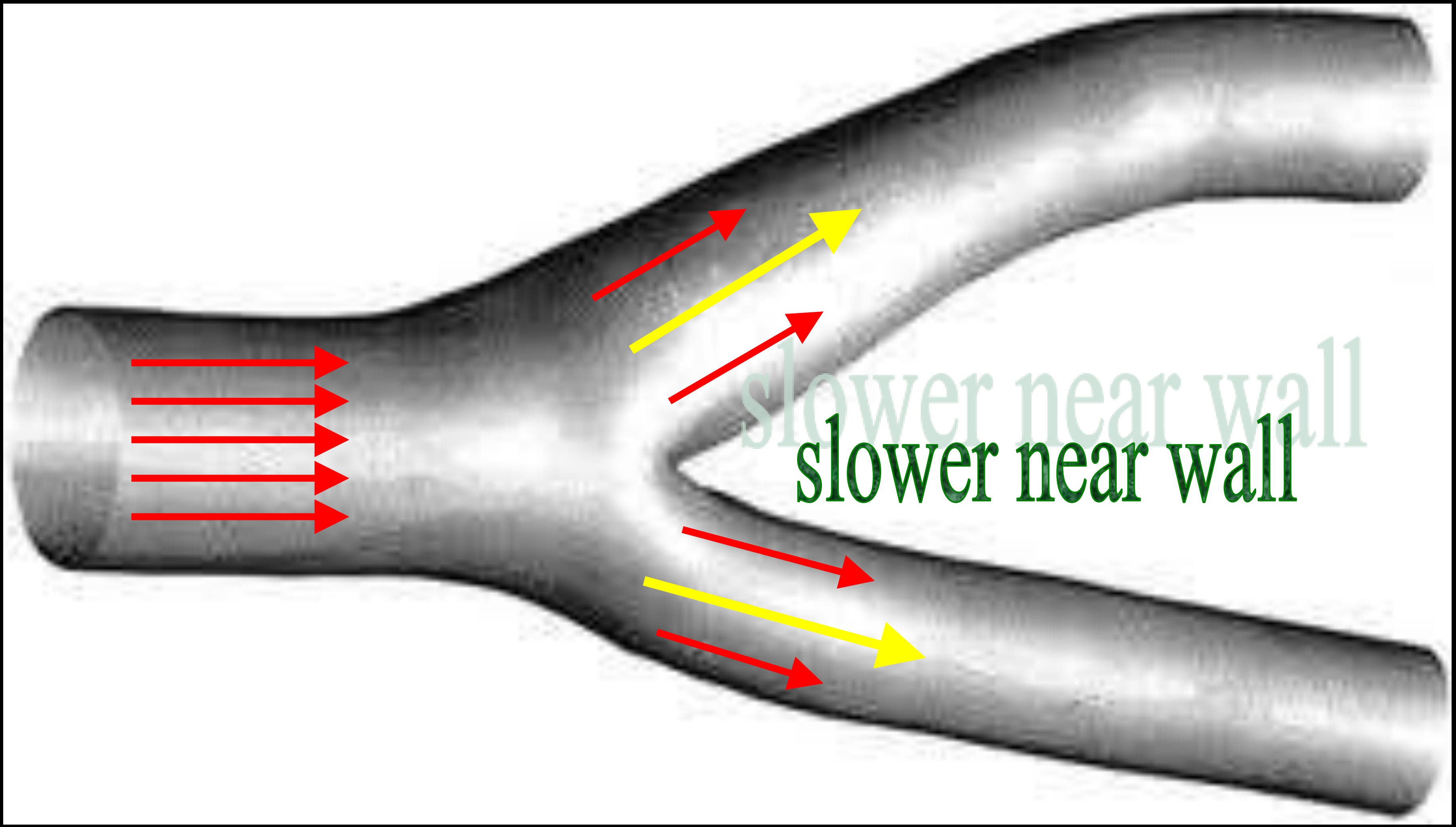


Figure 9.18 A normal triphasic Doppler waveform recorded from the SFA.

Low or High Resistance:

Flow change At A. Bifurcation

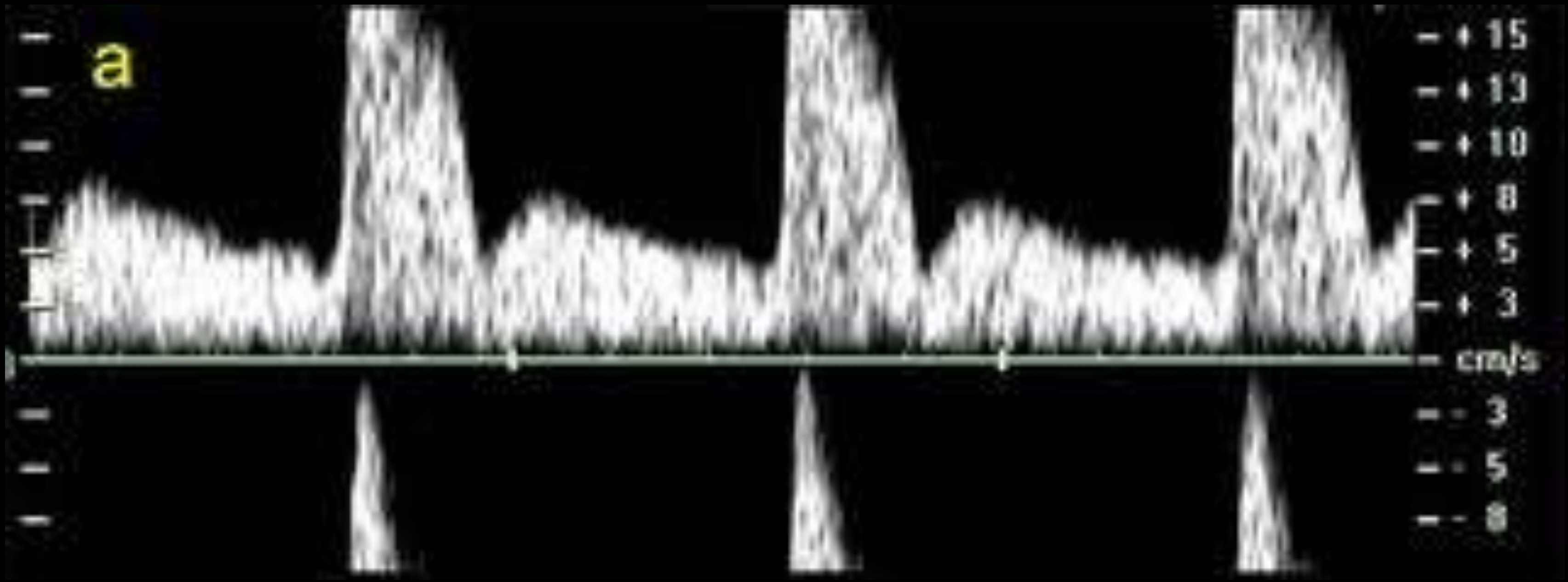


Doppler Artifacts

- **1-Aliasing**
- **2.Blooming:"Color Bleed"**
- **3.Cirectional Ambiguity**
- **4.Psudoflow**
- **5.Partial volume**
- **6.Flash artifact**
- **7.Mirror image Artifacts**
- **8.Edge Artifact**
- **9.Twinkling Artifact**

1-Aliasing

- -Disturbance of color homogeneity
- -occur when velocity exceed scale



ALIASING

- Compensating Aliasing by :
  - Increase PRF *"Pulse Repeated Frequency"*
    - *If use max PRF , then*
  - Decrease Depth
  - Shift base line
  - Lower Frequency
  - Increase Angle *"with in limits"*

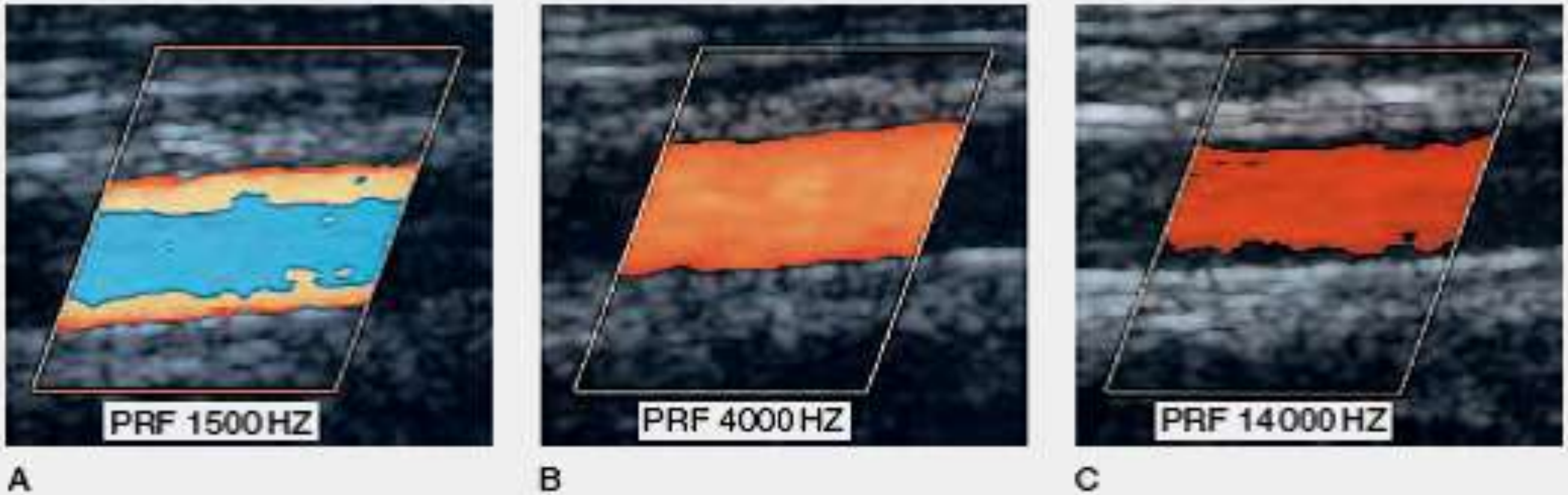
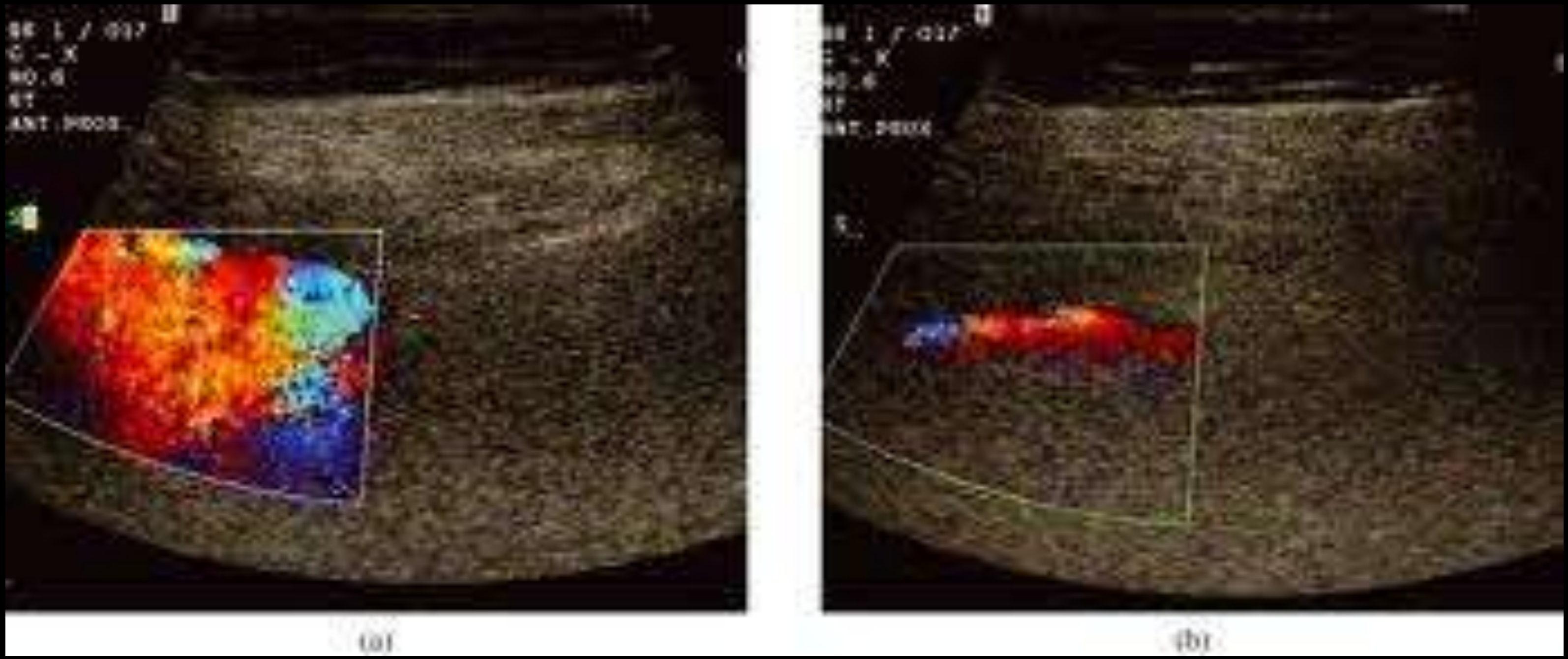
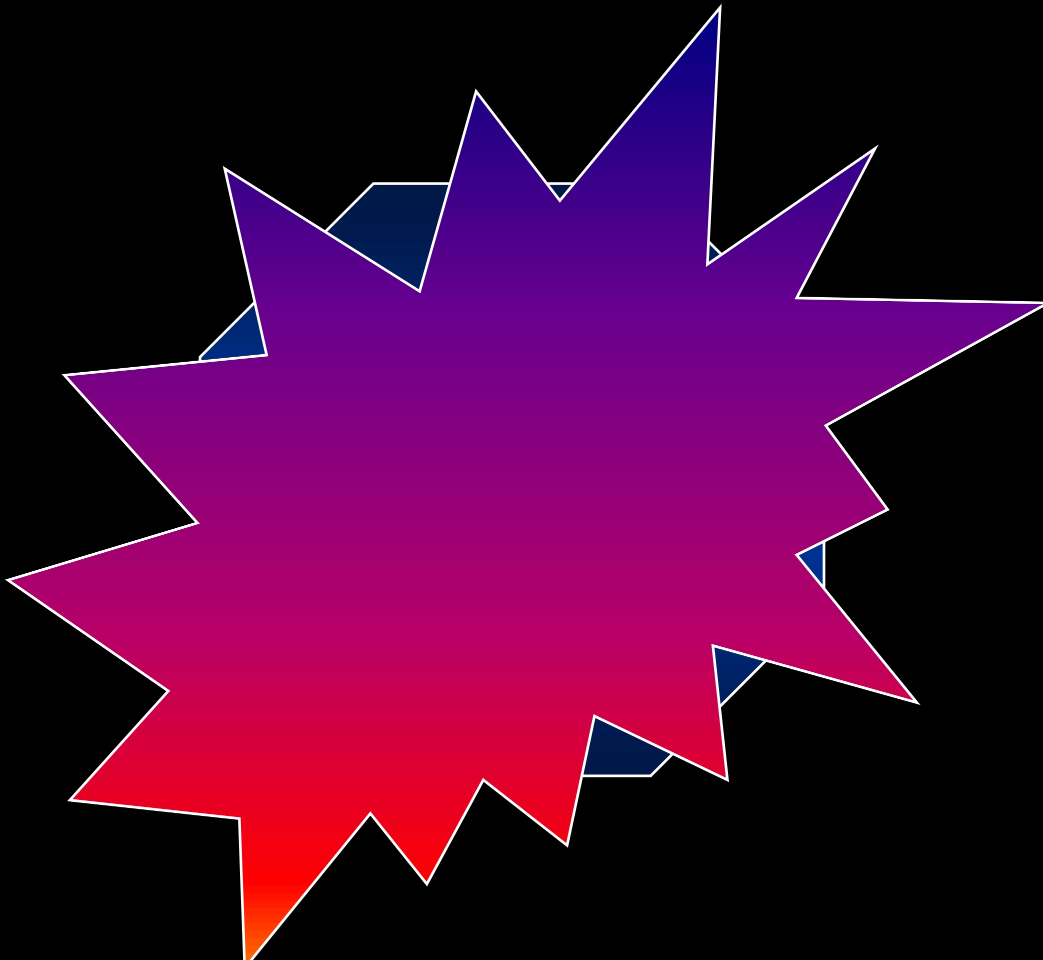


Figure 4.9 Aliasing. A: This will lead to the assignment of the incorrect color to represent the velocity present within the vessel, shown here in blue. B: Increasing the PRF may overcome aliasing. C: If the PRF is set too high, it may prevent low velocities, present at the vessel walls, from being detected.

۲- Blooming:"Color Bleed"

- -Color spread out vessels
- -it may over write partial thrombus





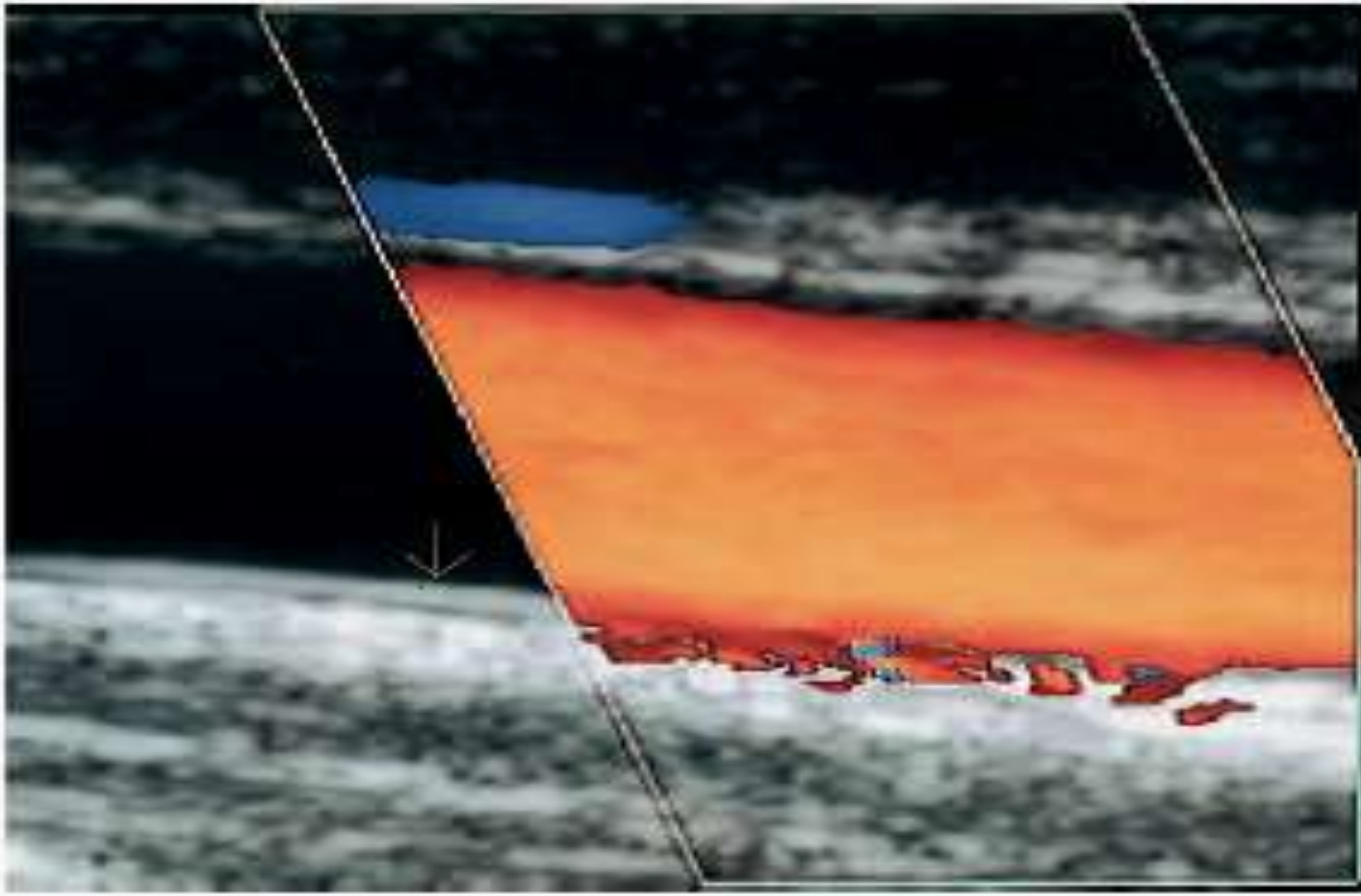


Figure 7.6 The color flow image may give the impression of flow 'bleeding out' of the vessel if the color gain is set too high (arrow shows position of posterior artery wall).

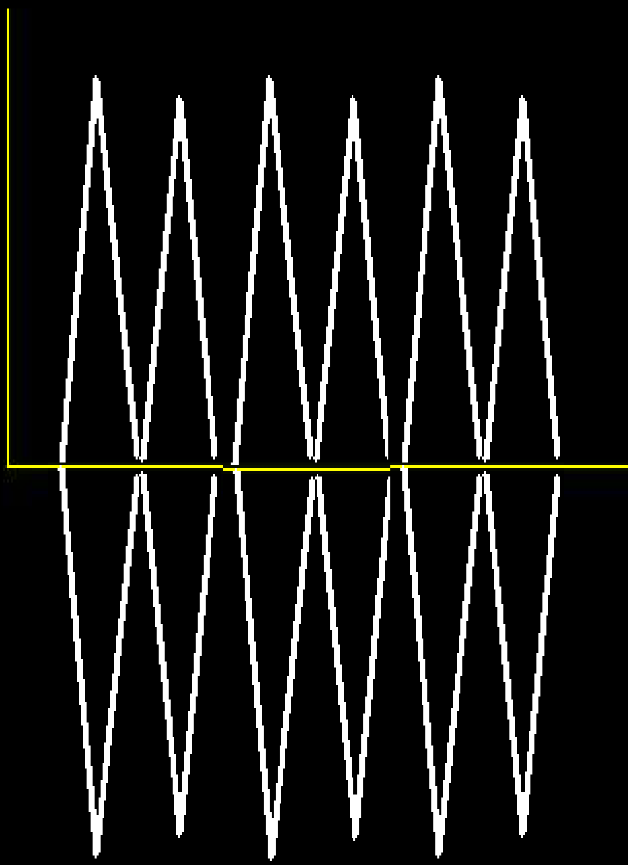
- ٣***- Directional Ambiguity:***
- -Indeterminate flow direction.
- -Wave form above & below baseline

“ as mirror"

-occur e small angle

- -***D.D***.: *Bidirectional Flow* , which ***not***

identical around baseline *"i.e. not mirror"*



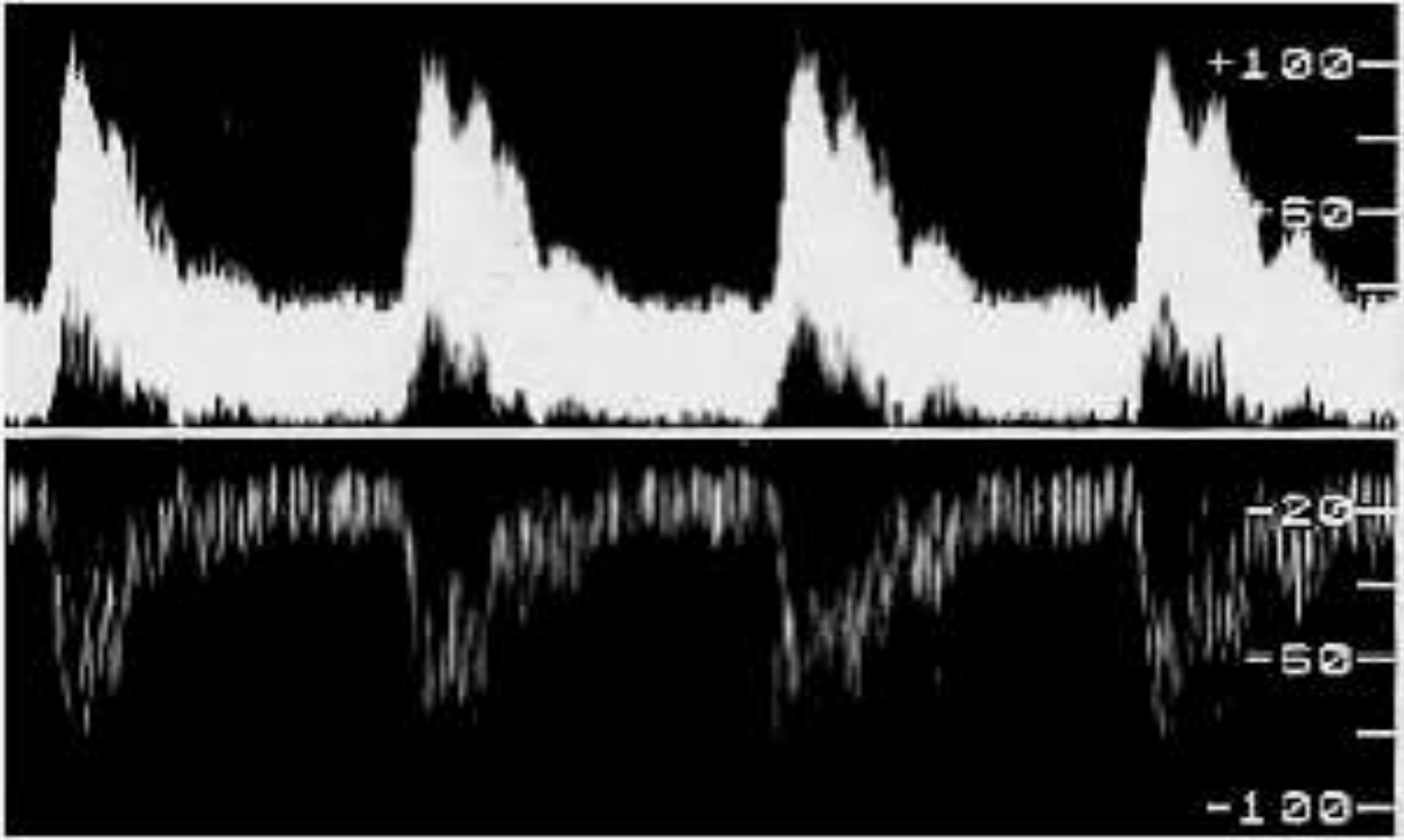
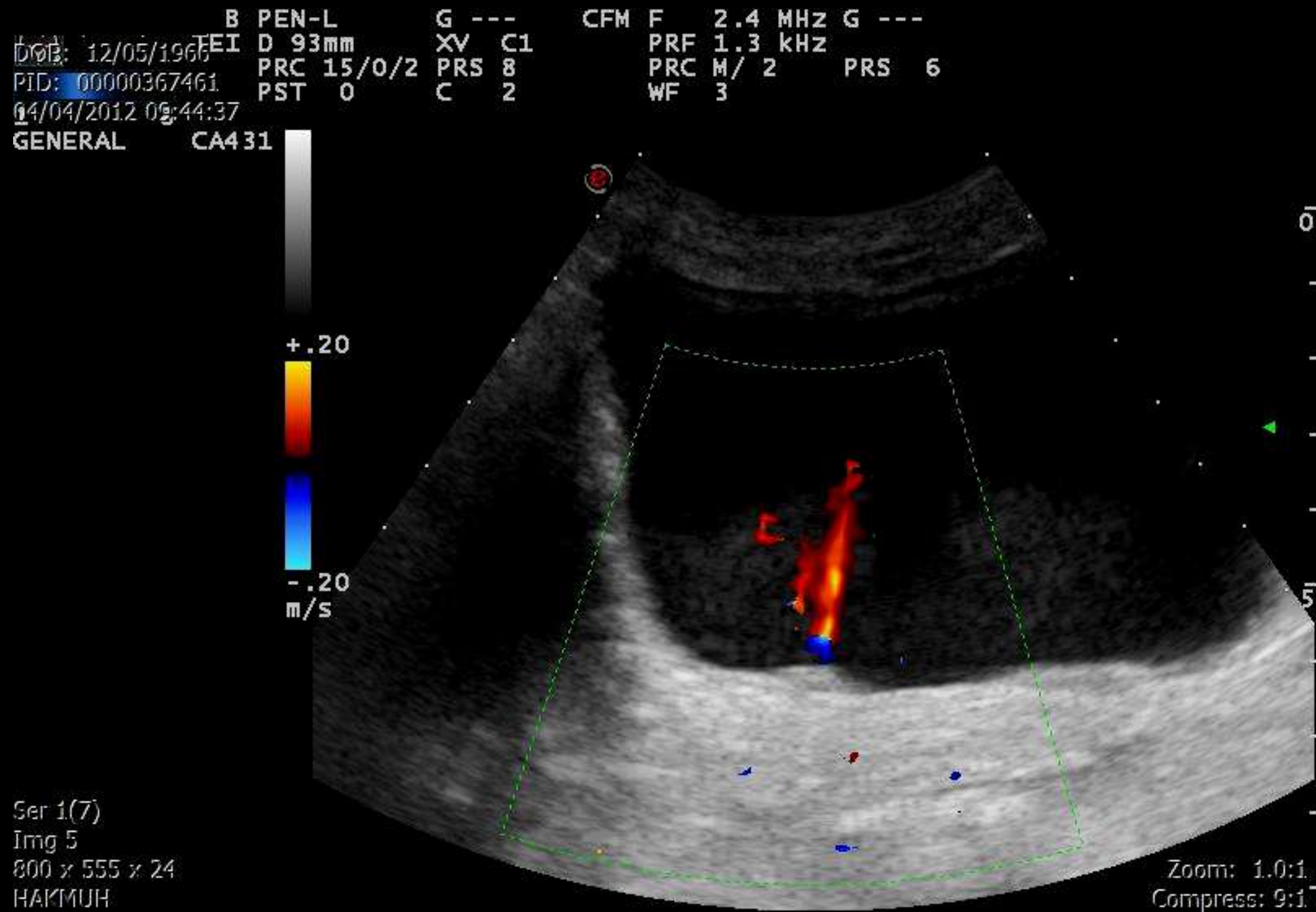


Figure 6.3 Doppler spectrum demonstrating the appearance of a mirror image below the baseline when the scanner's Doppler gain control is set too high.

4.Psudoflow

- Any moving fluid eg. Urine jet



5.Partial volume

- Thick slice partially cutting 2 objects.

6.Flash artifact

- Sudden burst of random colors.
- it obscure gray scale image.
- Due to *object* or *transducer* motion.

7.Mirror image Artifacts

- Seeing a false mirror image of the object.

- adjacent to reflecting surface

  eg. Pleura

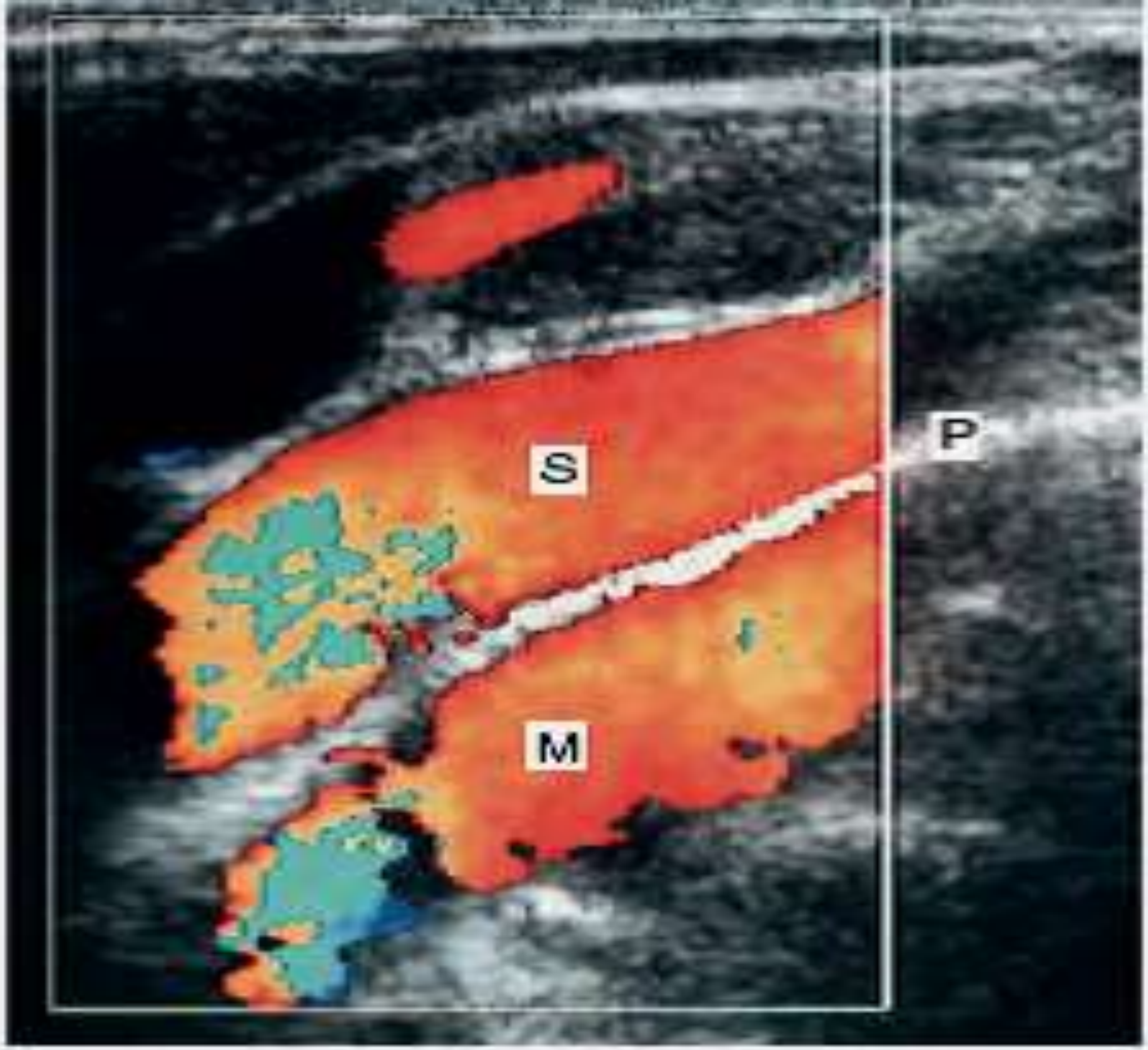


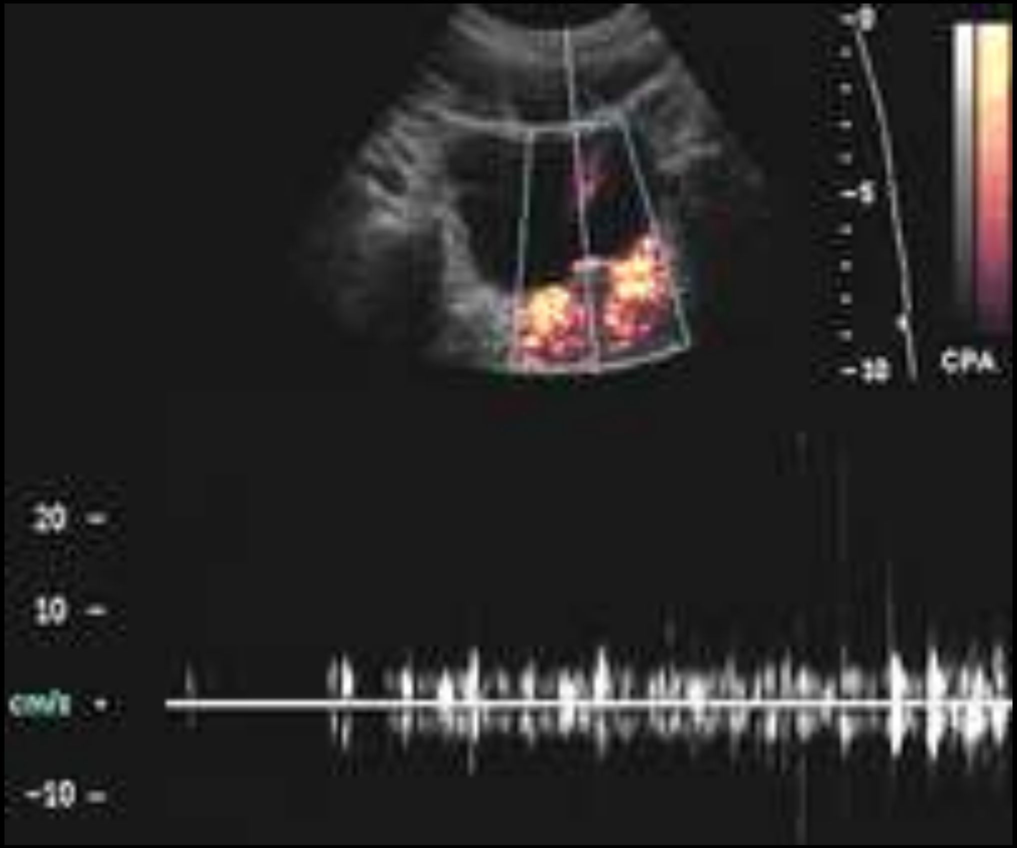
Figure 7.7 Color image of the subclavian artery (S) with a mirror image (M) below the pleura (P).

.٨ - Edge Artifact

- Signal at edge of manmade surface

eg.Catheter

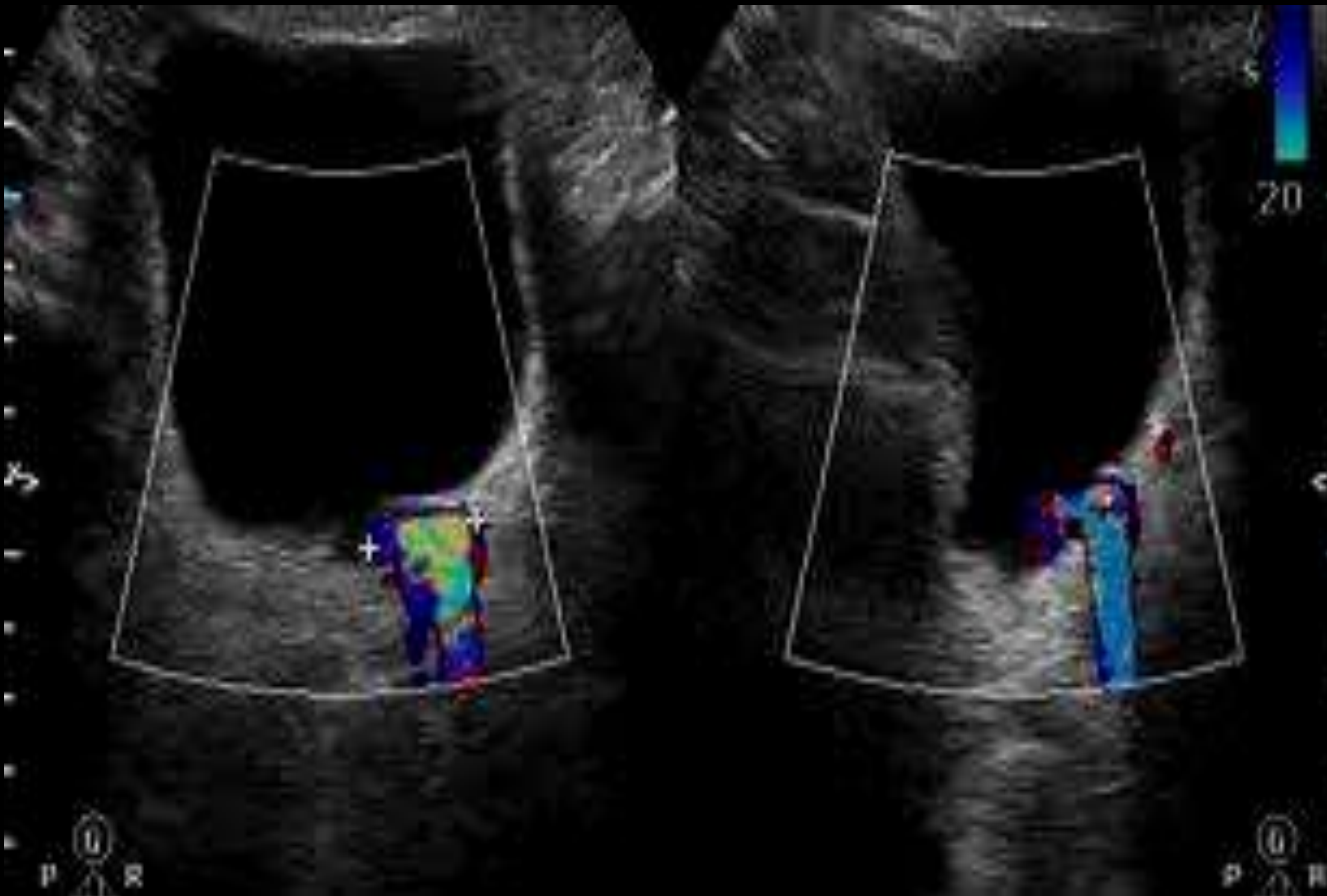
- More at low PRF



.٩Twinkling Artifact

- Signal behind *strong reflecting object*.
- Very important in detecting *small calculi*

as it occur e it.


20
P R
P R

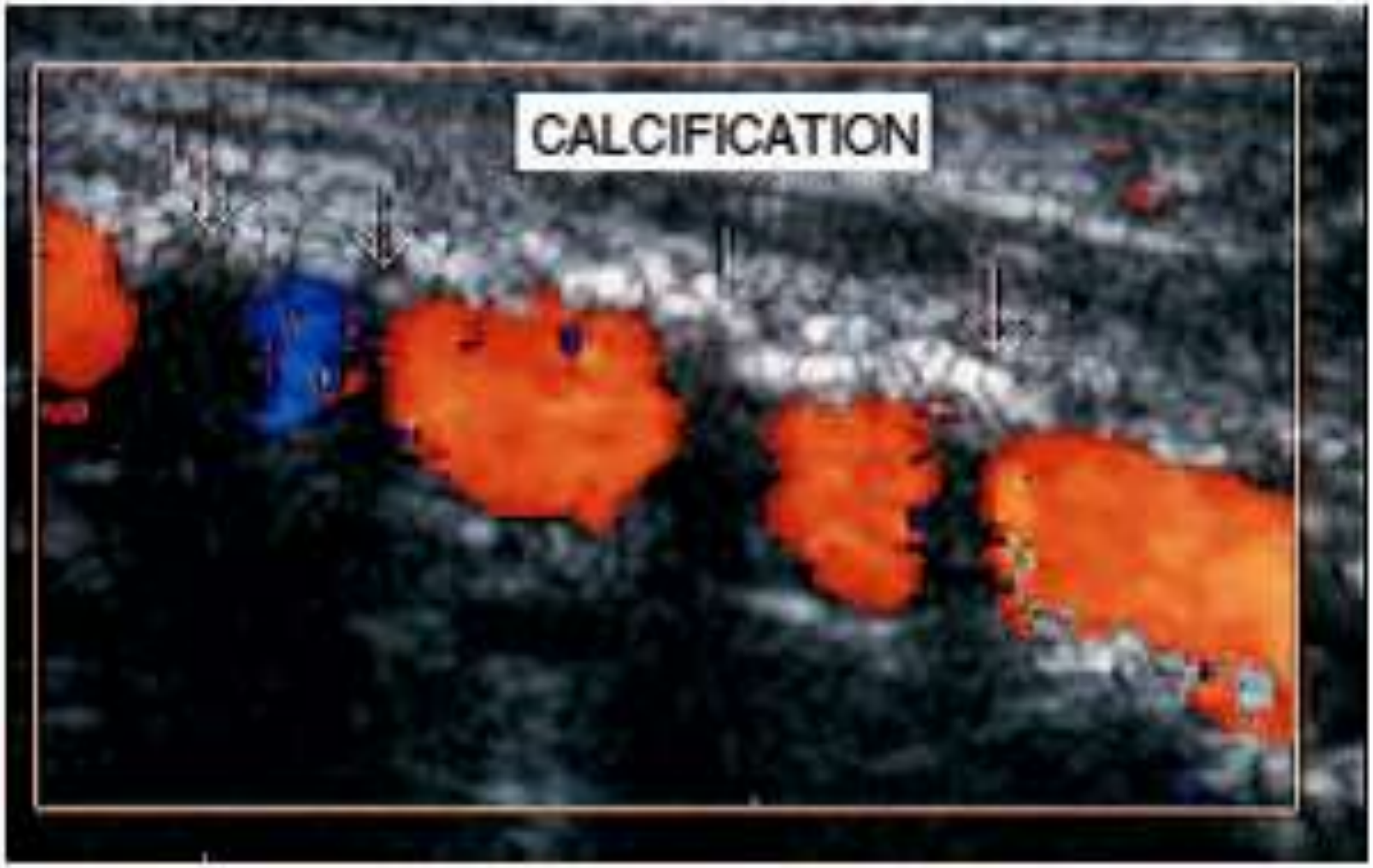


Figure 9.12 Calcified atheroma (arrows) is present in the SFA, leading to drop-out of the color flow signal in parts of the lumen.

Doppler Advantages:

- .١-Non Invasive
- .٢-Non Ionizing
- .٣-Portable
- .٤-No nephrotoxic agents
- .٥-See A. Lumen & wall
- .٦-Asses Hemodynamics
- .٧-Detect ocluded Aneurysm

Limitations:

.١-Ca Hender

.٢-Skin Henders

eg. ulcers, bandages, scars

.٣ - Need Co-operation

Averages PSV of L.L.As.

Artery	Diameter	V cm/sec
EIA	0.80+/-0.10	120 +/-20
CFA	0.82+/-0.15	115 +/-25
Prox SFA	0.60+/-0.10	90 +/-15
Dist SFA	0.55+/-0.10	95 +/-15
popl	0.50+/-0.10	65 +/-15

N.B. "PSV Ratio is more reliable"

Artery Stenosis

FOCAL ARTERIAL STENOSIS:

- *<u>***MILD***</u>: 1-19% lumen reduce
  - Triphasic preserved
  - PSV is 30% more
- *<u>***MODR***</u>: 20-40%
  - PSV is 100% more
  - Triphasic preserved
- *<u>***SEVER***</u>: 50% & More
  - PSV > 200%
  - Loss triphasic + Spectral broadening.

- PSV – Ratio in relation to stenosis :

< 2.5	0 - 49%
> 2.5	50 – 75 %
> 5.5	75 – 99 %

Interpretation

Duplex-derived velocity spectra		
% Stenosis	Peak Systolic Velocity	Ratio
Normal	< 150 cm / sec	< 1.5
< 50	150–200 cm / sec	1.5–2.0
50–75	200–400 cm / sec	2.0–4.0
> 75	> 400 cm / sec	> 4.0
Occlusion	No flow by colour Doppler/pulsed Doppler spectra From Cossman *et al*. JVS 1989	

Table 9.5 Suggested criteria for grading lower limb arterial disease using velocity ratios, based on several references (see text)

Diameter reduction	Velocity ratio (V_s/V_p)	Comments
0–49%	<2	Waveform is triphasic but mild spectral broadening and an increase in end diastolic velocities are recorded as the degree of narrowing approaches 49%
50–74%	⩾2	Waveforms tend to become biphasic or monophasic; there is an increase in end diastolic velocity; spectral broadening is present; flow disturbance and some damping are recorded distal to the stenosis
75–99%	⩾4	Waveform is usually monophasic with a significant increase in end diastolic velocity; marked turbulence and spectral broadening are demonstrated; flow is damped distal to the stenosis
Occluded	No flow detected	Doppler waveforms proximal to an occlusion often demonstrate a high-resistance flow pattern

Table 14.2 Spectral Doppler criteria for grading a graft stenosis

Diameter reduction	Spectral Doppler criteria
$<50\%$	PSV ratio < 2
50–70%	PSV ratio 2–3; increased spectral broadening and turbulence just beyond the stenosis; waveform becomes more monophasic
70–99%	PSV ratio > 3; marked turbulence distal to the stenosis; waveform may be monophasic
Occlusion	No flow signal present

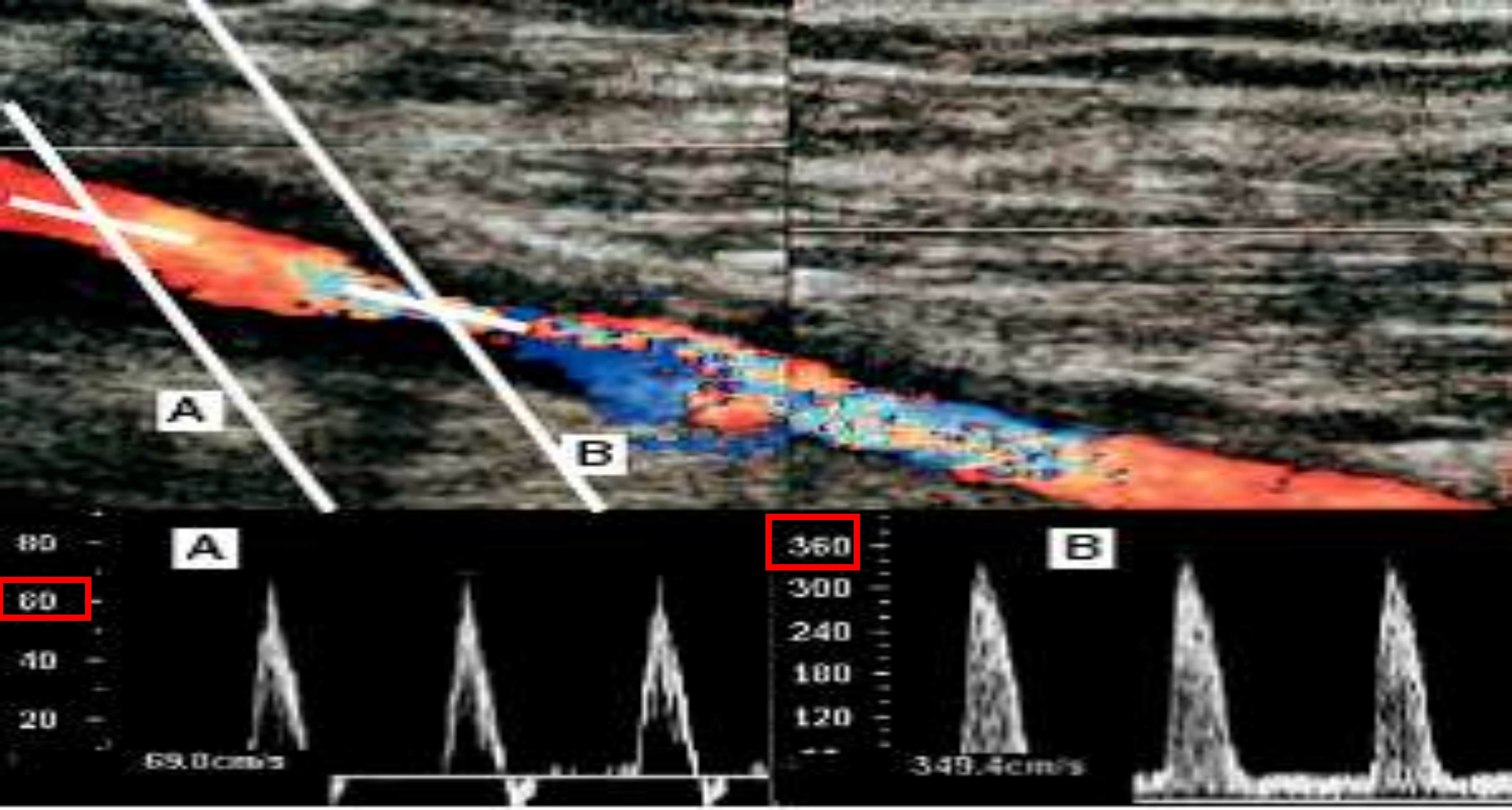
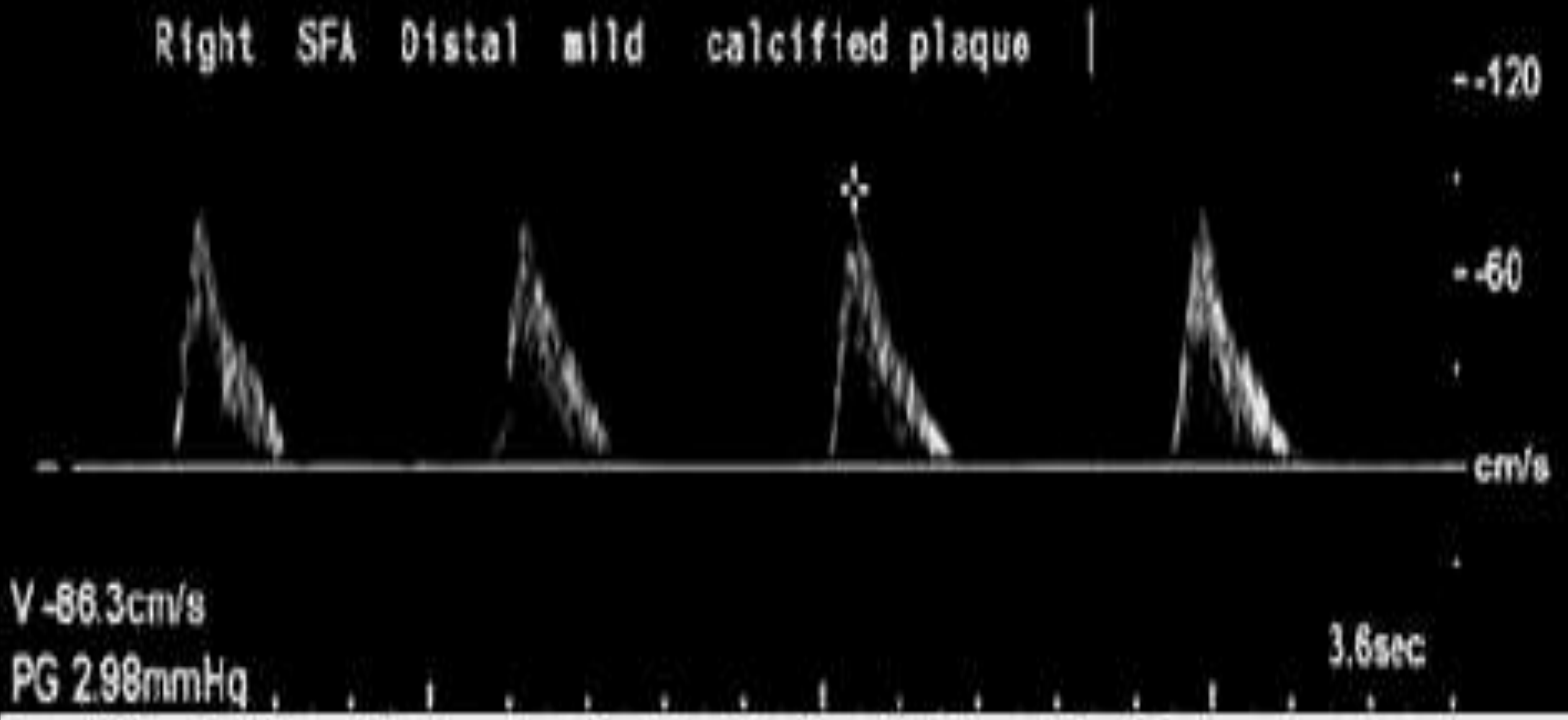


Figure 9.19 An SFA stenosis is assessed using spectral Doppler. A: Measurement of the peak systolic velocity just proximal to the stenosis. B: Measurement of the peak systolic velocity across the stenosis. The peak systolic velocity ratio is calculated by dividing B by A, producing a velocity ratio of 5. This would indicate a severe stenosis.



ig. 15b. High resistance flow proximal to occlusion.

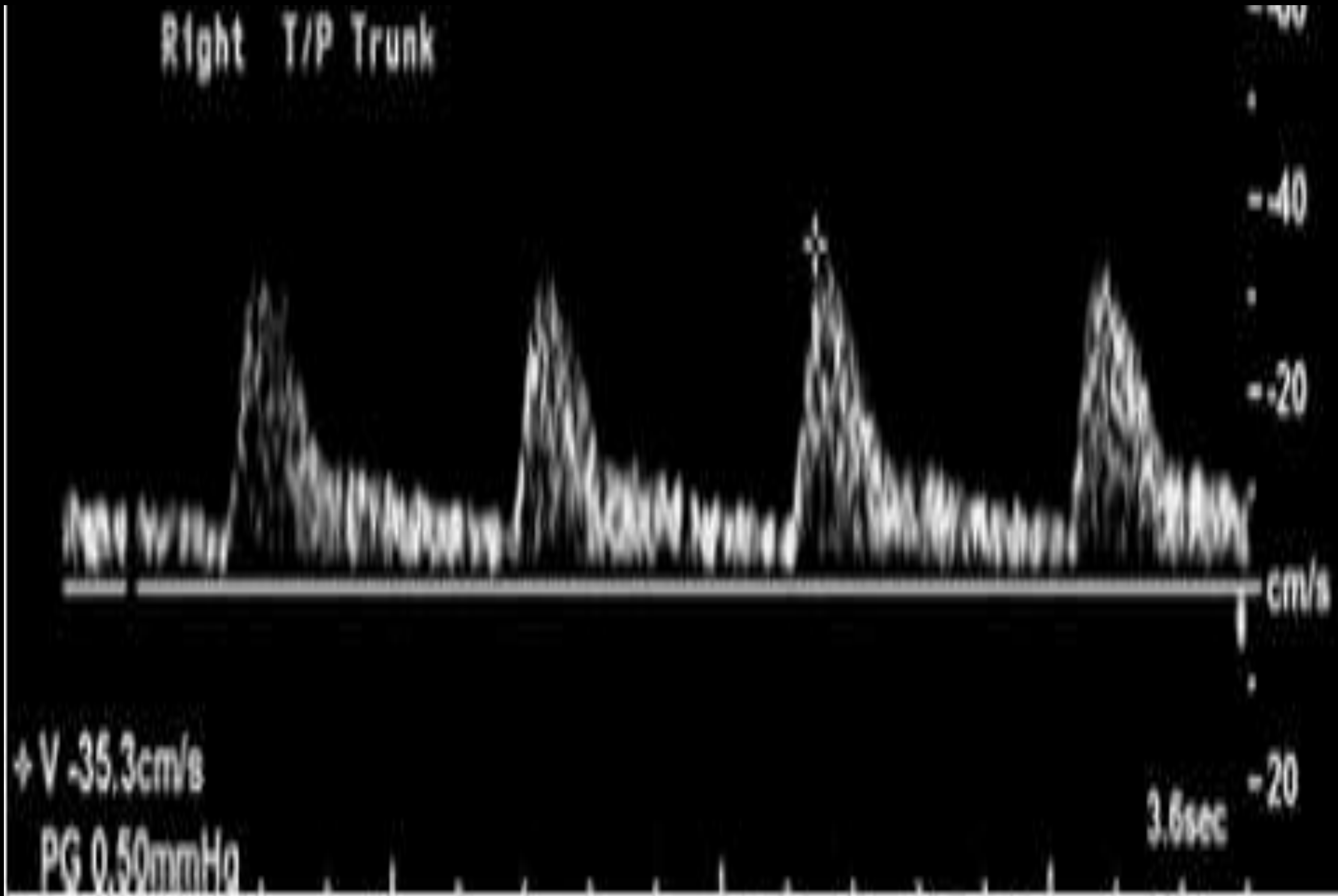


Fig. 16a Dampened monophasic waveform distal to the occlusion.

where the resistance to flow is given by:

$$R = \frac{\text{viscosity} \times \text{length} \times 8}{\pi \times r^4}$$

where r is the radius.

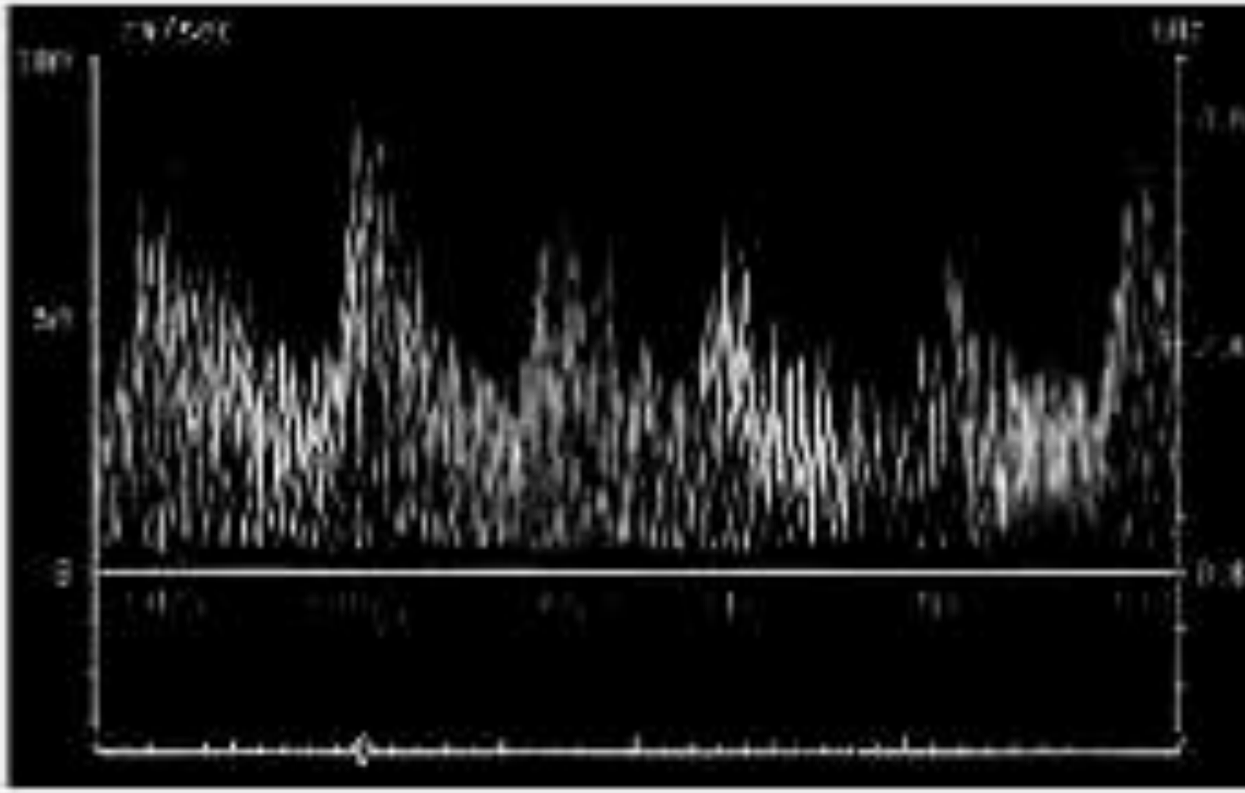


Figure 5.20 Doppler waveform demonstrating turbulent flow.

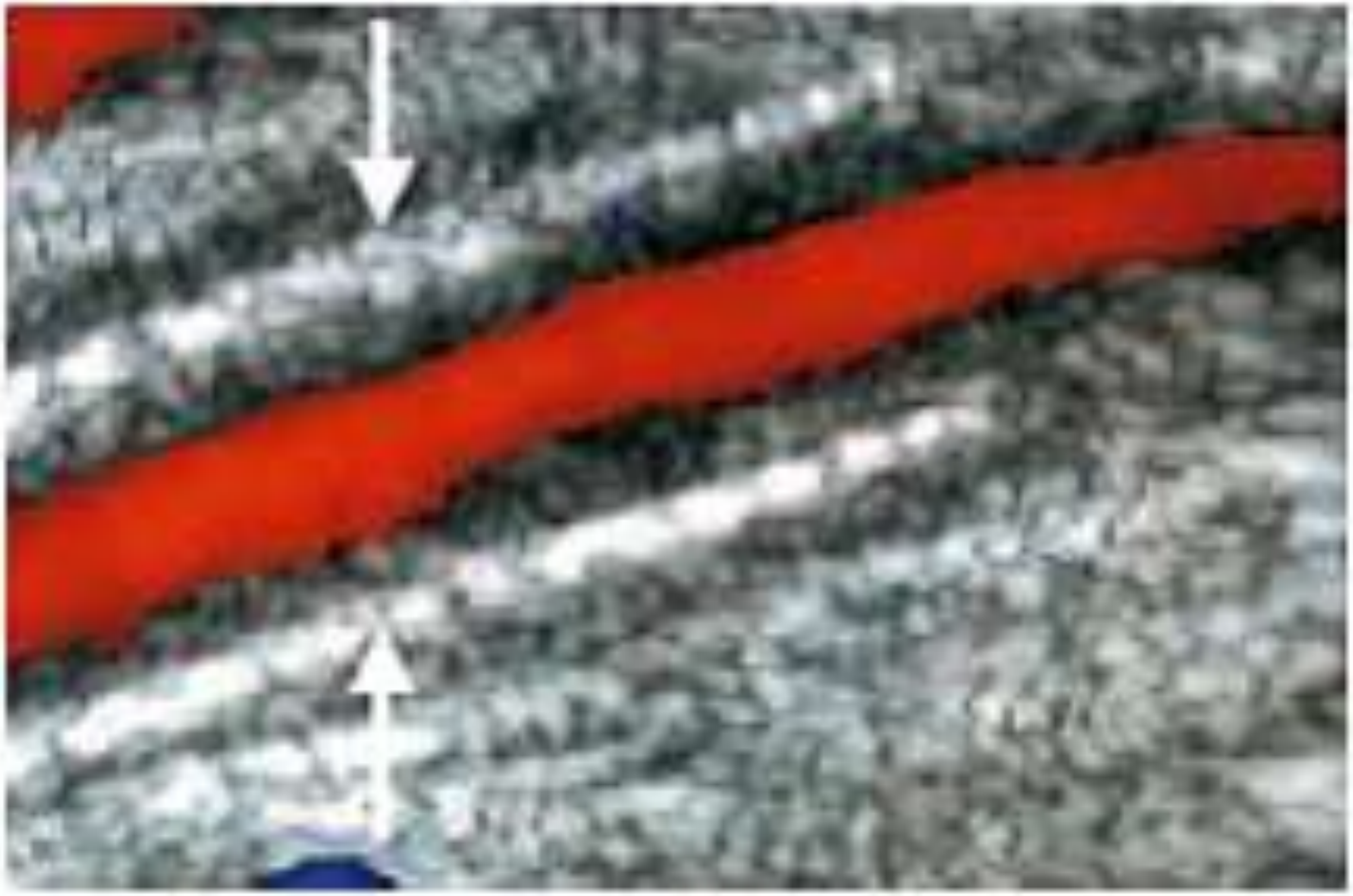
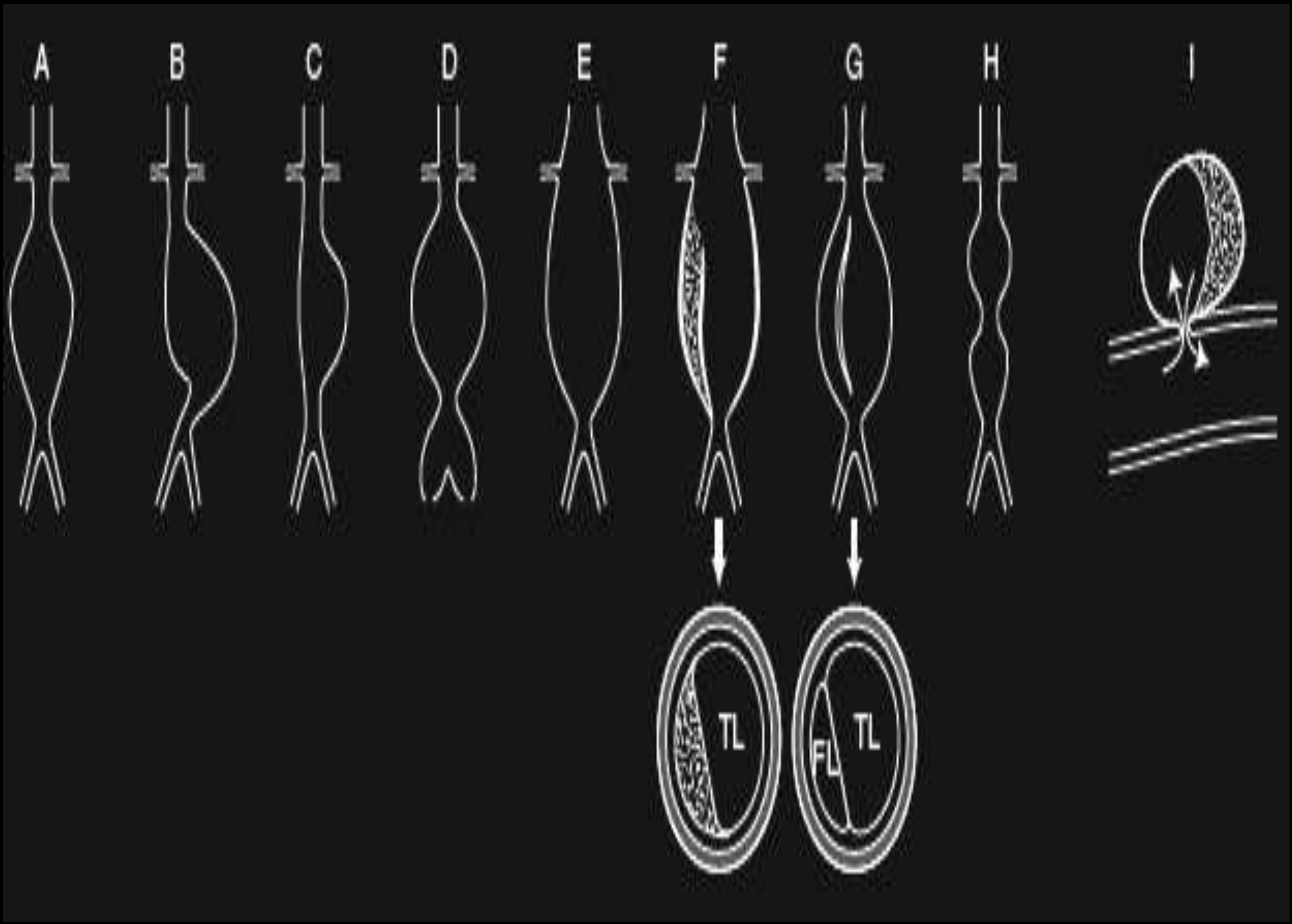


Figure 9.21 Color flow imaging demonstrates a long stricture in a CFA stent caused by intimal hyperplasia. The stent walls are clearly visible (arrows).

- ***WAGNER's CLASSIFICATION***

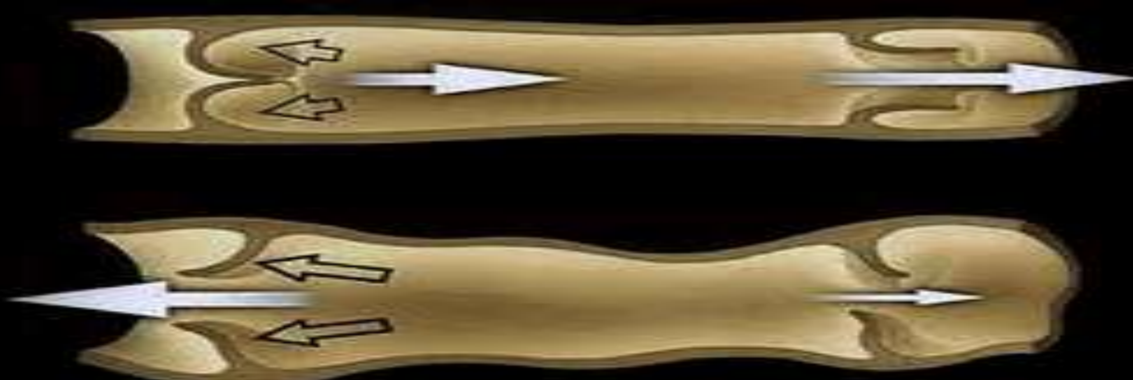
OF Diabetic Foot:

- -٠ No Open Lesions
- -١ Superficial ULcer
- -٢ Deep " " reach tendon or Capsule
- - ٣ “ " " " + Abscess or Osteomylitis
- -٤ Local Gangreen
- -٥ Foot Gangreen



A
B
C
D
E
F
G
H
I
TL
FL
TL

Venous Doppler



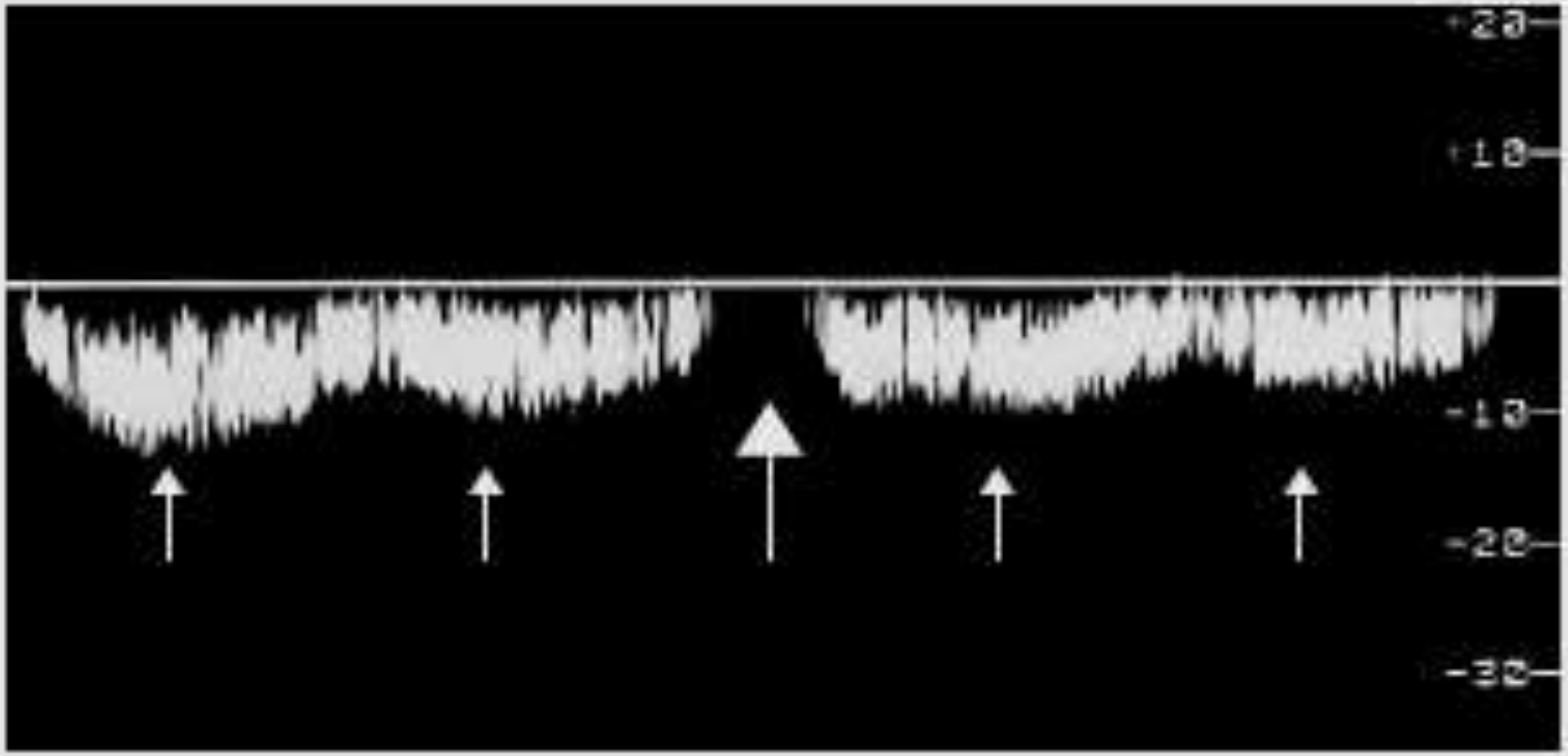


Figure 5.22 Doppler waveform demonstrating the effect of respiration on the blood flow in the common femoral vein. The large arrow indicates the cessation of flow during inspiration and the small arrows show small changes in flow due to the cardiac cycle, which may not always be seen in the common femoral vein.

Checklist of DVT

1. Is Thrombus present?
2. What extent?
3. What Age?
4. Is it adherent?
5. What is the cause?

Box 13.1 Risk factors for the development of deep vein thrombosis

- Coagulation disorders
- Immobilization
- Surgery and trauma
- Malignancy
- Septicemia
- Oral contraceptives
- Increasing age
- Stroke
- Heart failure
- Previous history of deep vein thrombosis
- Long-haul air travel

Competence examination

*U.L.V → By deep inspiration
*L.L.V. → By valsalva maneuver

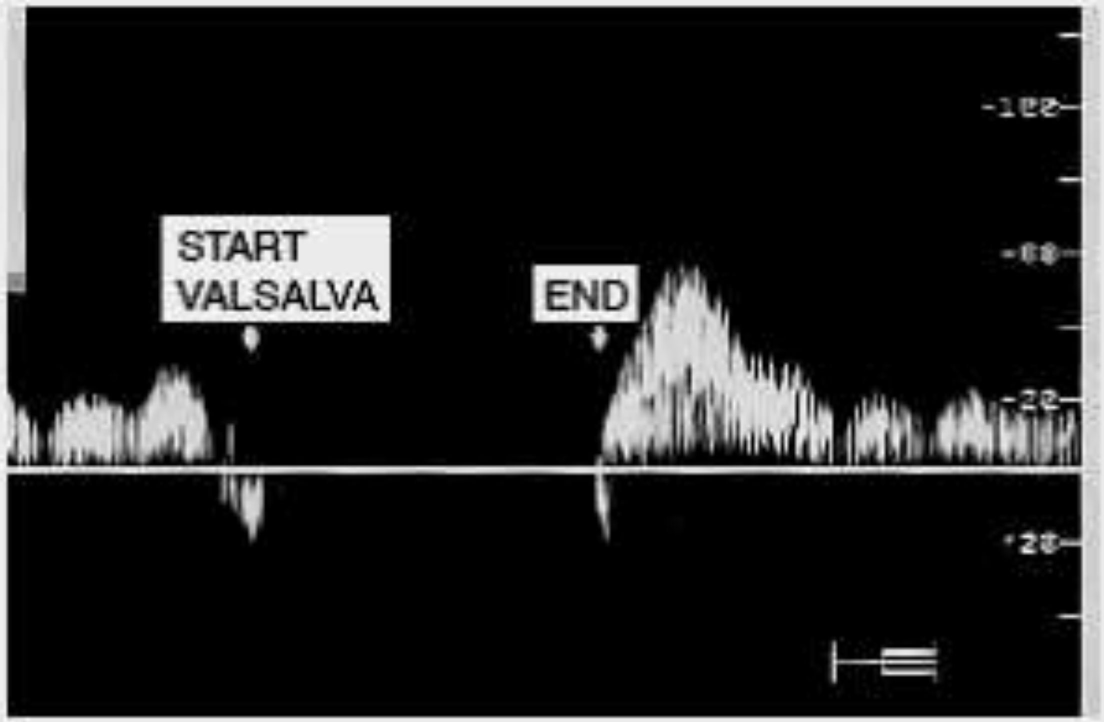


Figure 12.12 The Valsalva maneuver demonstrates competency of the proximal superficial femoral vein. There is a cessation of normal phasic flow during the Valsalva maneuver followed by a surge of flow during expiration (END).

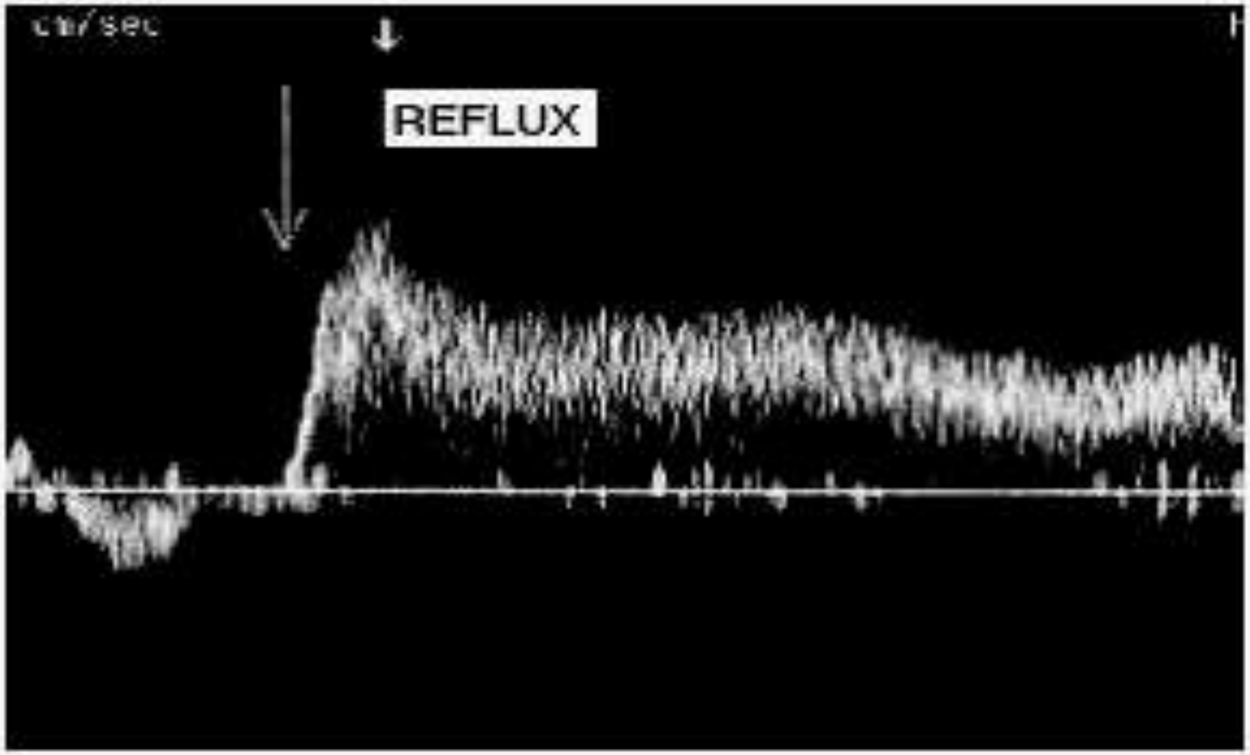


Figure 12.13 Incompetence of the saphenofemoral junction is demonstrated by a large volume of reflux during a Valsalva maneuver (the arrow indicates the start of Valsalva).

General Criteria of Thrombosis

- Vein is non comprisable completely.
- Echogenicity is <u>*not Reliable*</u> for thrombus age.
- <u>***V. Diameter in relation to Artery***</u> *is the best method to assess Thrombus age*
  - *< 10 Days = > twice of Artery.*
  - *> 10 Days regress again.*

شام

Table 12.1 Grading of venous reflux

Grade	Reflux duration
Normal valve function	Reflux duration of <0.5 s, rapid closure of venous valves
Moderate reflux	Reflux duration of 0.5–1 s, mild to moderate retrograde flow
Significant reflux	Reflux duration of >1 s, large volume of retrograde flow

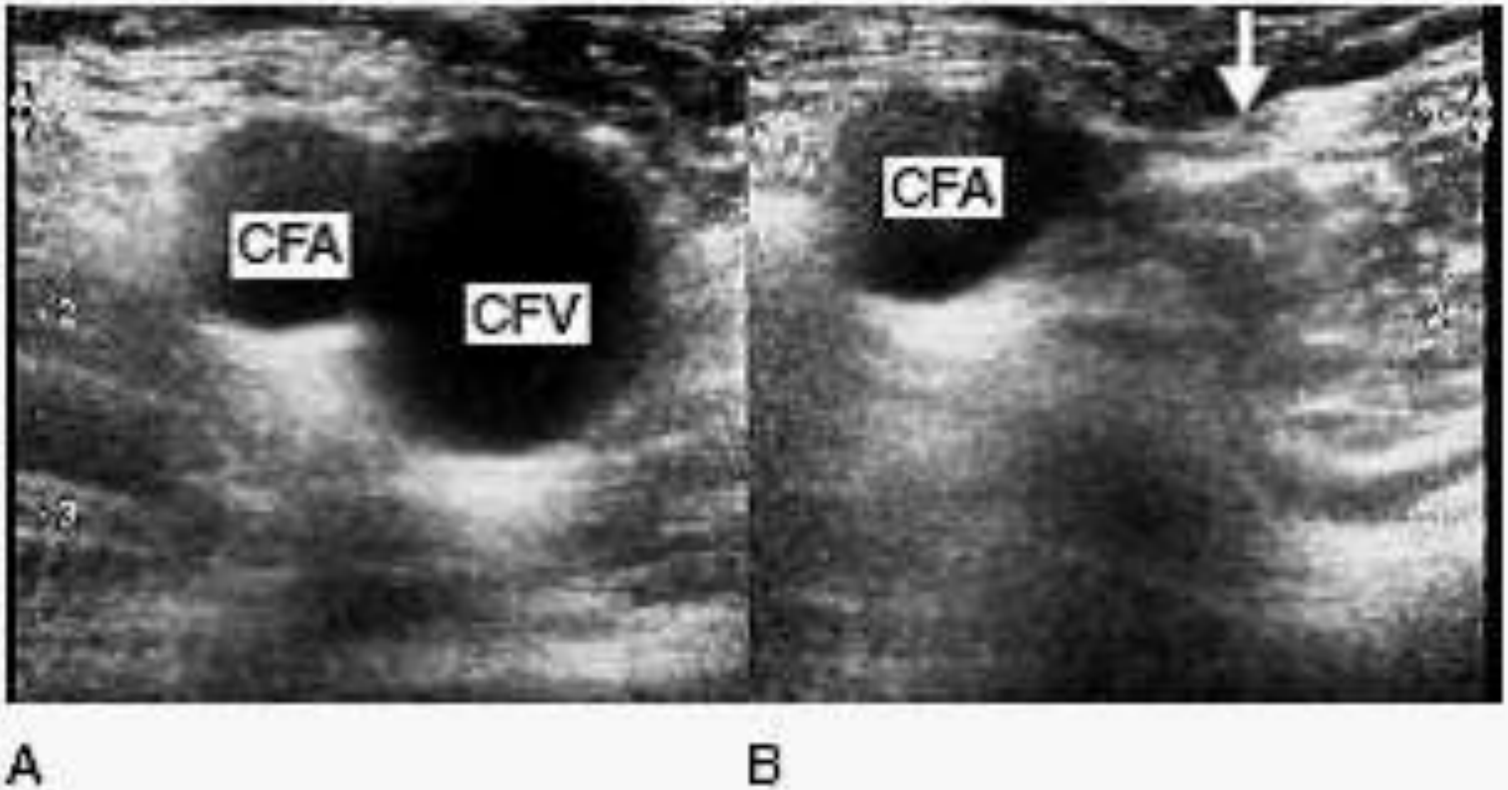
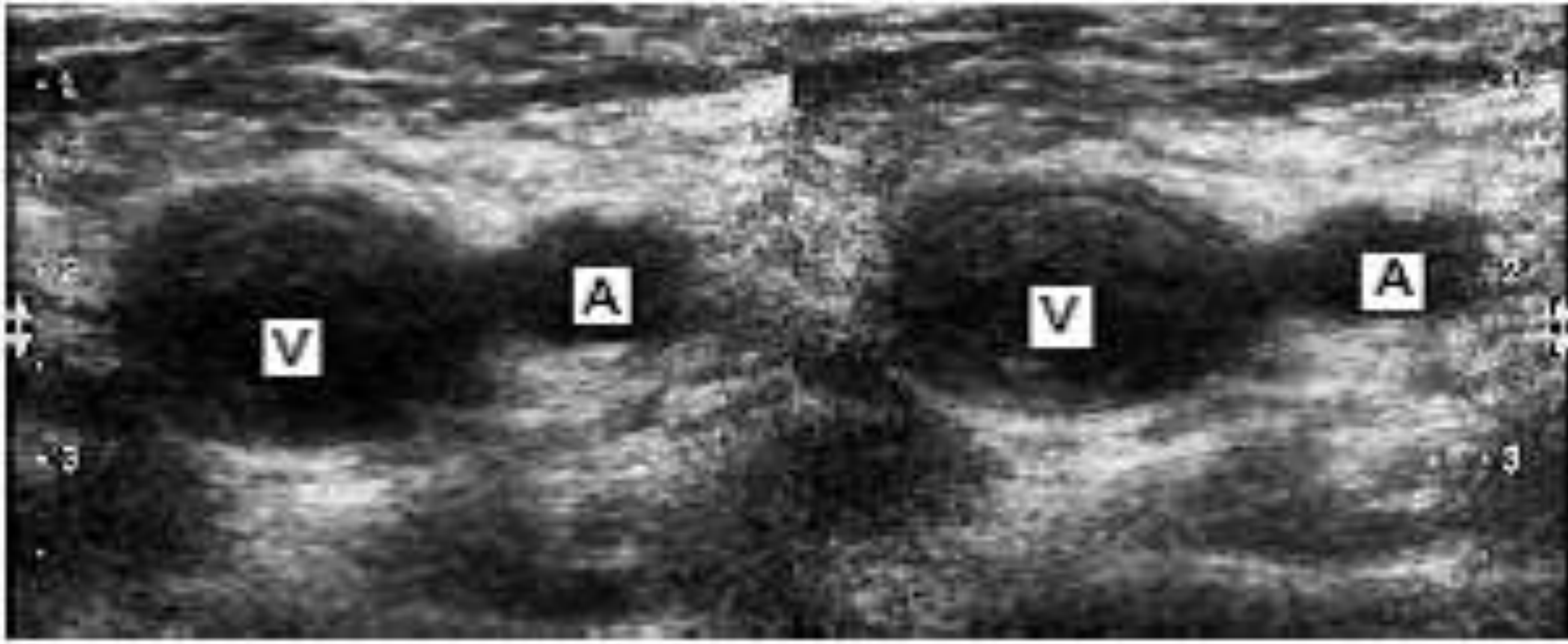


Figure 13.3 A: A transverse image of the right common femoral vein (CFV) and femoral artery (CFA). B: Patency of the CFV is demonstrated by complete collapse of the vein (arrow) during transducer pressure.



A B

Figure 13.7 A: A transverse image of the common femoral vein (V) and common femoral artery (A). The common femoral vein appears distended and contains some low-level echoes. B: The common femoral vein is seen to deform but not collapse during firm transducer pressure, confirming DVT.

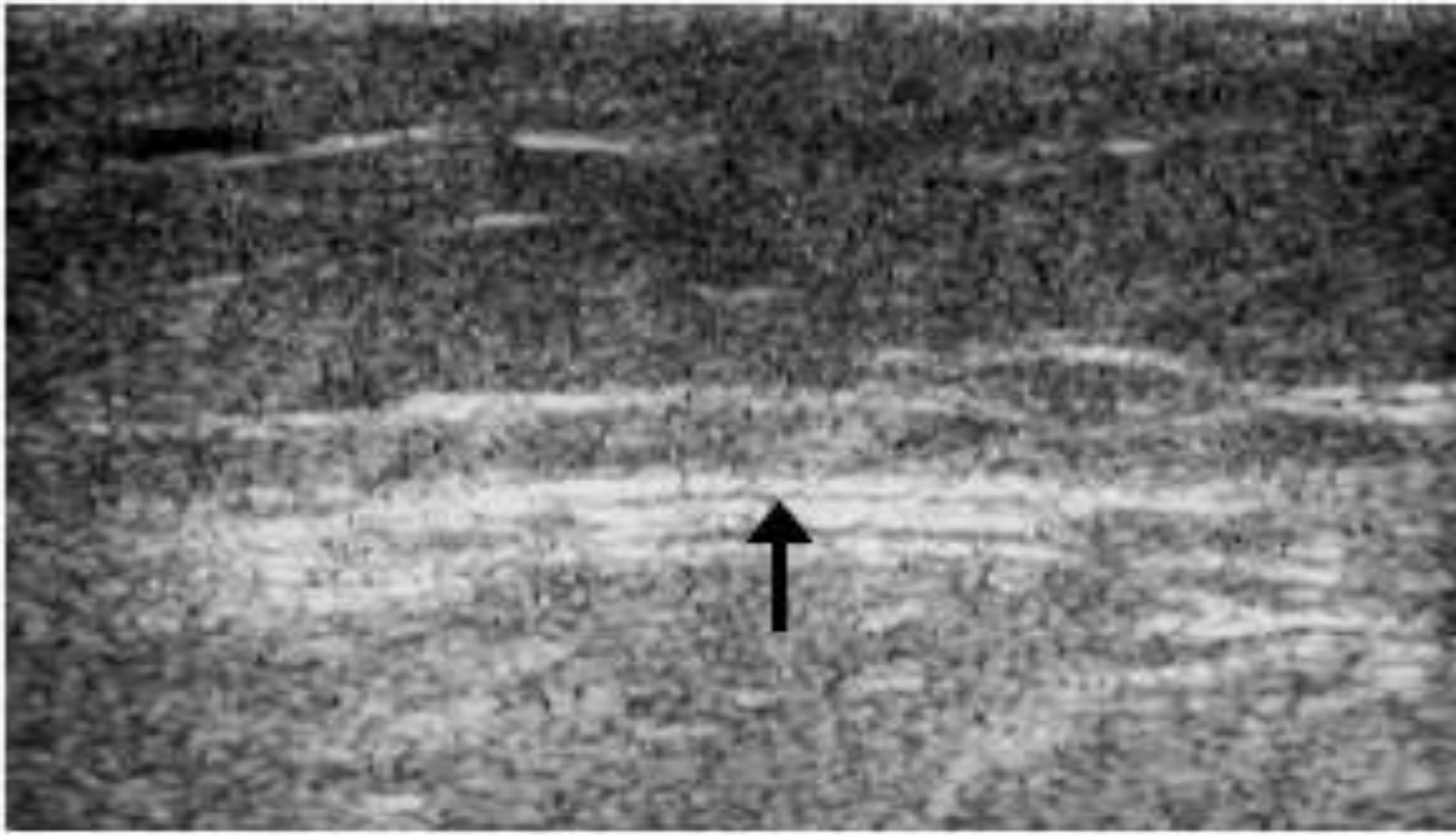


Figure 13.15 Lymphedema produces a grainy appearance in the subcutaneous tissues, as demonstrated on this transverse B-mode image. The superficial tissue is relatively thick. The muscular fascia is demonstrated by the arrow. Note the degraded image quality, typical of this disorder.

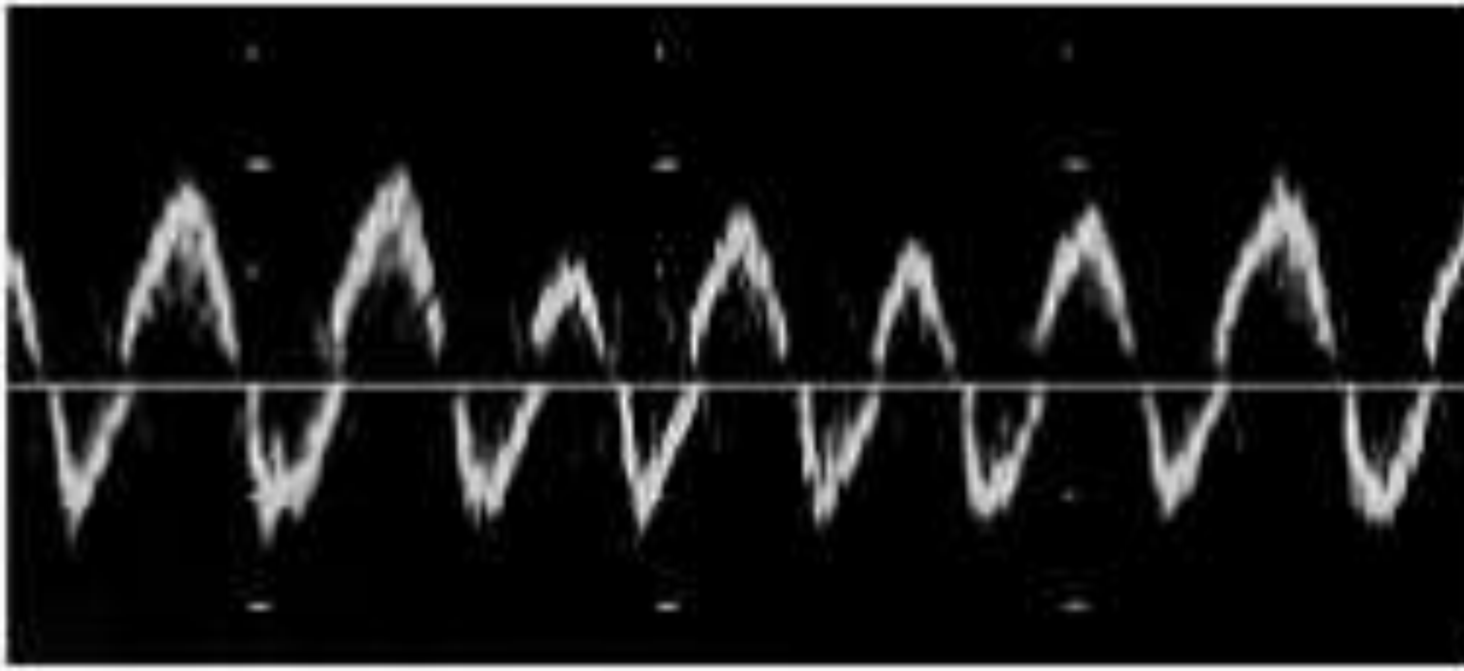


Figure 13.17 The venous flow signals recorded from the common femoral vein of a patient with congestive cardiac failure demonstrate a pulsatile flow pattern.

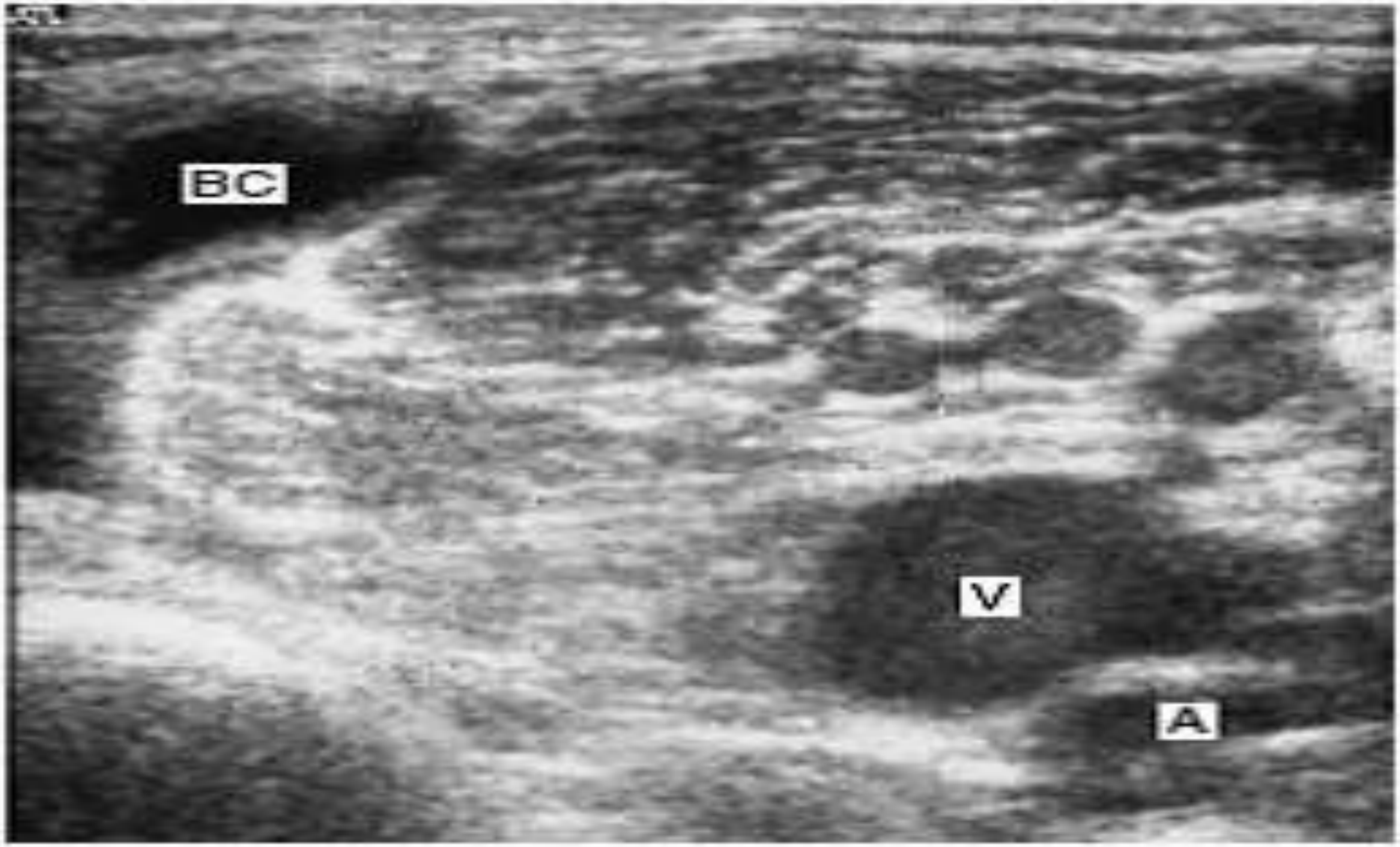
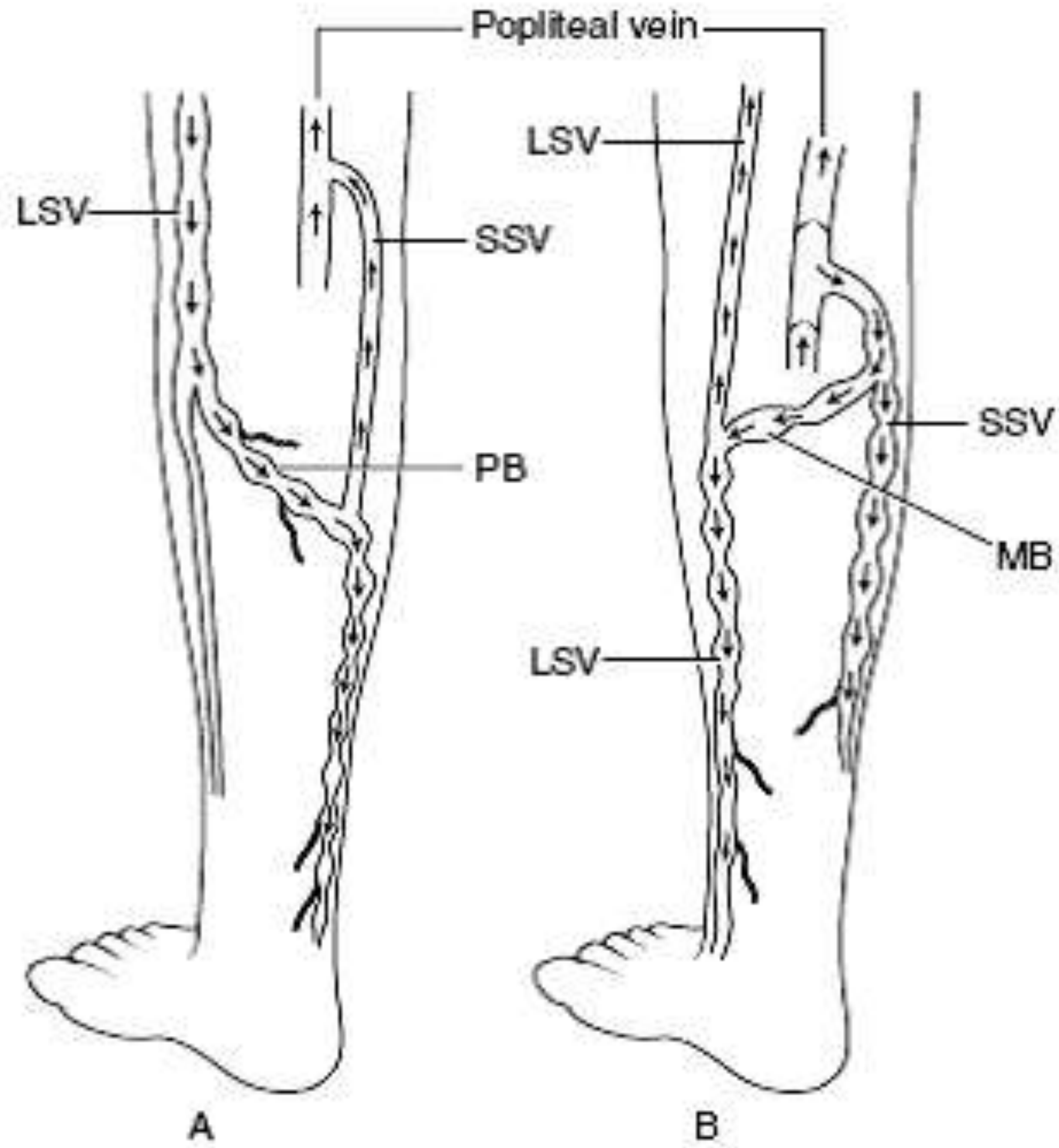


Figure 13.18 A Baker's cyst (BC) is demonstrated in thi
transverse image of the popliteal fossa. The popliteal
artery (A) and vein (V) are also seen in the image.

Baker's cyst → connected to posterior aspect of knee joint space



Popliteal vein
LSV
SSV
PB
A
LSV
SSV
MB
LSV
B

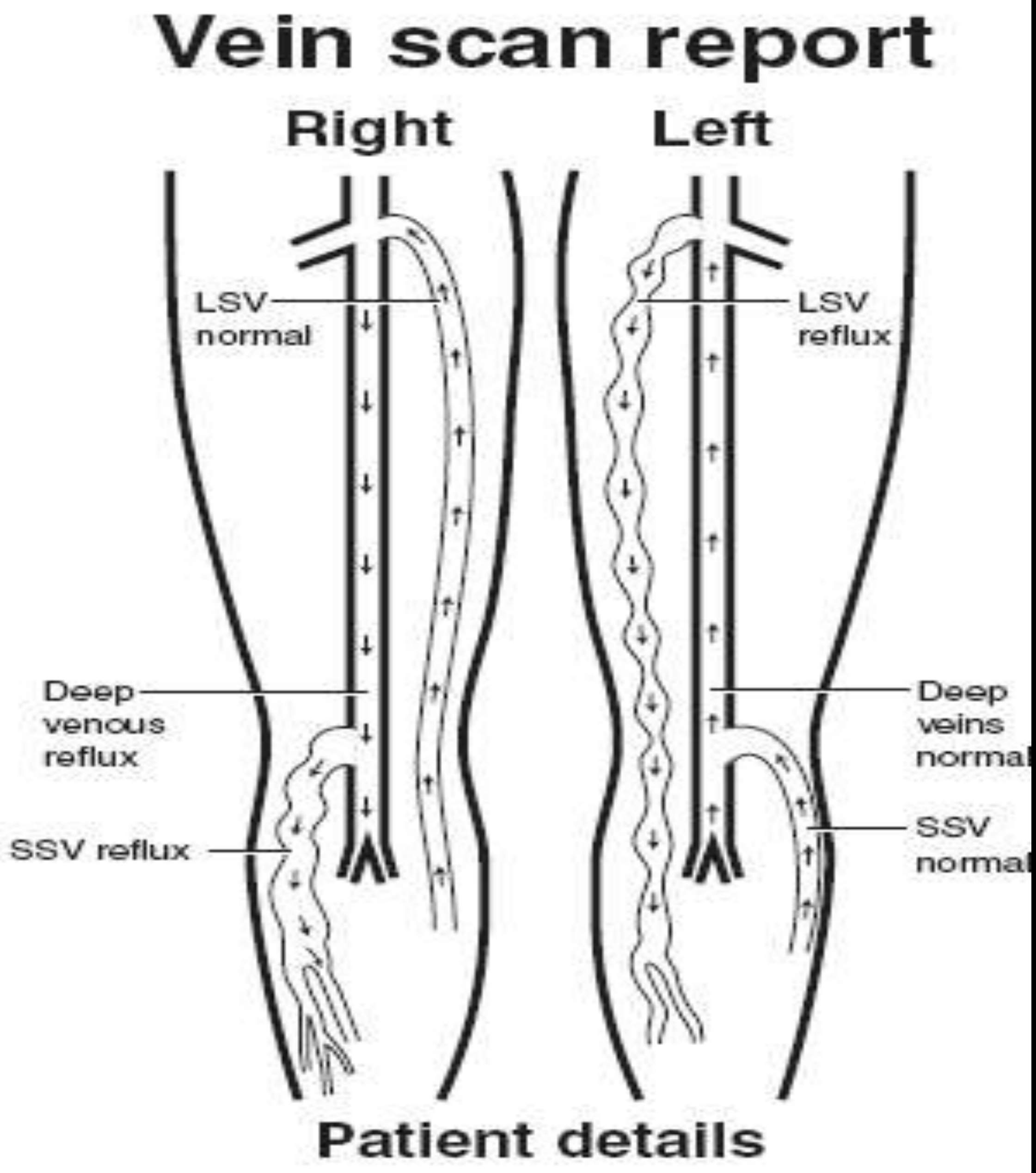


Figure 12.33 The use of diagrams makes it easier for the clinician to interpret the findings of a venous duplex examination (see text).


DON'T FORGET TO SAY THANKS.