# *Carotid Artery Doppler*

## *Patient Position*

- supine or semisupine
- head slightly hyper-extended
- rotated 45° away from the side being examined.
- Higher-frequency linear transducers (7 MHz)

- Vessels should be imaged as completely as possible
- Caudal angulation of the transducer in the supraclavicular region and cephalic angulation at the level of the mandible
- Assessed both in gray scale and colour doppler settings

## *Limitations*

- »short muscular neck
- »a high carotid bifurcation
- »tortuous vessels
- »calcified shadowing plaques

# *Optimal Scanning Techniques and Doppler Settings*

- Scan both in transverse and longitudinal plane.
- Starting from proximal most CCA, bulb, ECA and ICA.
- Distal carotid - 2 cm from the bulb
- ICA or ECA ?

  Large in caliber, posterior and lateral

  low resistance wave form (not reliable)

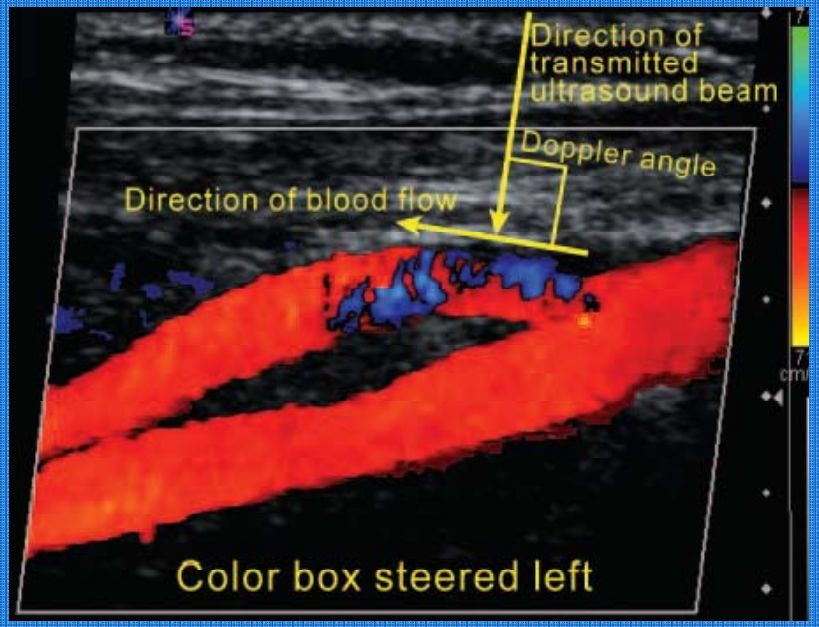
  no branches

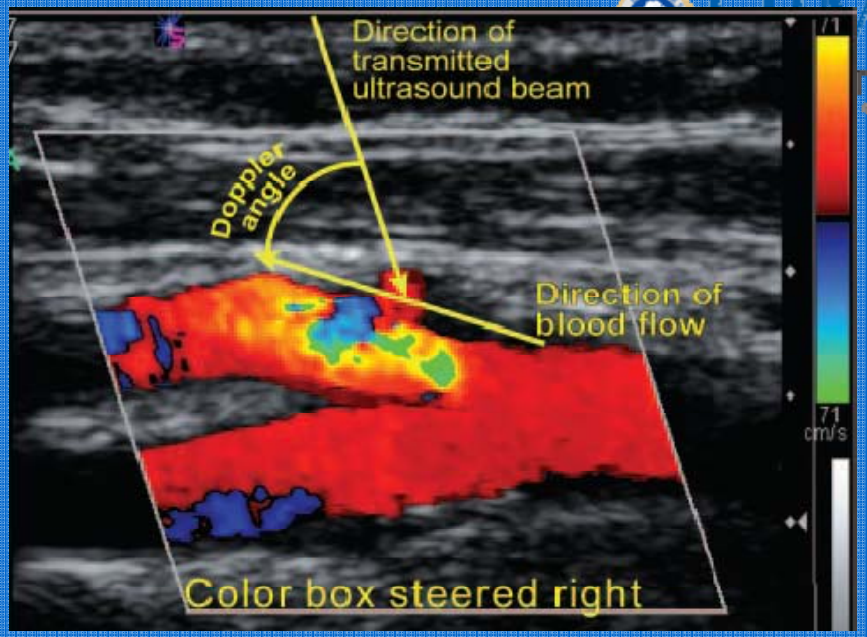
  no cluttering with temporal artery tapping,

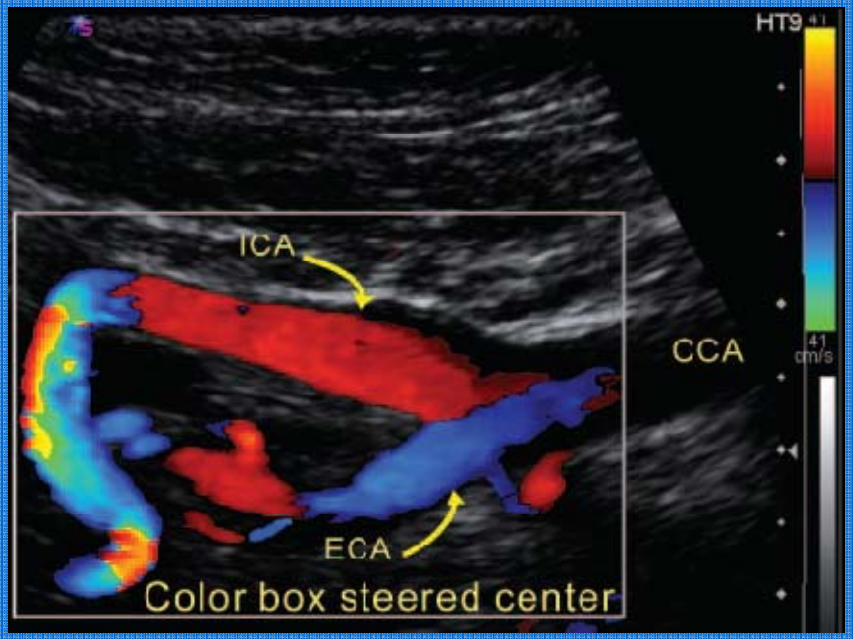
*'Internal is not Internal'*

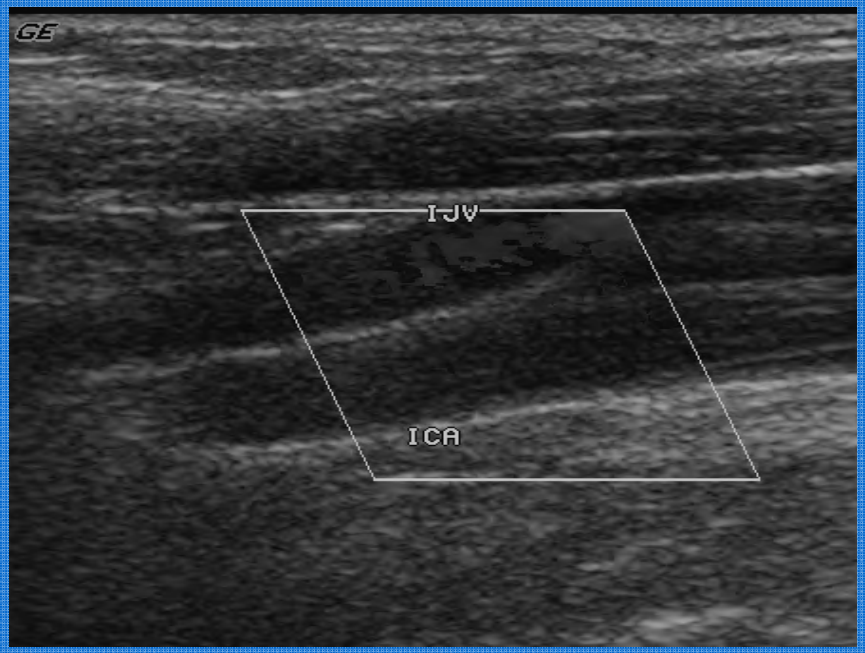
## *Color Doppler Sampling Window*

- also known as the color box
- The size is adjusted to include all regions of interest.
- Adjustment of the angle- by changing the box angles from left to center or right
- angling the transducer to ensure that the Doppler angle is less than 60° to the direction of blood flow

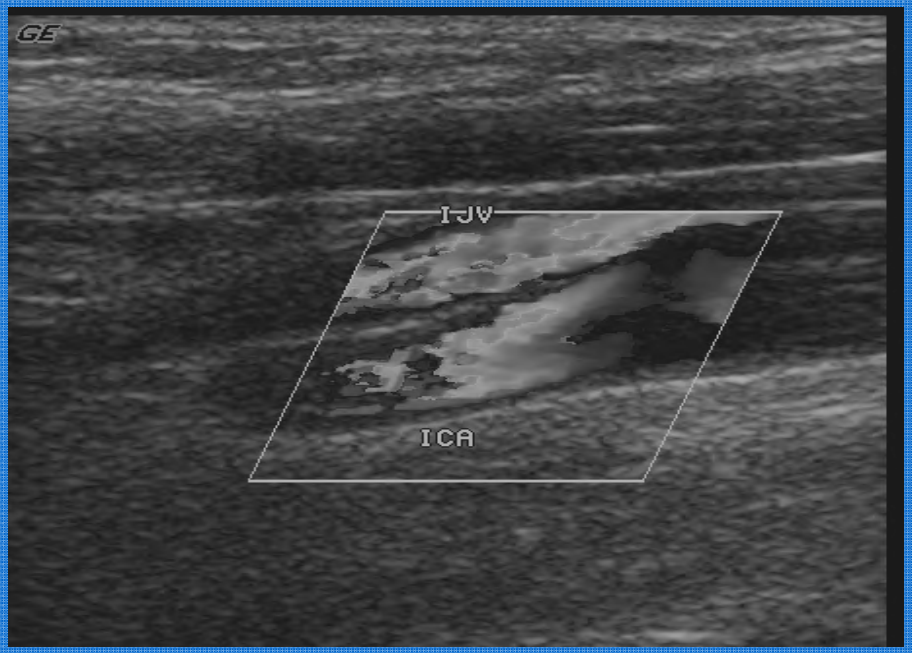

Direction of transmitted ultrasound beam
Doppler angle
Direction of blood flow
Color box steered left


Direction of transmitted ultrasound beam
Doppler angle
Direction of blood flow
71 cm/s
Color box steered right


HT9
ICA
CCA
ECA
41 cm/s
Color box steered center




Proper steering



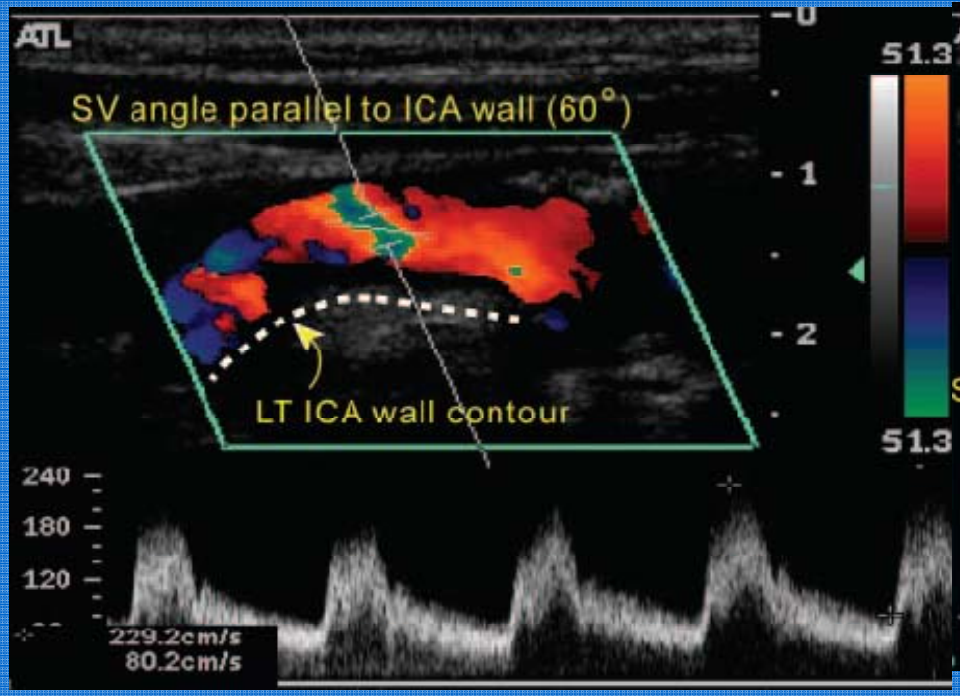
# *Sample Volume Gate and Angle Correction*

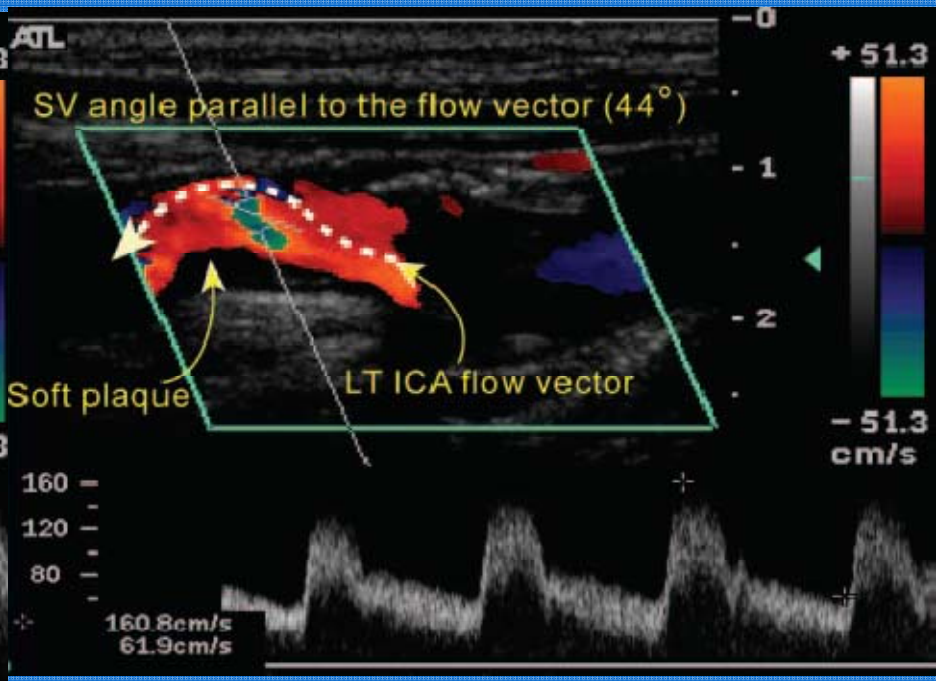
- If the Doppler angle is small or more than 60 degree - small error in the estimated velocity.
- preferred angle of incidence is 45° ± 4.

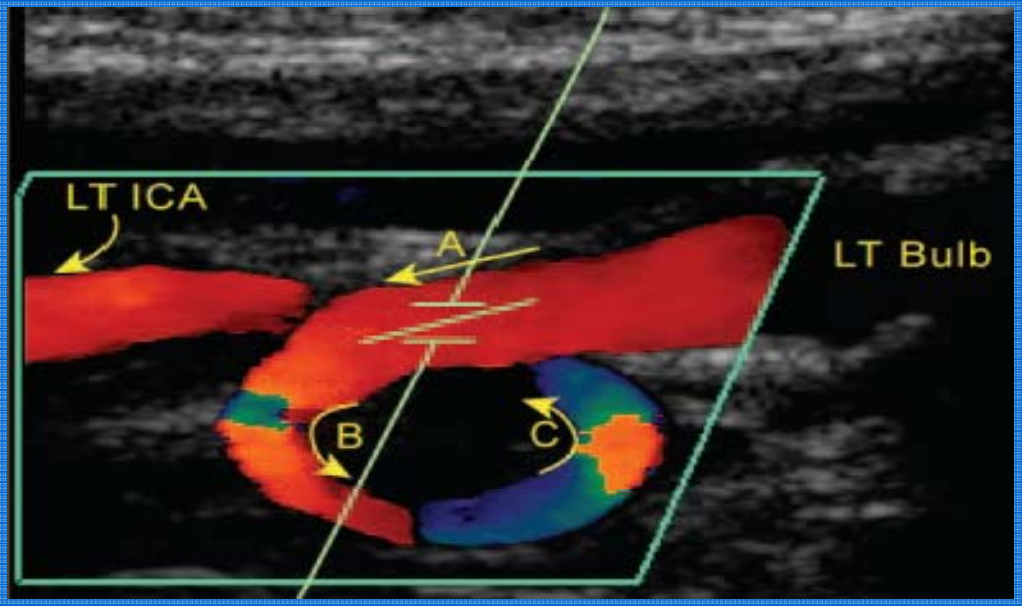
The optimal position of the sample volume gate

- in a normal artery is in the mid lumen parallel to the vessel wall
- in a diseased vessel, parallel to the direction of blood flow
- should not be placed on the sharp curves of a tortuous artery - falsely high velocity reading

- Should not be placed too close to the vessel wall - spectral broadening.


ATL
SV angle parallel to ICA wall (60°)
LT ICA wall contour
51.3
- 0
- 1
- 2
51.3
240
180
120
229.2cm/s
80.2cm/s


ATL
SV angle parallel to the flow vector (44°)
Soft plaque
LT ICA flow vector
+ 51.3
- 0
- 1
- 2
- 51.3
cm/s
160
120
80
160.8cm/s
61.9cm/s


LT ICA
A
LT Bulb
B
C

# *Spectral Broadening*

- Spectral broadening results from turbulence in the blood flow.

## Spurious spectral broadening

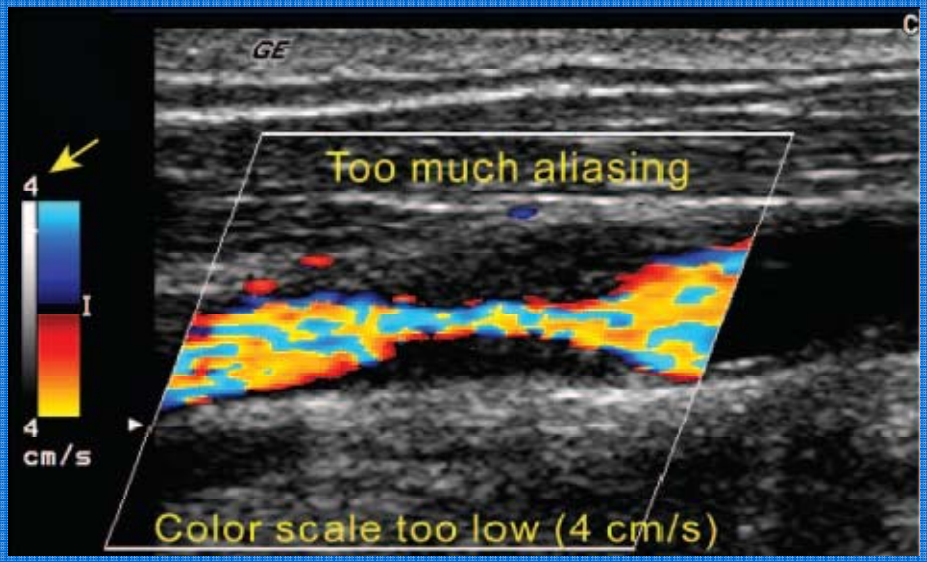
- a large Doppler angle
- a sample volume gate located close to the vessel wall
- a high Doppler gain setting

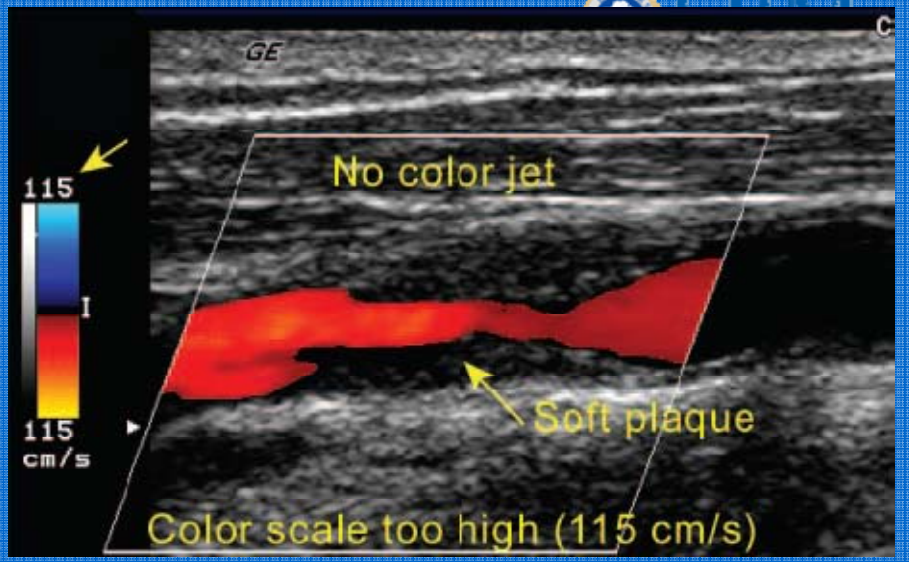
- The size of the gate is normally - between 2 and 3 mm.

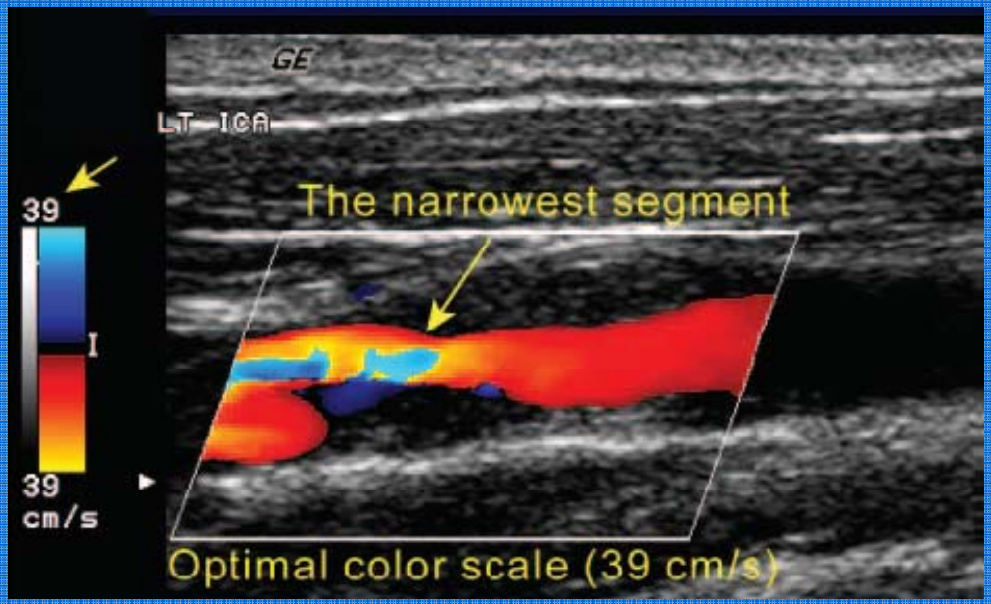
- too small (1.5 mm) - the Doppler signal may be missed
- too large >3.5 - spectral broadening

# *Color velocity scale*

- If **set below** the mean velocity of blood flow, **Aliasing** throughout the vessel lumen
- set significantly higher than the mean velocity of blood flow, aliasing may disappear resulting in a **missed stenosis**
- In a normal carotid US examination, the color velocity scale should be **set between 30 and 40 cm/sec** (mean velocity).

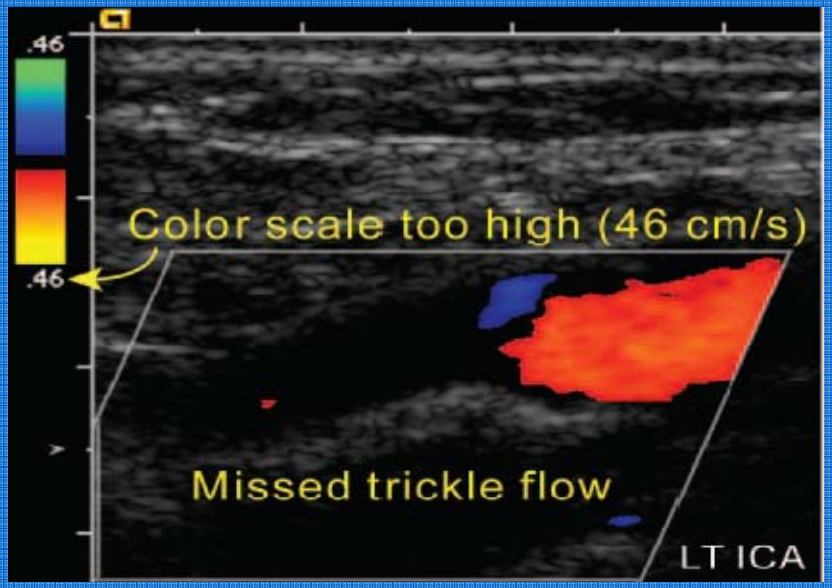

GE
Too much aliasing
4
I
4
cm/s
Color scale too low (4 cm/s)

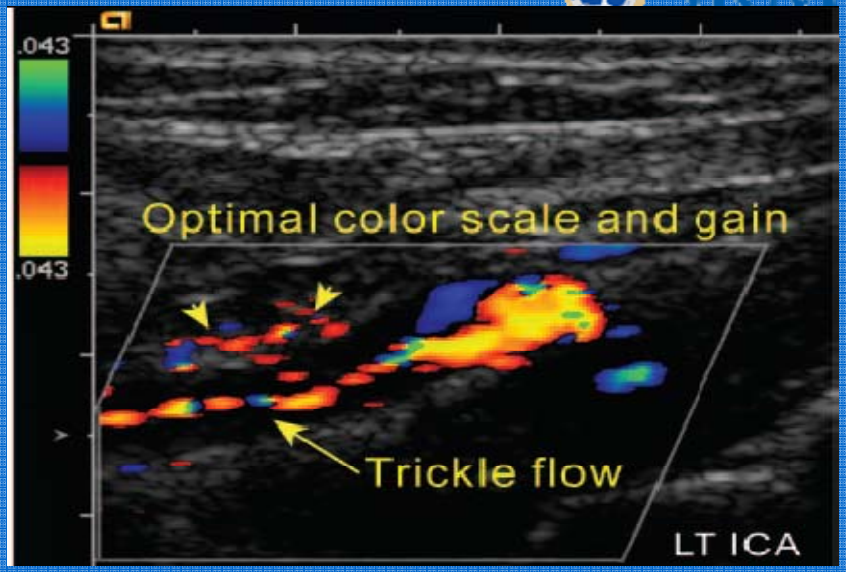

GE
No color jet
115
I
115
cm/s
Soft plaque
Color scale too high (115 cm/s)

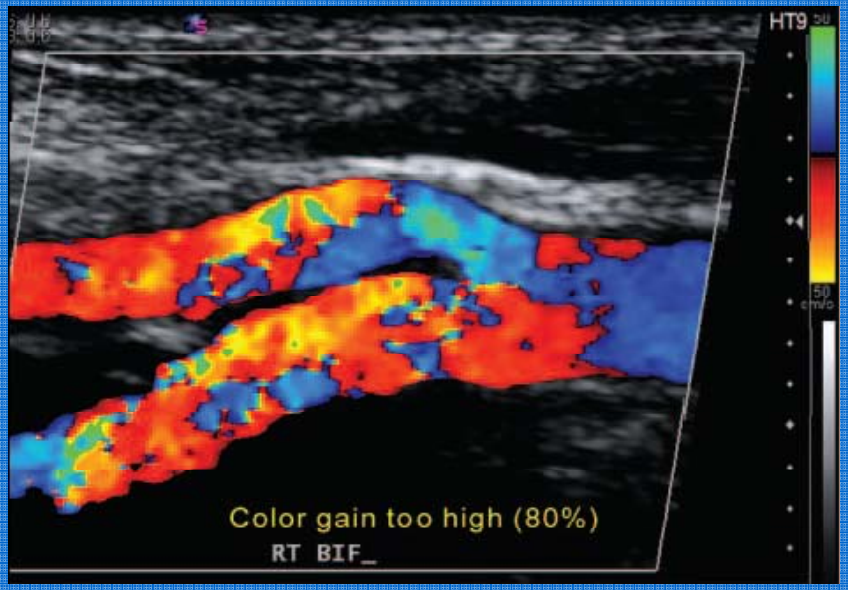

GE
LT ICA
The narrowest segment
39
I
39
cm/s
Optimal color scale (39 cm/s)

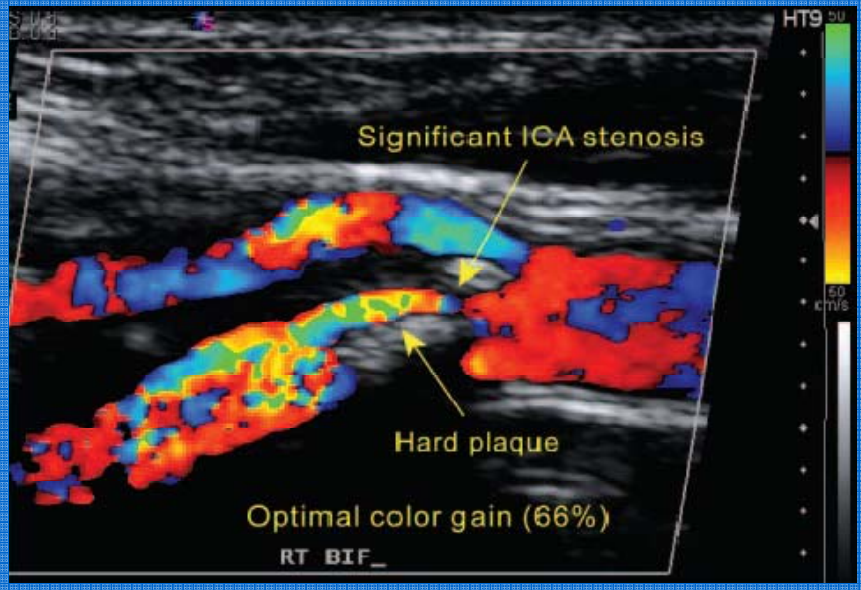
## *Color Gain Control*

- The color gain should be set so that color just reaches the intimal surface of the vessel.
- If the color gain setting is too low, trickle flow may go undetected.
- If a color gain setting is high, “bleeding” of the color into the wall and surrounding tissues - limit visualization of the plaque surface

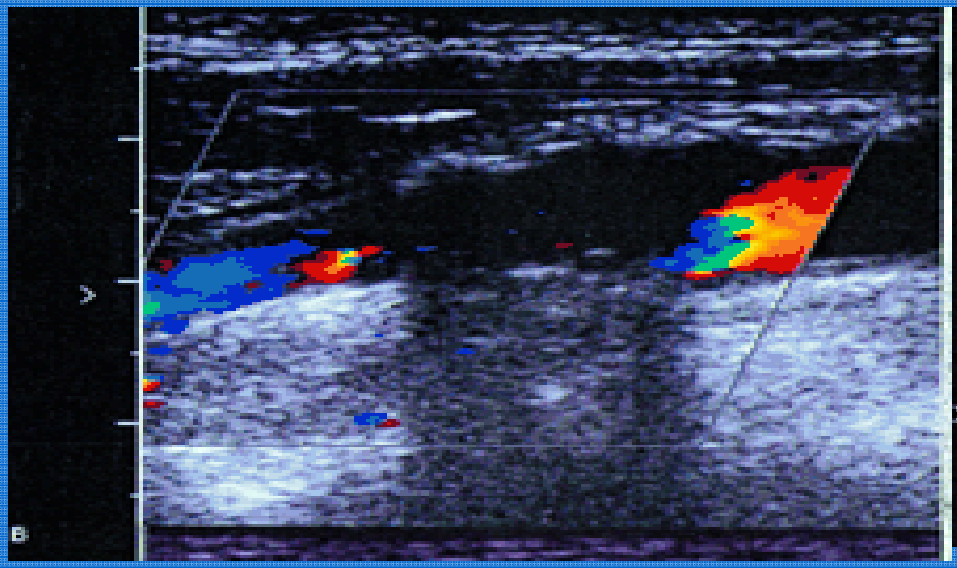

.46
Color scale too high (46 cm/s)
.46
Missed trickle flow
LT ICA

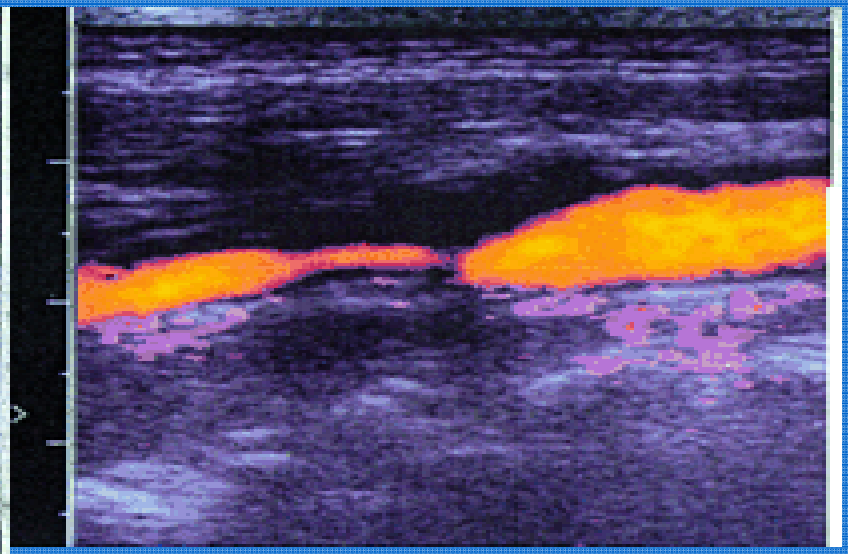

.043
Optimal color scale and gain
.043
Trickle flow
LT ICA


HT9
Color gain too high (80%)
RT BIF_


HT9
Significant ICA stenosis
Hard plaque
Optimal color gain (66%)
RT BIF_

# *Role of power doppler*





- PDI may provide increased sensitivity to visualize the continuity of blood flow in arterial stenoses

# *Advantages of power doppler*

- Angle independent
- No aliasing
- Very sensitive to low velocity and low amplitude flow
- Helps in differentiating critical stenosis from occlusion

***Disadvantages:***

motion sensitive

does not give direction and velocity of flow

# *Carotid plaque*

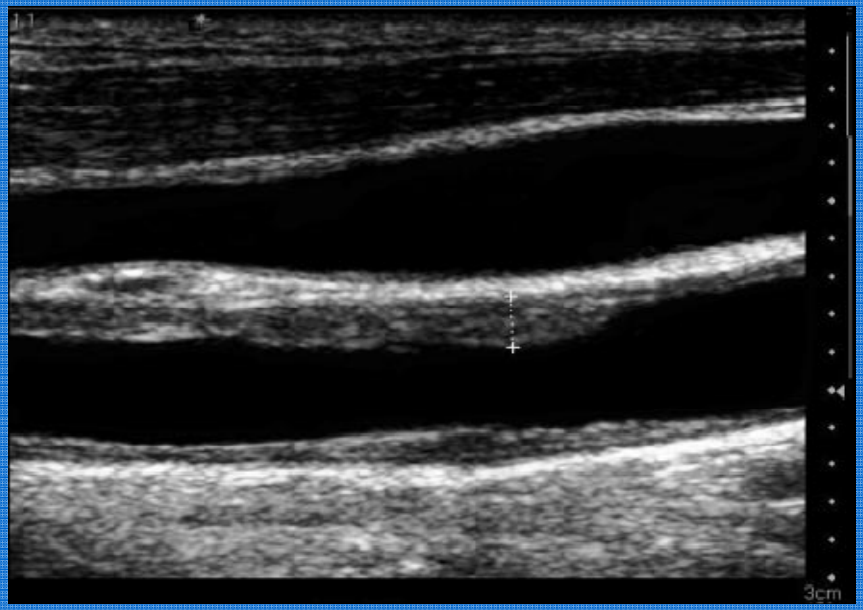
- Defined as a localized protrusion from the wall into the lumen with an area 50% greater than the intima - media thickness of neighboring sites.

- low and high echogenic plaque.
- heterogeneous or homogeneous.
- regular (smooth) or irregular.

- If more than 20% of the plaque echogenicity differed from the echogenicity of the rest of the plaque by two or more echogenicity grades – is heterogenous.

- When height variations between 0.4 and 2 mm along the contour of the lesion – is irregular

- Ulcerated plaques - recesses in the contour of the lesion at least 2 mm in depth, with a well-defined back wall at the base showing flow.

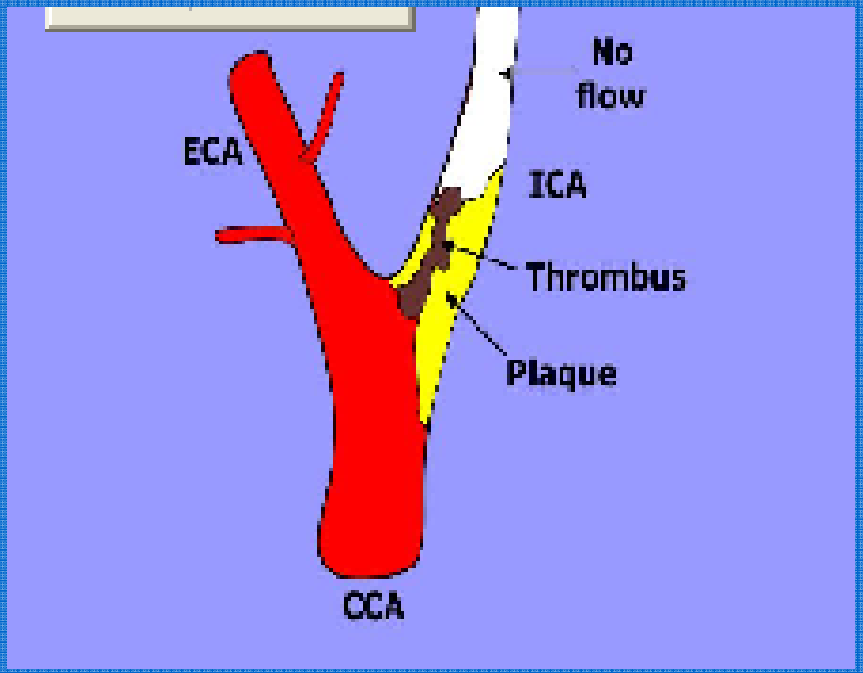

3cm

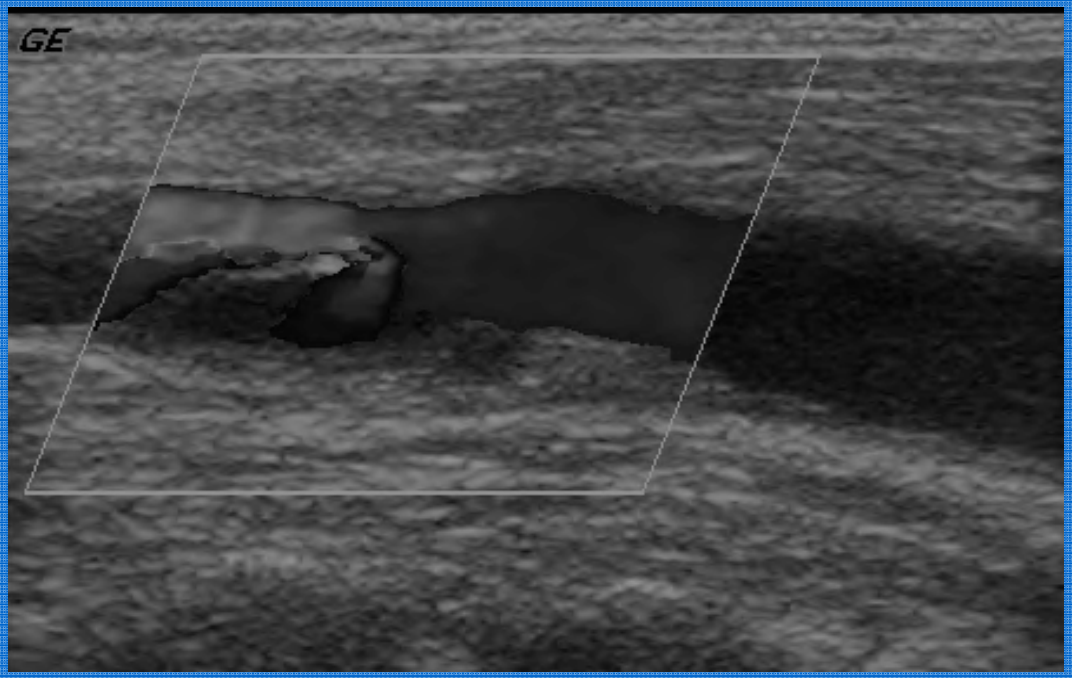

RT ICA
Heterogeneous plaque


RT ICA
Homogenous echogenic soft plaque

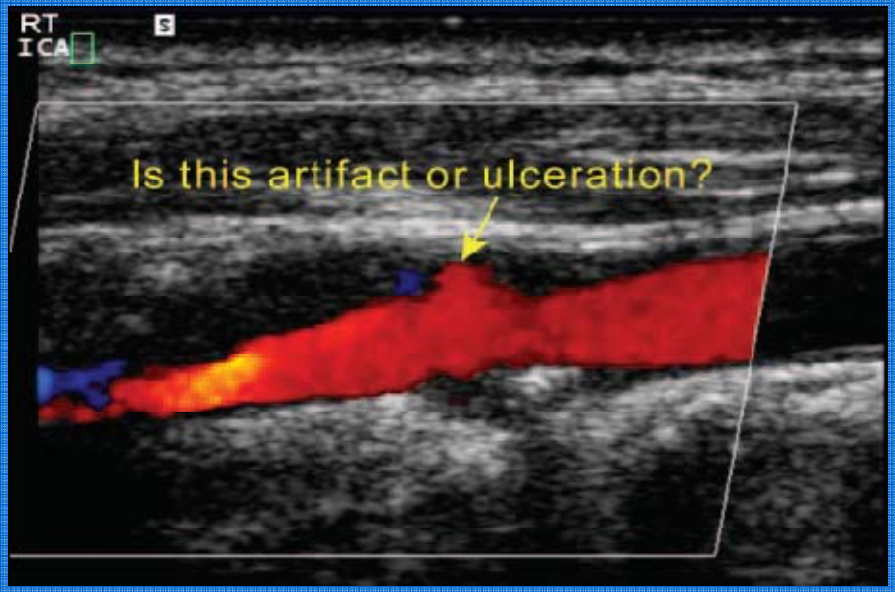

RT BIF
Intraplaque hemorrhage

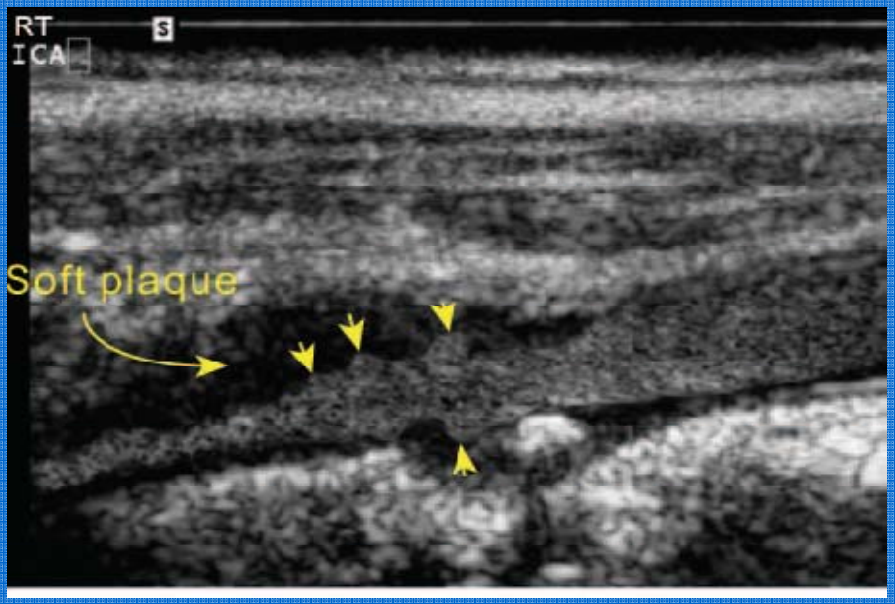
- Heterogeneous plaques and ulcerated plaques are unstable or friable
- Potential for embolic TIA and cerebro-vascular accidents

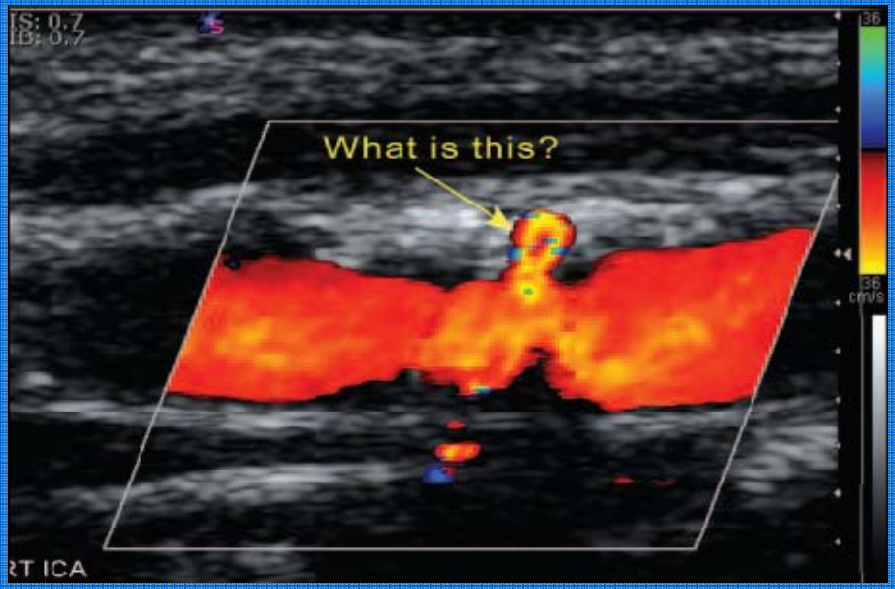


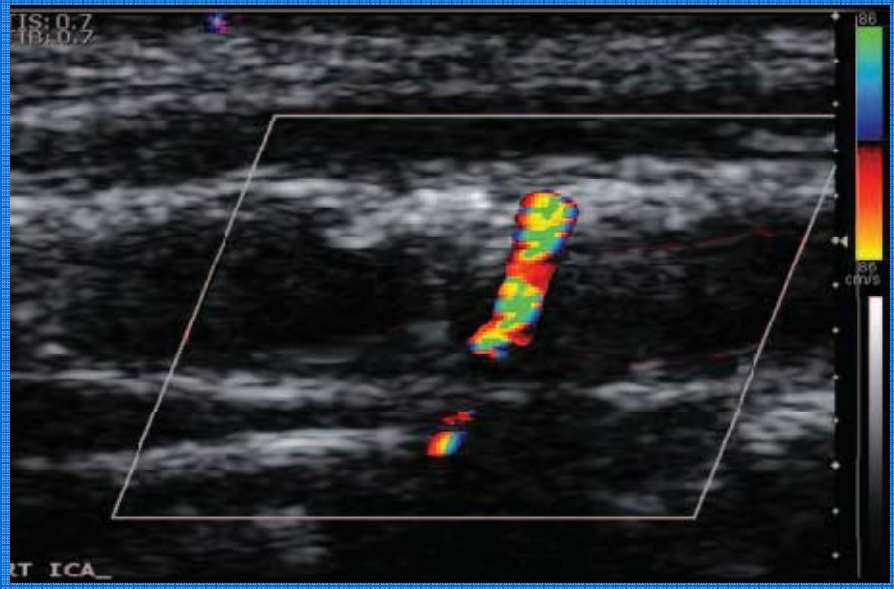



Fissuring or ulceration in the plaque


RT
ICA
S
Is this artifact or ulceration?


RT
ICA
S
Soft plaque


What is this?
RT ICA


RT ICA

## *Plaque Classification*

- ***Class I,*** *homogeneous texture, uniformly hypoechoic*
- ***Class II,*** *heterogeneous texture, predominantly hypoechoic*
- ***Class III,*** *heterogeneous texture, predominantly hyperechoic*
- ***Class IV,*** *homogeneous texture, uniformly hyperechoic*
- ***Class V,*** *unclassified calcified plaques*

## *After optimizing the setting* ****

Measure the velocity – PSV and DV

Proximal and distal CCA

ICA and ECA

Vertebral artery

Wherever stenosis present –

at stenosis

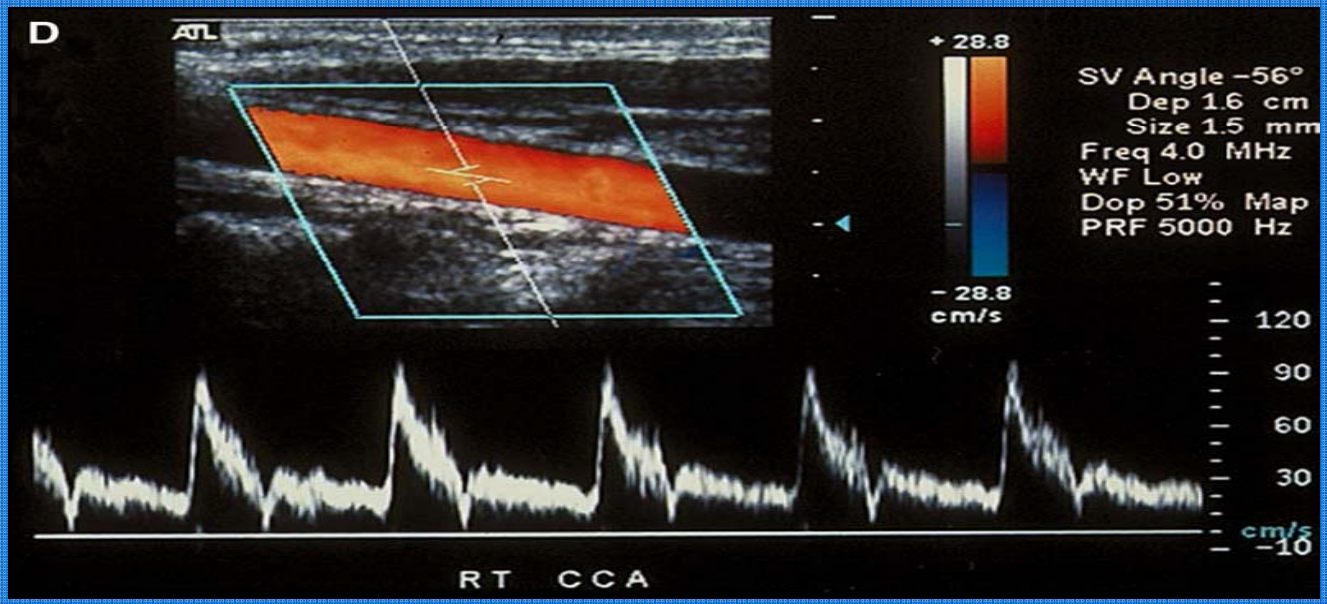
proximal to and

distal to stenosis

- Compare bilateral carotid velocities – symmetric or asymmetric

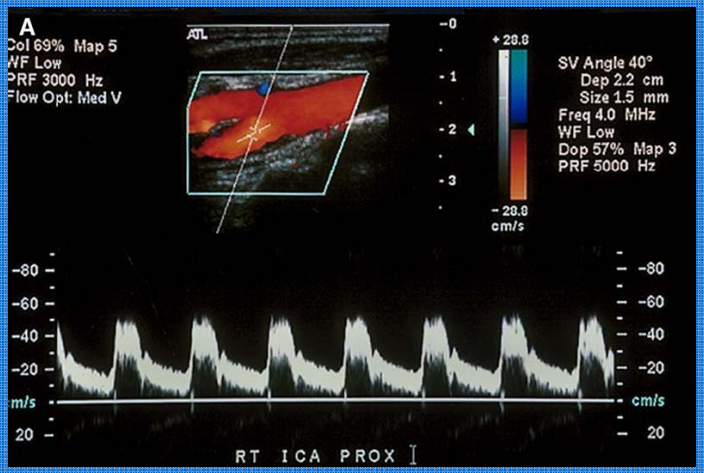
# *Waveform Analysis*
# *Normal Carotid Artery*

# CCA



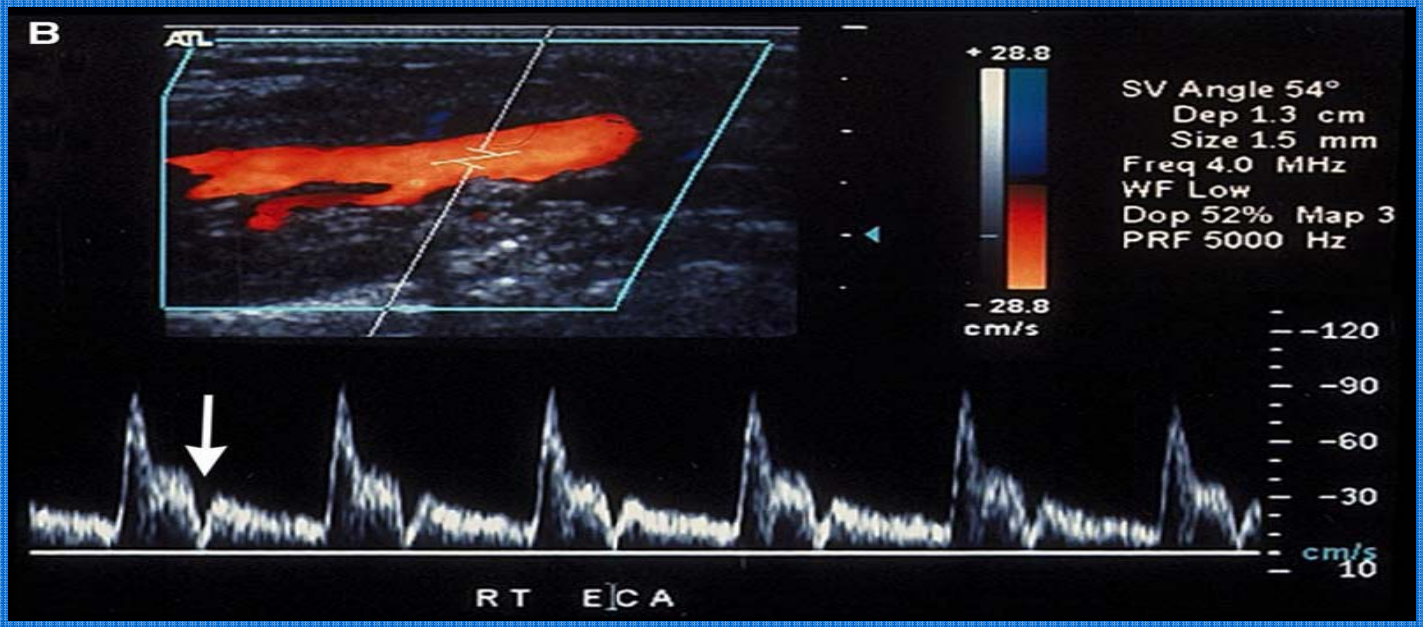

- *combination of ICA and ECA patterns,*
- *intermediate amount of continuous forward diastolic flow*
- *a sharp systolic upstroke and thin spectral envelope*
- *flow below the baseline or filling in of the spectral window normally* ***should not be seen***

# *ICA*

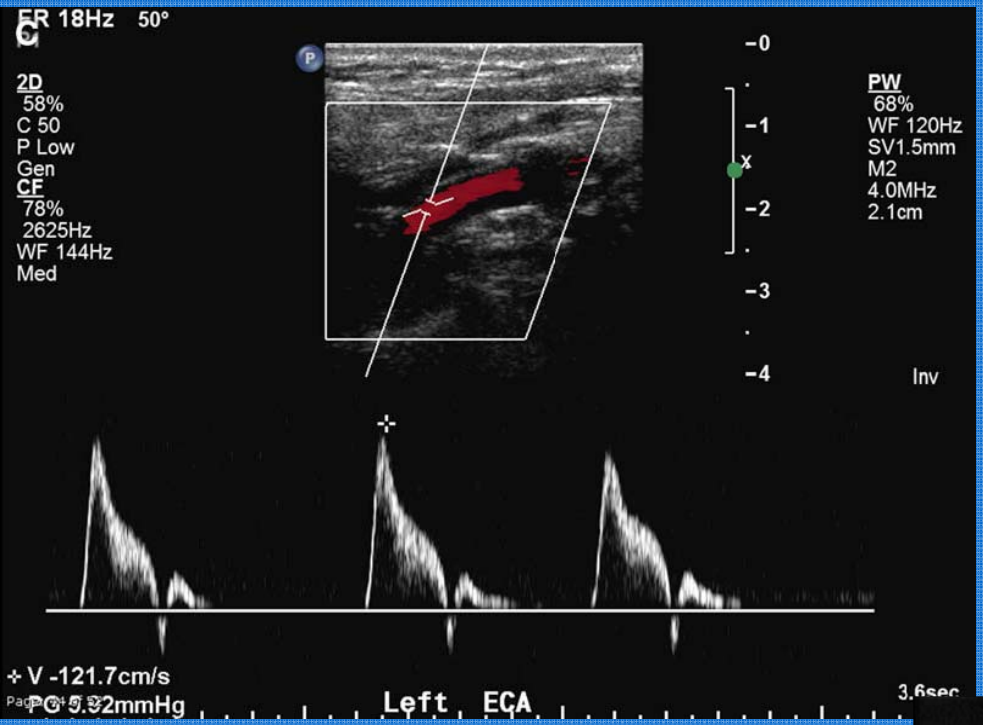


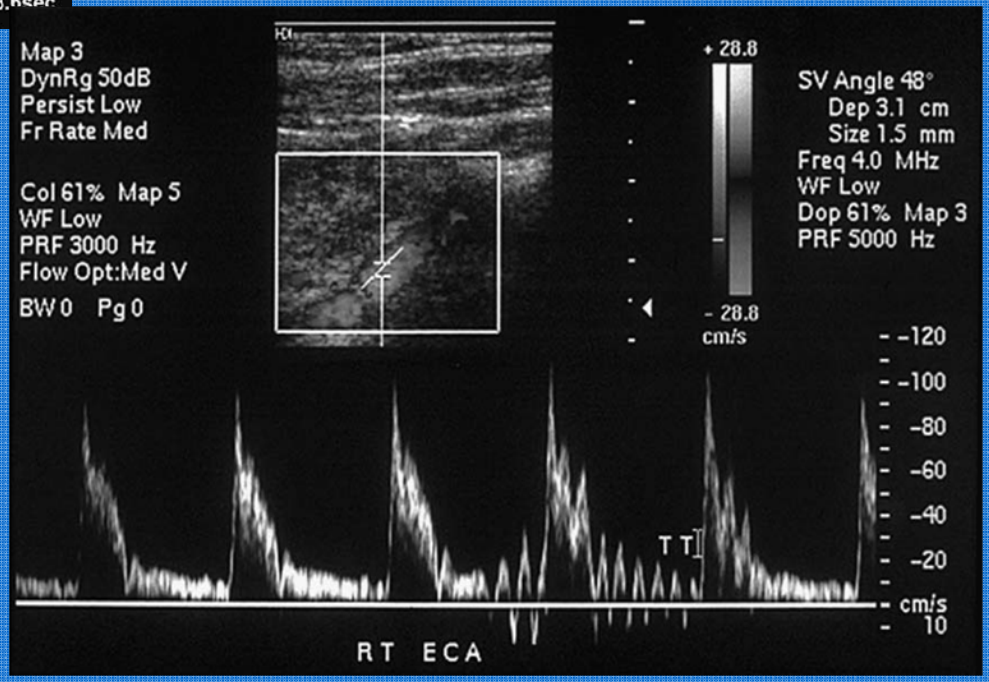

- *a low-resistance waveform pattern*
- *systolic peak should be sharp and the spectral envelope thin*
- *continuous forward diastolic flow*
- *the systolic peak may be slightly blunter than the systolic peak of the ECA*

# ECA

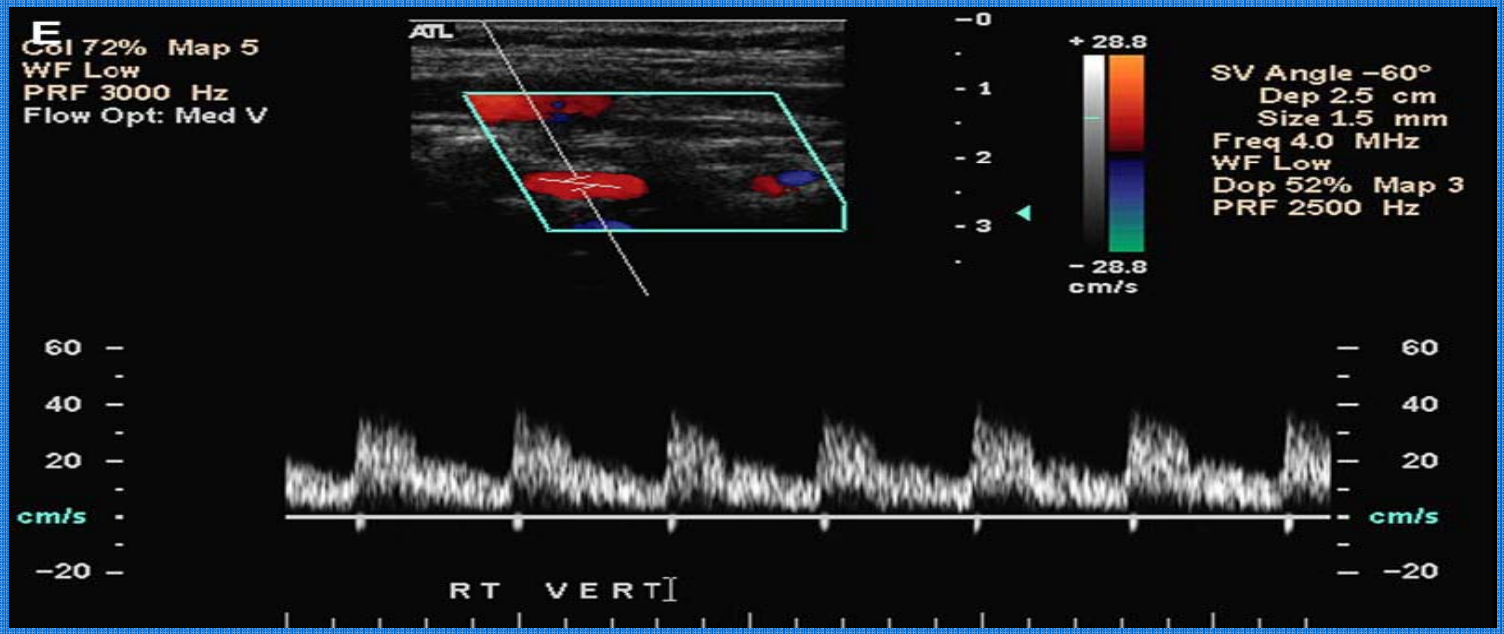



- *the systolic upstroke is sharp*
- *the spectral envelope is thin.*
- ***reduced to no diastolic flow***
- *diastolic flow should be symmetrical bilaterally*
- *Transient reversal in early diastole (characteristic early diastolic notch ) - **a normal finding***


FR 18Hz 50°
2D
58%
C 50
P Low
Gen
CF
78%
2625Hz
WF 144Hz
Med
PW
68%
WF 120Hz
SV1.5mm
M2
4.0MHz
2.1cm
Inv
V -121.7cm/s
PG 5.92mmHg
Left ECA
3.6sec


Map 3
DynRg 50dB
Persist Low
Fr Rate Med
Col 61% Map 5
WF Low
PRF 3000 Hz
Flow Opt:Med V
BW 0 Pg 0
+ 28.8
- 28.8
cm/s
SV Angle 48°
Dep 3.1 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 61% Map 3
PRF 5000 Hz
-120
-100
-80
-60
-40
-20
cm/s
10
RT ECA

# VERTEBRAL ARTERY




- *low resistance wave pattern*
- *forward diastolic flow*
- *no systolic or diastolic notch*
- *similar to carotid in flow (colour)*
- *no reversal of wave form*

## *Look At*

- *Pattern*
- *Systolic contour*
- *Diastolic pattern*
- *PSV*
- *DV*
- *ICA PSVs / CCA PSVs ratio*
- *Compare Right and Left side*

# *Abnormal CCA*

- either low or high PSVs.
- abnormally high-resistance waveform,
- an abnormally low-resistance waveform,

# Abnormally low PSVs

- A normal CCA PSV should be in the range of approximately 60 – 100 Cm/s
- IF less than this, examine opposite side

Symmetric → Low cardiac output

Asymmetric (near normal) → Evaluate further

- A velocity difference of >20 cm/sec between the right and left is abnormal.

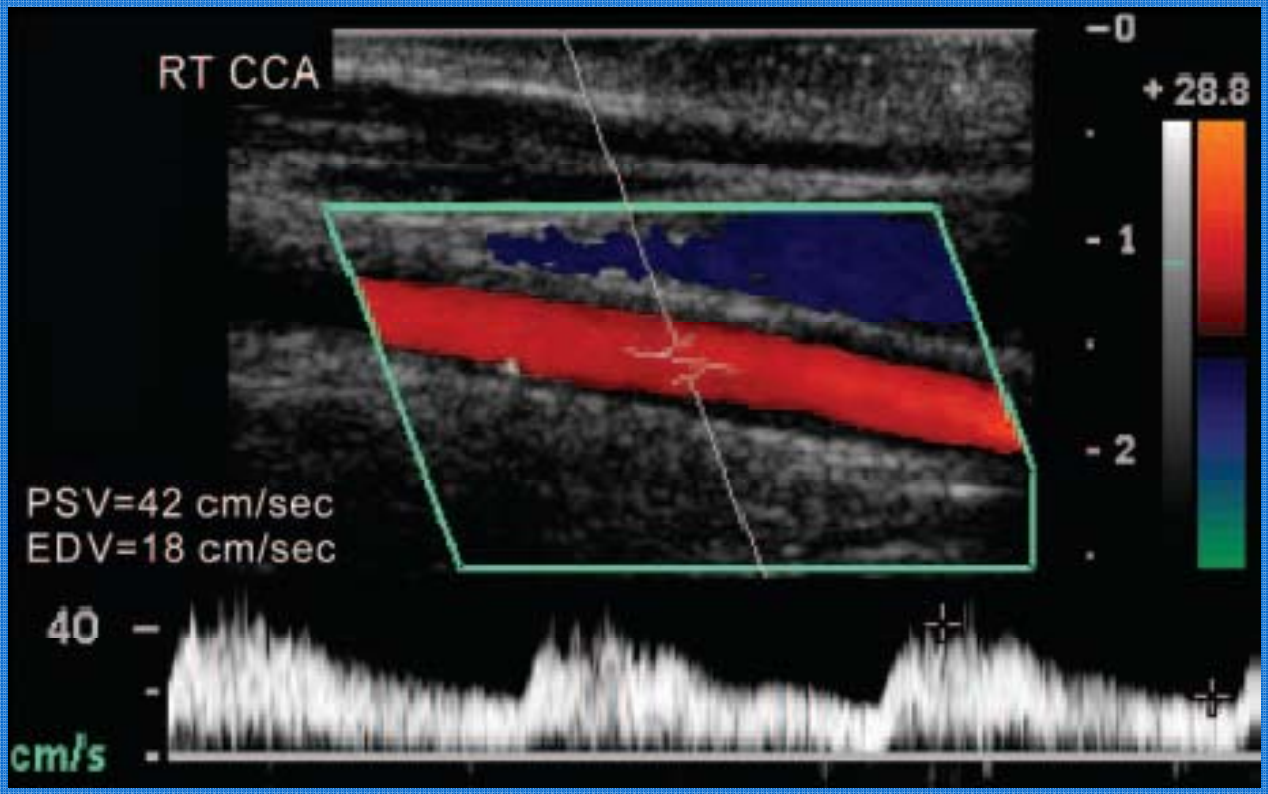
# *Causes for unilateral low PSVs*

- Proximal stenosis (brachiocephalic)

  Parvus - tardus waveform or normal pattern but asymmetrical PSVs.

- Distal stenosis (carotid bulb level)

  High resistance wave form




Innominate artery occlusion

# *High-resistance waveform in CCA*

↓

High-grade ICA stenosis or occlusion
(externalization of the CCA)

↓

Distal waveforms should be assessed
(support the diagnosis)

↓ ↓ ↓

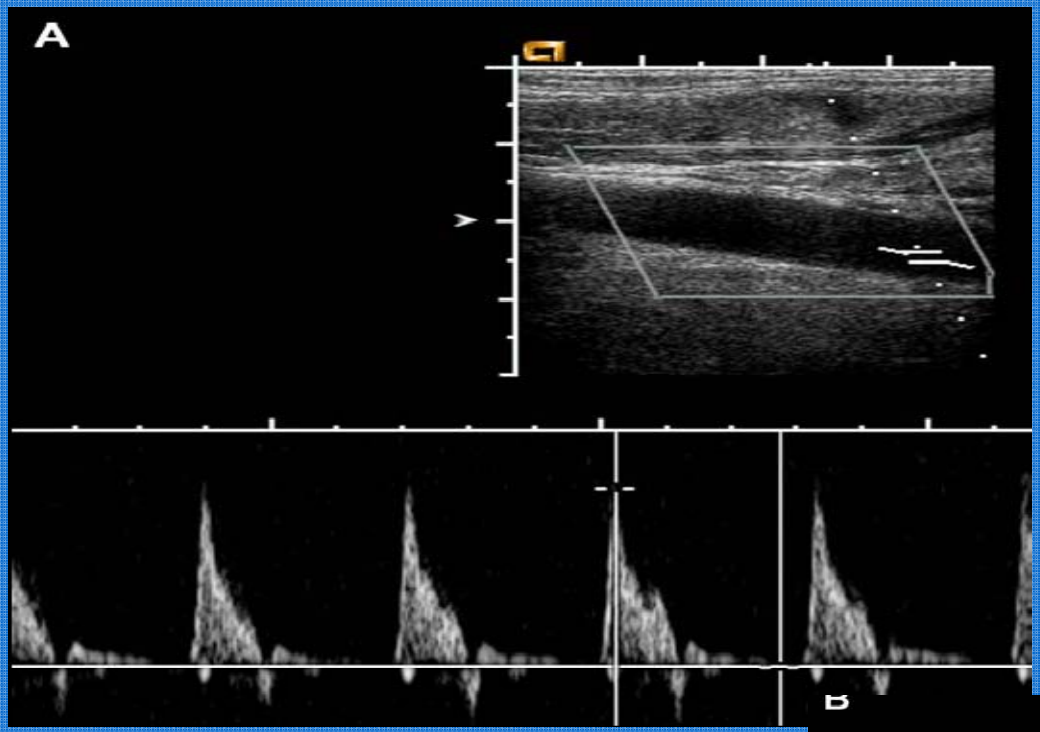
EXCEPTION IF

↓ ???

is bilateral and low PSVs indicates

↓

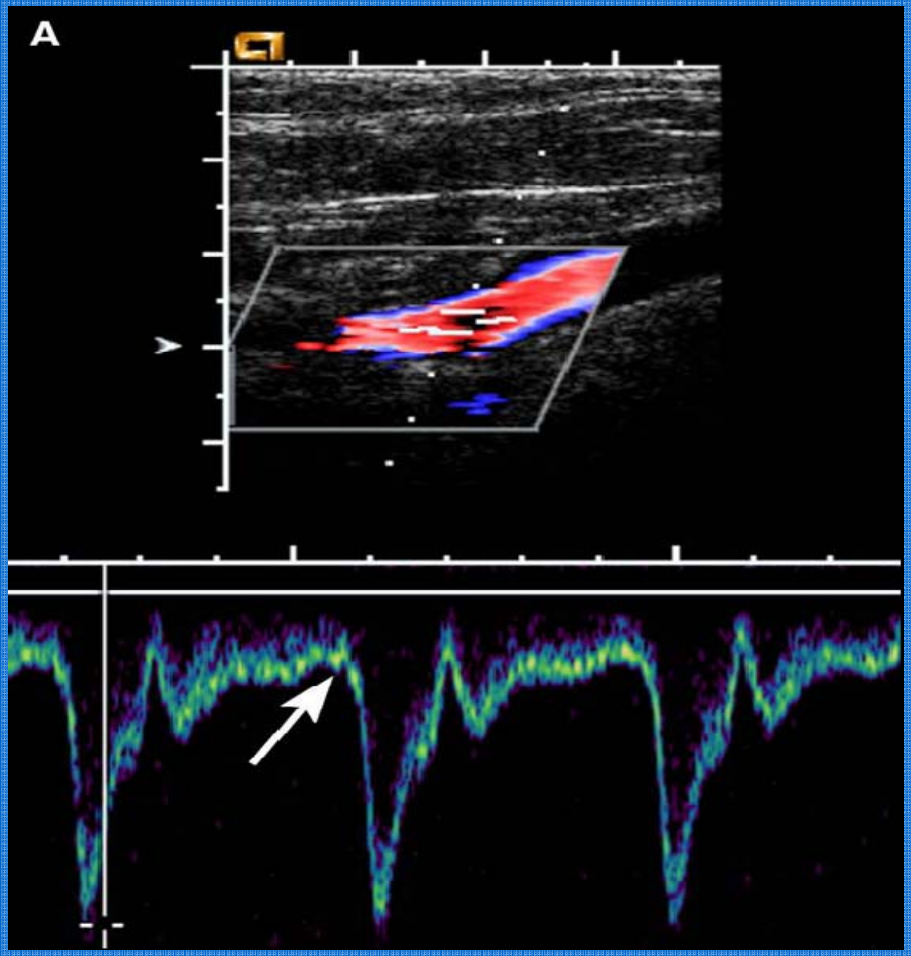
Aortic stenosis
Severe cardiac failure


A

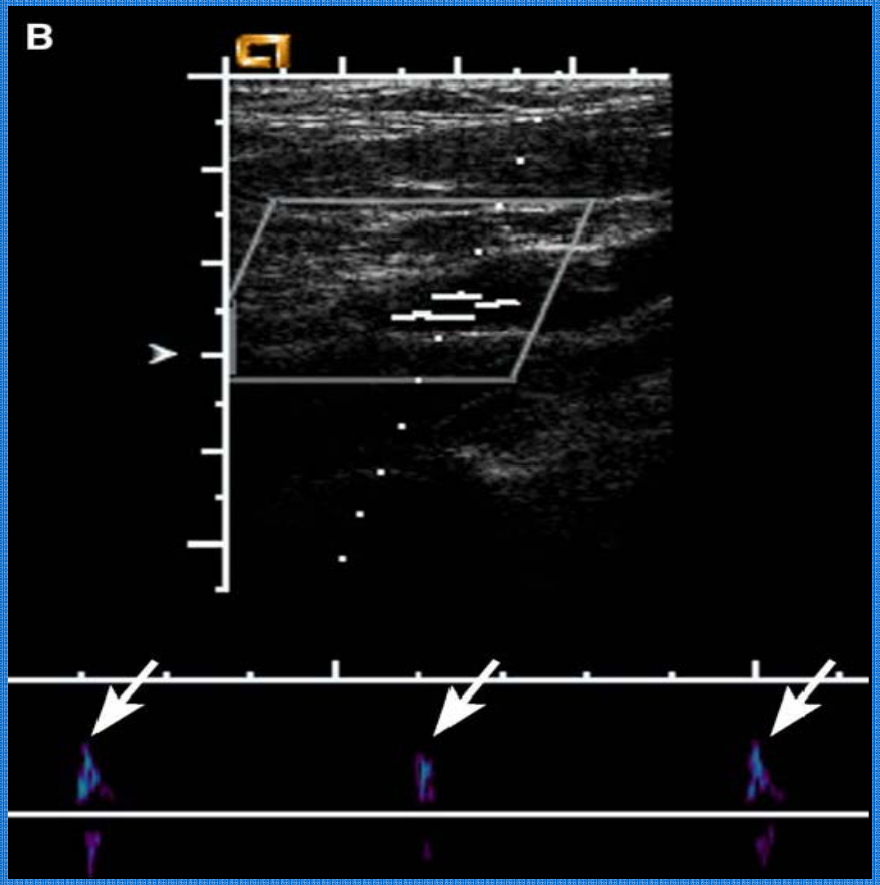
CCA

ICA


Carotid (Left)
ICA Mid psv = 0.000 m/s
> ICA Mid edv = −0.003 m/s
IC/CC = 0.000




ICA




**Internalisation of ECA**

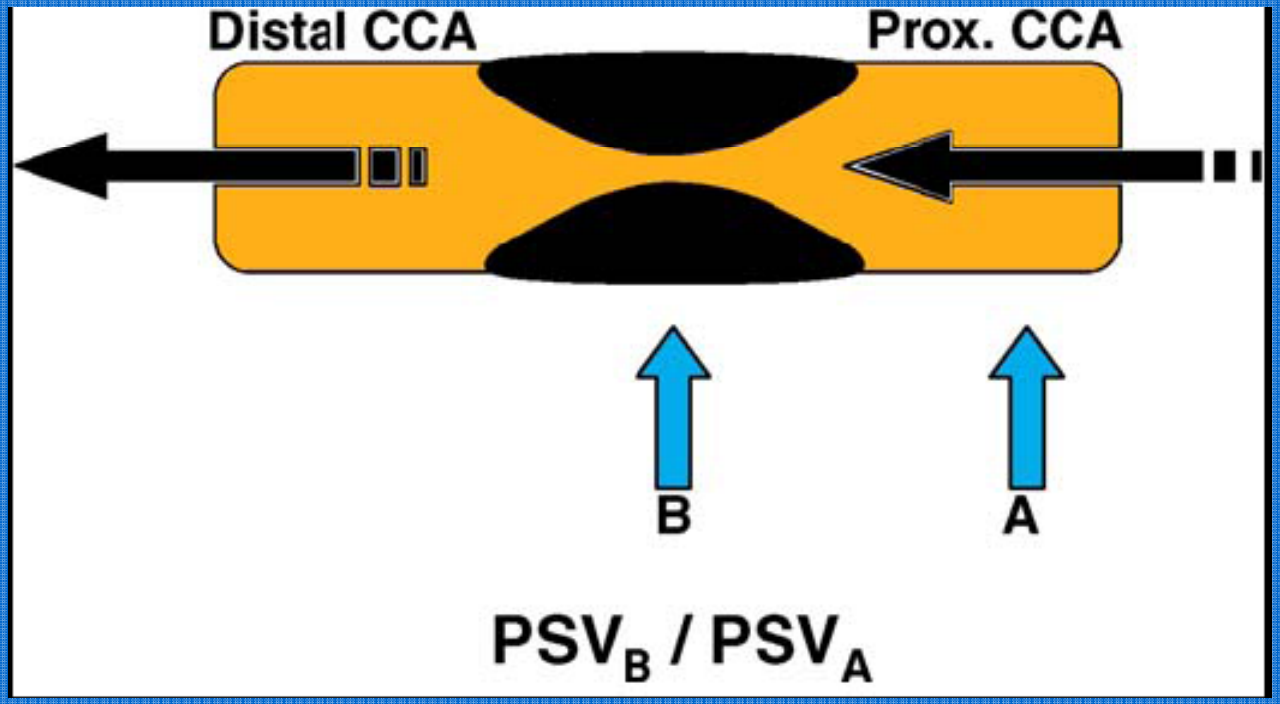
# *Focal stenosis of the CCA*

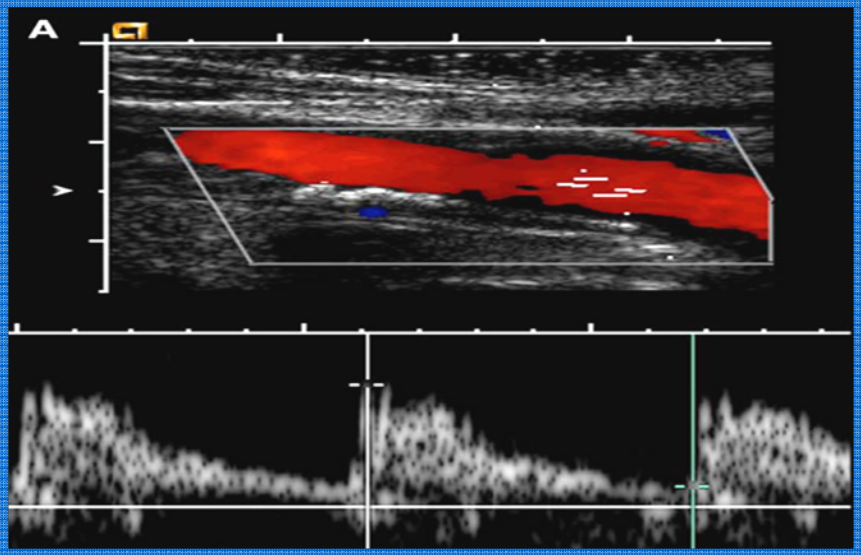
- The ratio of the highest PSV at the CCA stenosis divided by the PSV 2 cm proximal to the stenosis should be calculated.

PSVcca at stenosis/PSVcca prox.

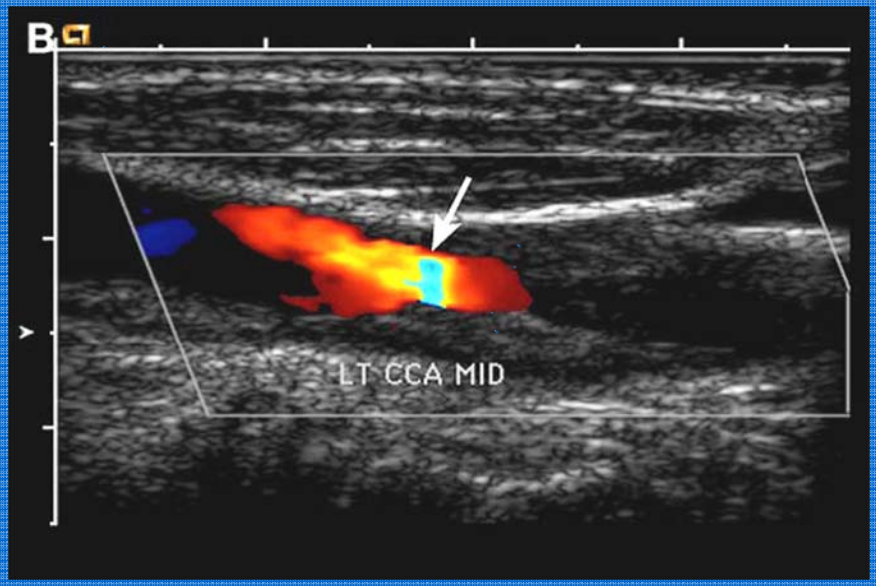
- If the ratio is 2 or more and less than 2.99 - stenosis of 50% or more.
- If the ratio is 3 or more stenosis of 75% or more.

- also used if there are tandem stenosis.

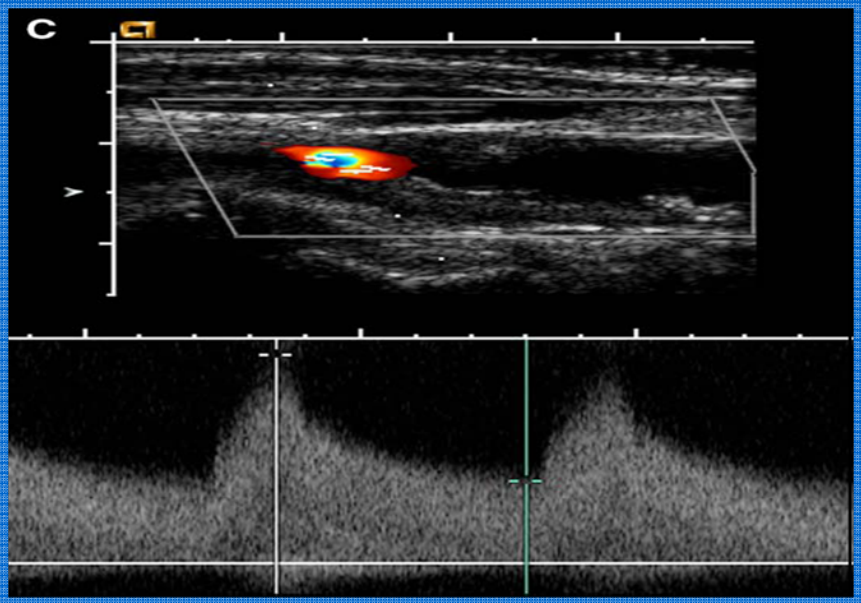

Distal CCA
Prox. CCA
B
A
PSV$_B$ / PSV$_A$



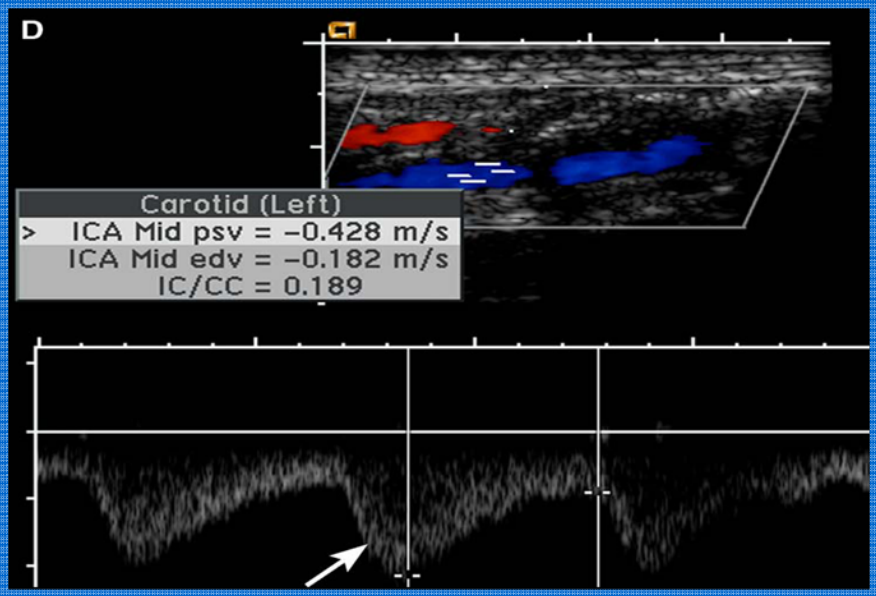

CCA - mildly elevated resistance




Luminal narrowing with color Aliasing




High-velocity flow 627 cm/s, turbulence

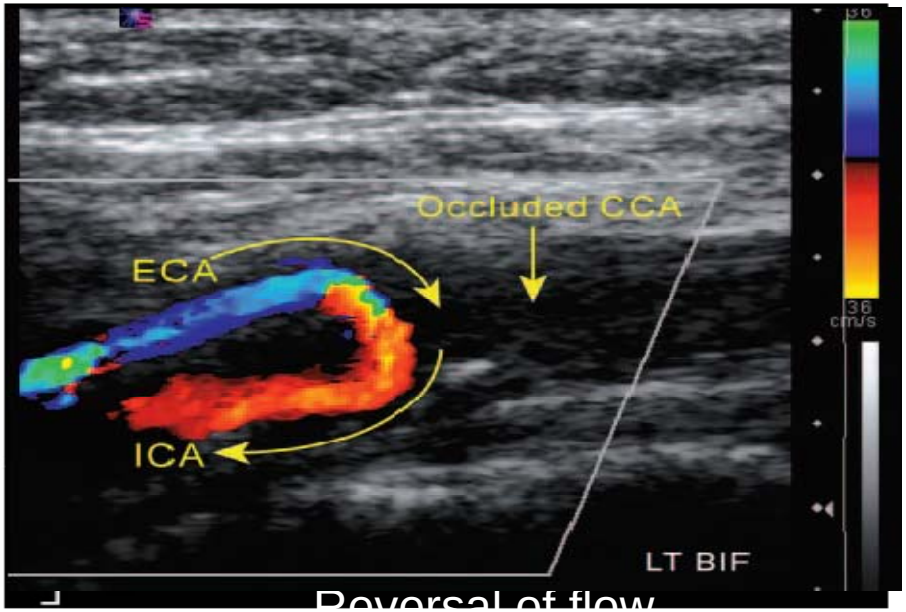



ICA- tardus-parvus waveform

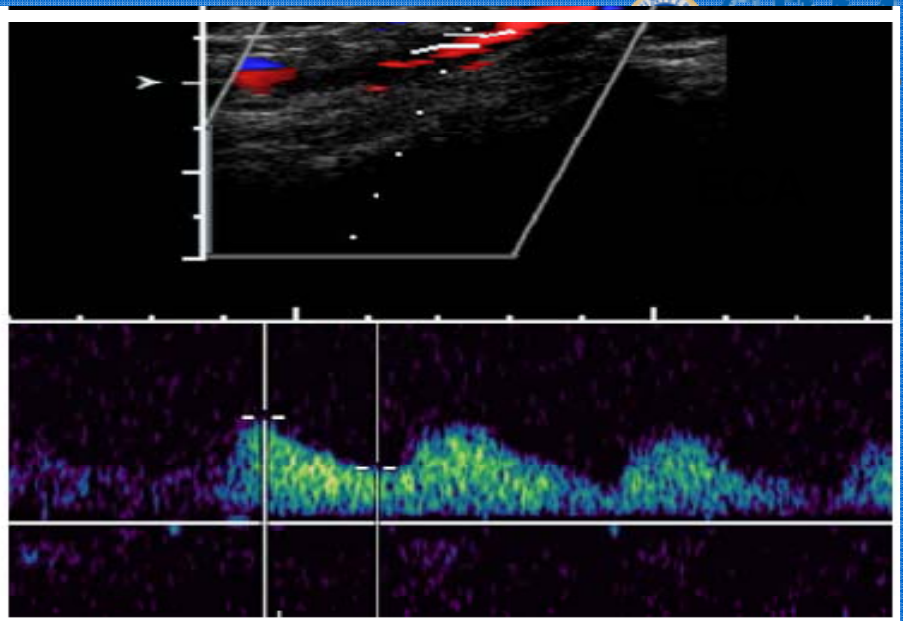
Unusual finding in Case of CCA occlusion

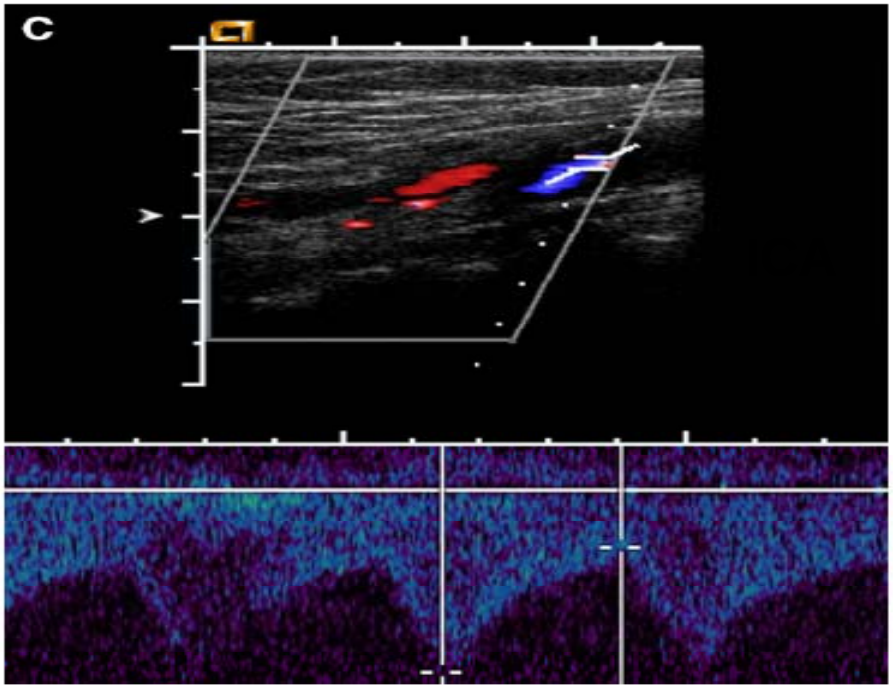
Reversal of flow in ECA and low resistance and low PSVs in ICA as it is fed by collaterals.

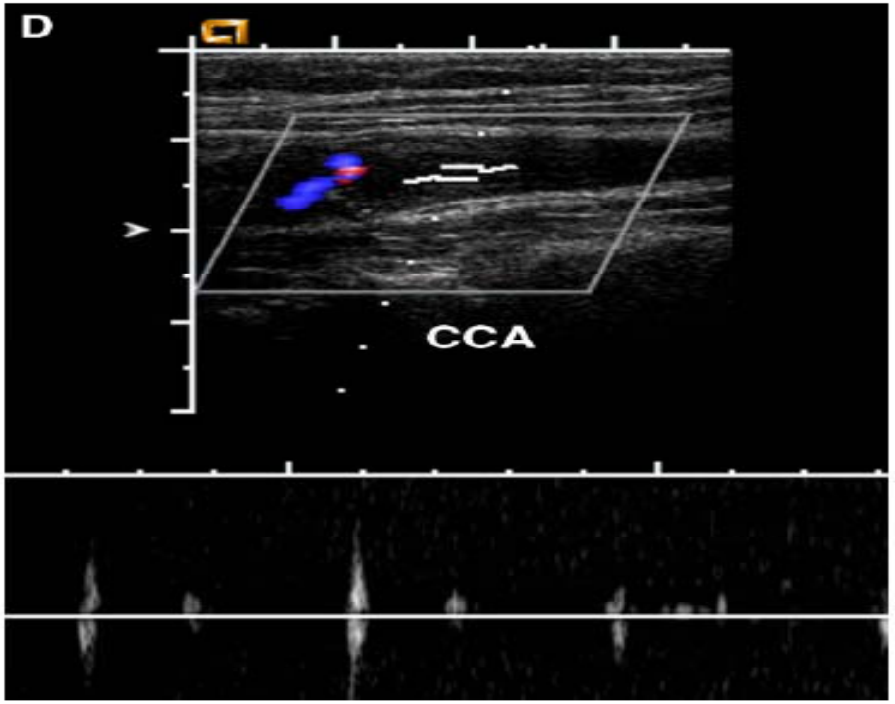
This is to maintain the antegrade flow in ICA

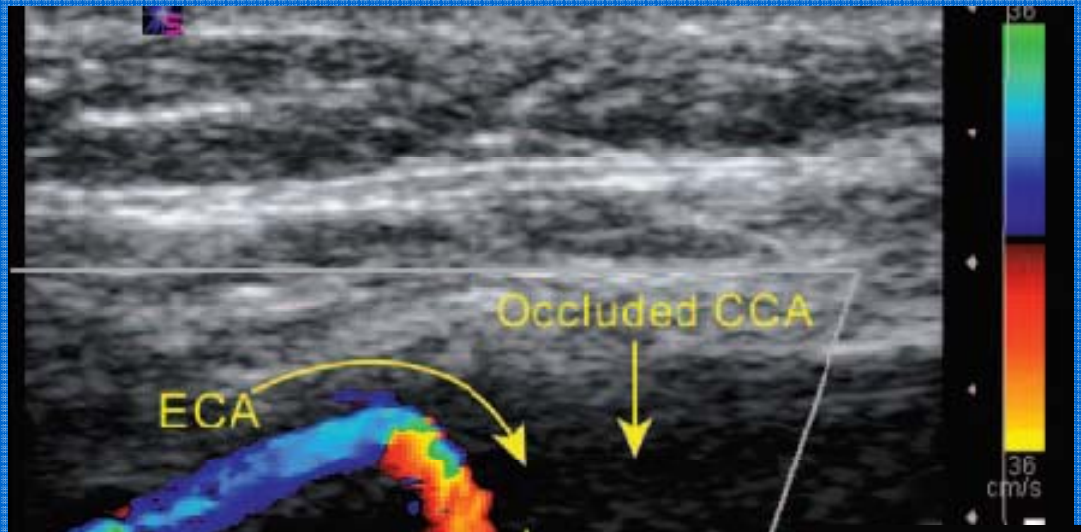


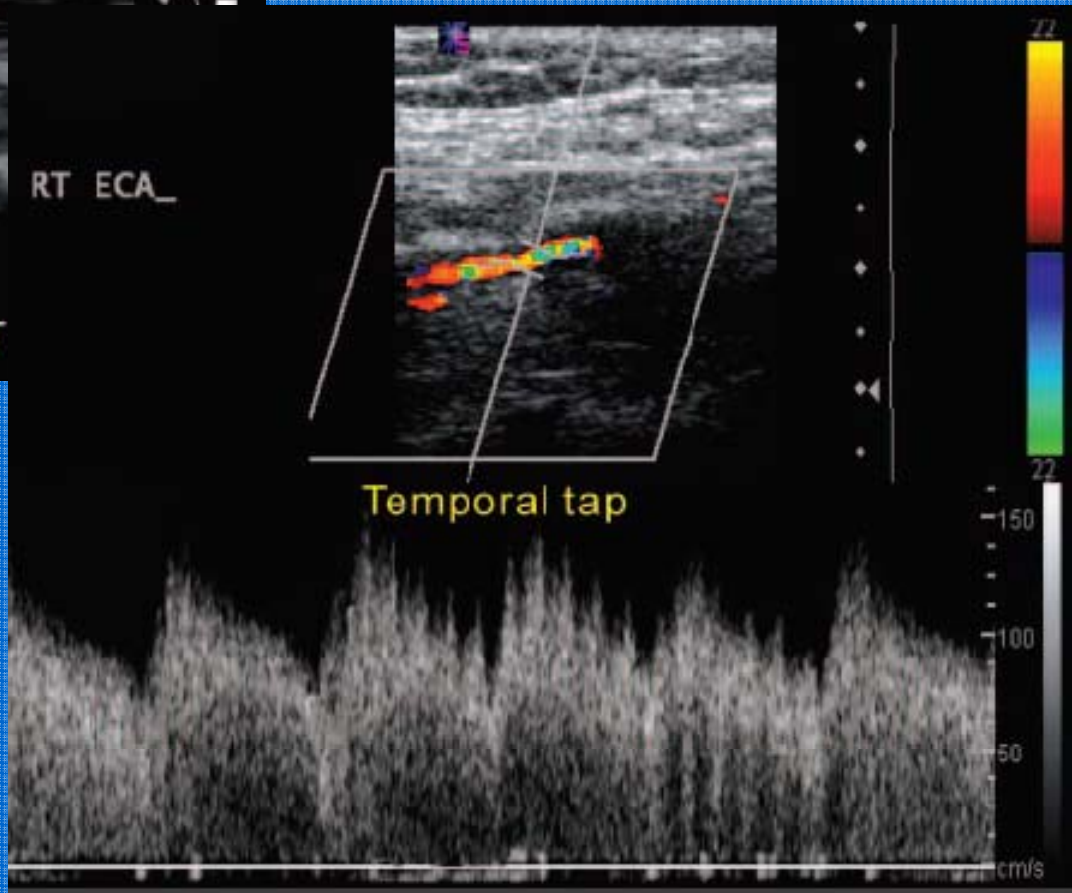

Reversal of flow






Occluded CCA
ECA
ICA
36
cm/s
LT


RT ECA_
Temporal tap
150
100
50
cm/s

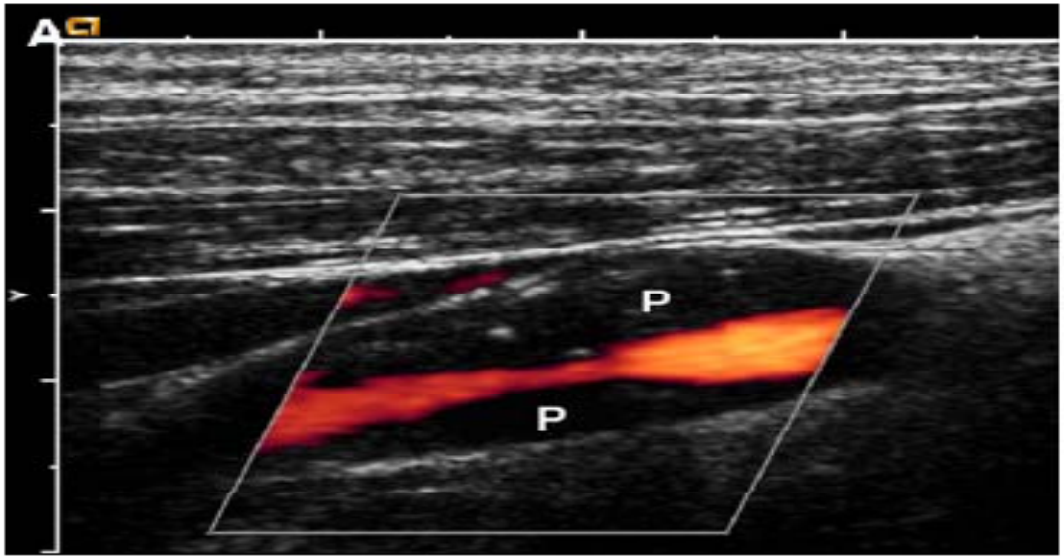
# *Remember….*

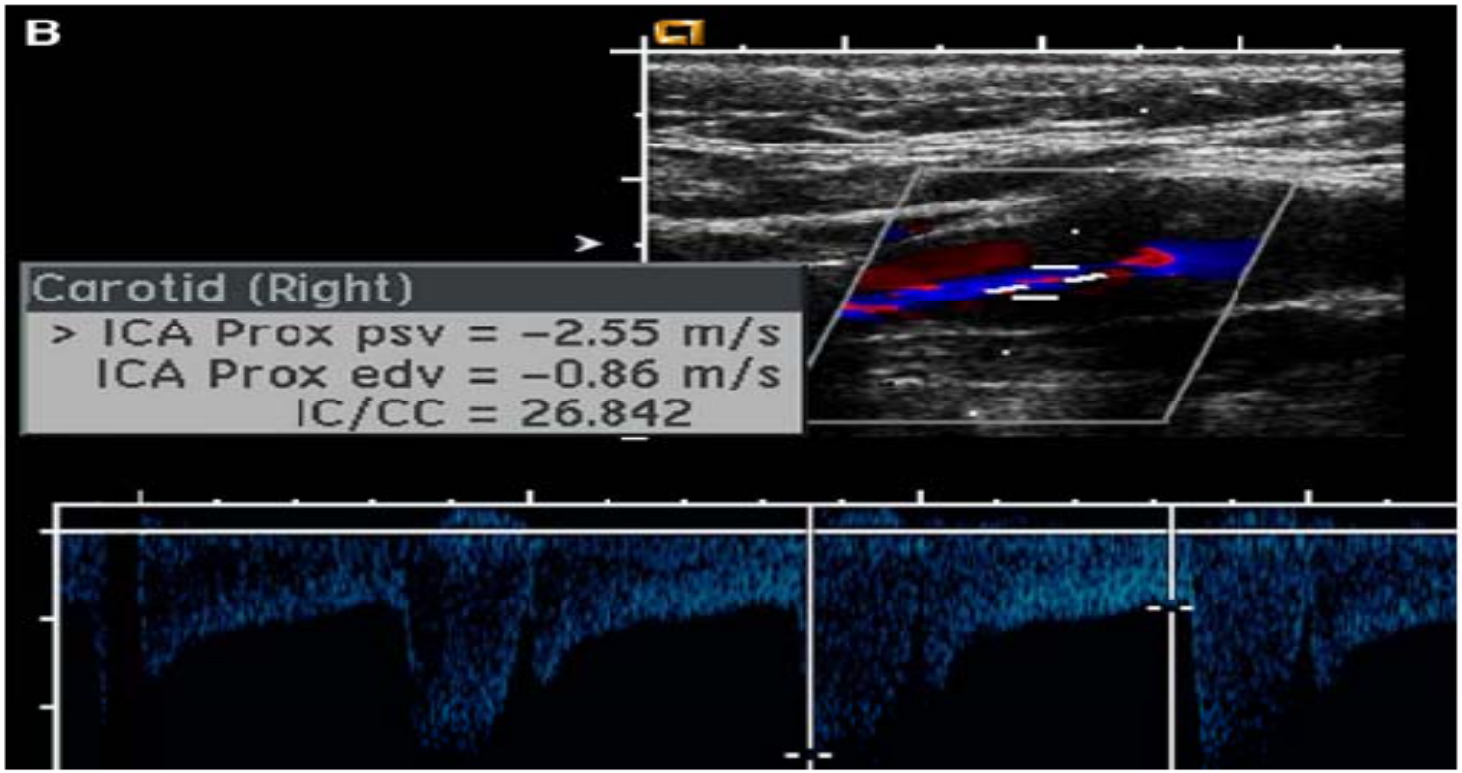
- If the stenosis is unilateral, there is marked asymmetry in the systolic contour of the waveforms of the right and the left CCAs.

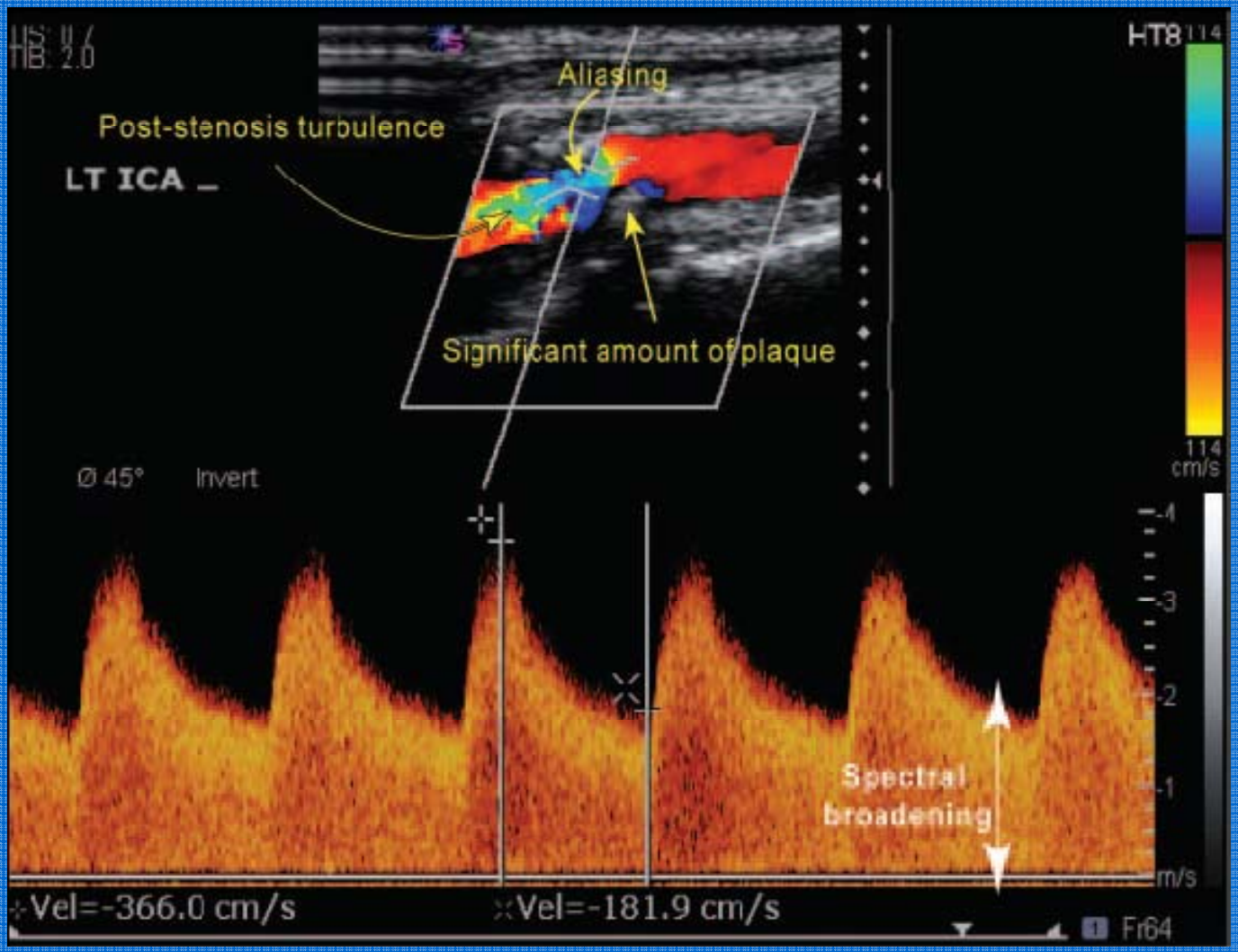
- If the stenosis is central, such as with aortic stenosis, the waveforms are affected bilaterally.

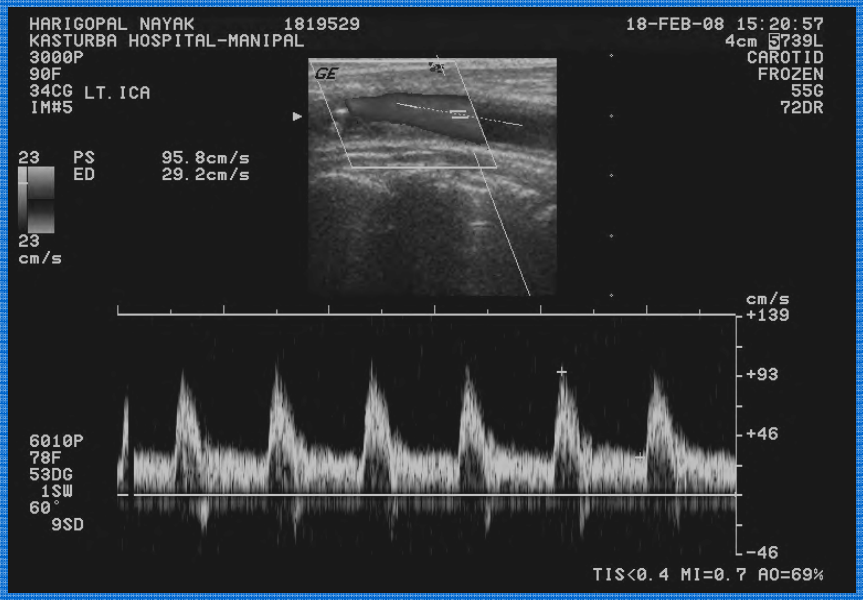
# *ICA*

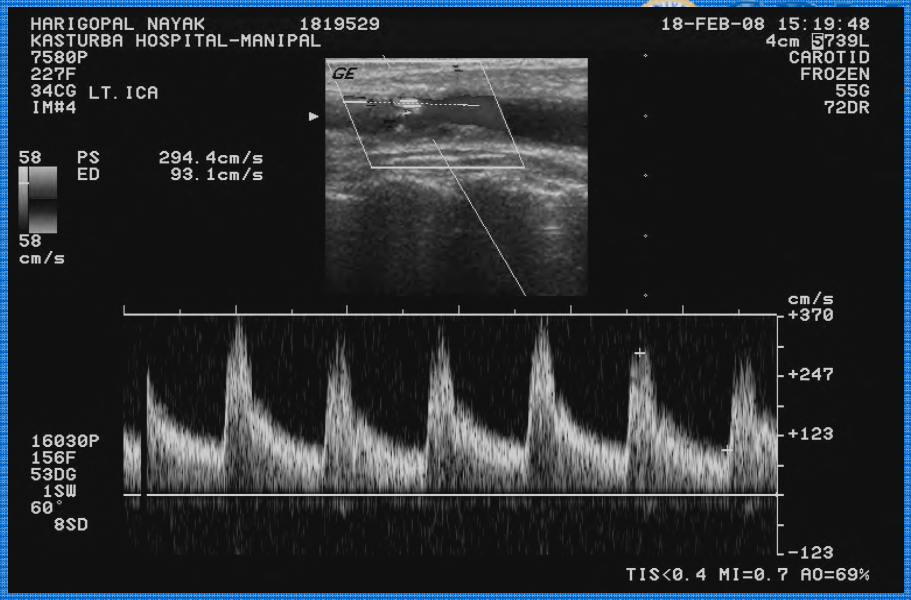
- Normal is - low resistance with high diastolic pattern.
- Most common site is ICA origin – plaque extending from the bulb.
- High resistance pattern in the ICA- Stenosis distally.
- PSVs raises - Significant stenosis


A
P
P


B
Carotid (Right)
> ICA Prox psv = −2.55 m/s
ICA Prox edv = −0.86 m/s
IC/CC = 26.842


Aliasing
Post-stenosis turbulence
LT ICA
Significant amount of plaque
Ø 45°
Invert
Spectral broadening
Vel=-366.0 cm/s
Vel=-181.9 cm/s
cm/s
m/s


HARIGOPAL NAYAK 1819529
KASTURBA HOSPITAL-MANIPAL
3000P
90F
34CG LT.ICA
IM#5
18-FEB-08 15:20:57
4cm 5739L
CAROTID
FROZEN
55G
72DR
23 PS 95.8cm/s
ED 29.2cm/s
23
cm/s
cm/s
+139
+93
+46
-46
6010P
78F
53DG
1SW
60°
9SD
TIS<0.4 MI=0.7 AO=69%


HARIGOPAL NAYAK 1819529
KASTURBA HOSPITAL-MANIPAL
7580P
227F
34CG LT.ICA
IM#4
18-FEB-08 15:19:48
4cm 5739L
CAROTID
FROZEN
55G
72DR
58 PS 294.4cm/s
ED 93.1cm/s
58
cm/s
cm/s
+370
+247
+123
-123
16030P
156F
53DG
1SW
60°
8SD
TIS<0.4 MI=0.7 AO=69%

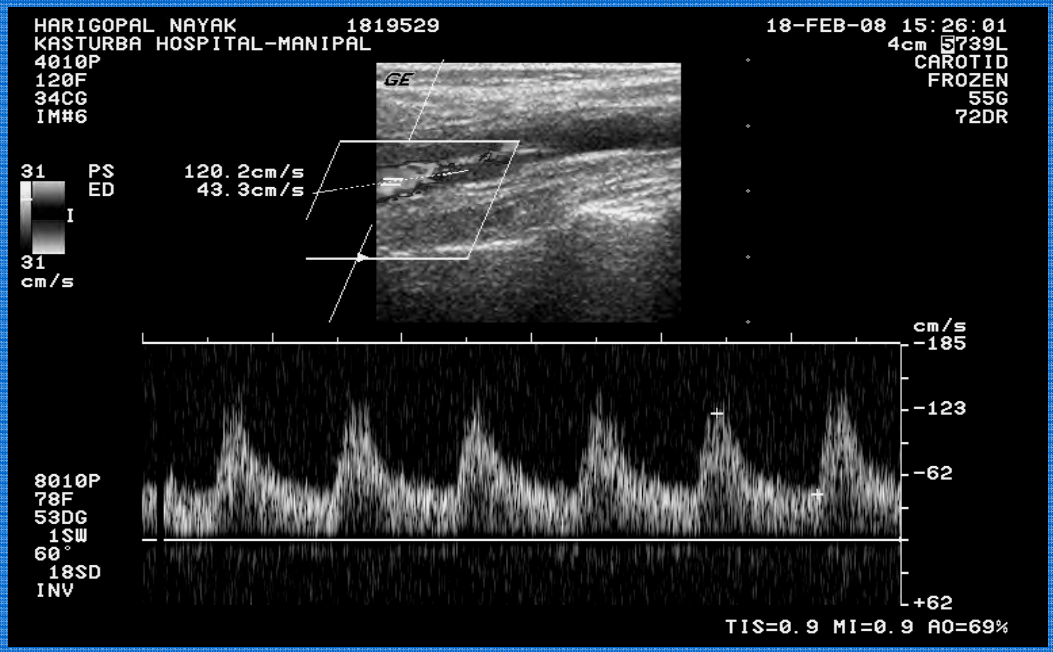
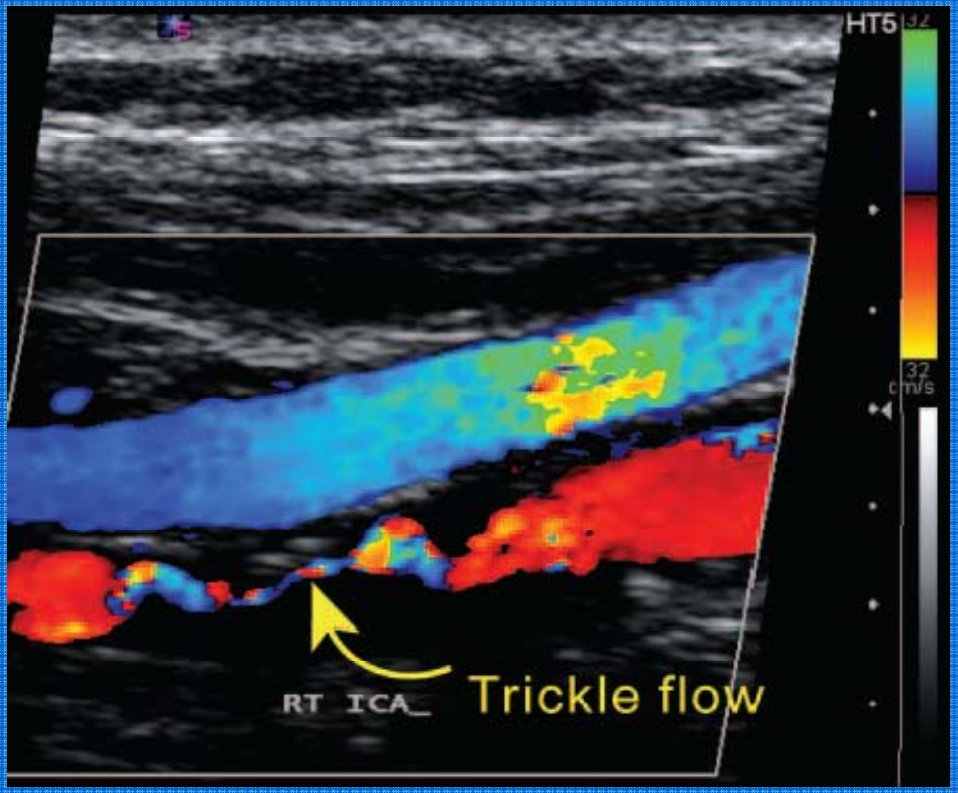

HARIGOPAL NAYAK 1819529
KASTURBA HOSPITAL-MANIPAL
4010P
120F
34CG
IM#6
18-FEB-08 15:26:01
4cm 5739L
CAROTID
FROZEN
55G
72DR
31 PS 120.2cm/s
ED 43.3cm/s
31
cm/s
cm/s
-185
-123
-62
+62
8010P
78F
53DG
1SW
60°
18SD
INV
TIS=0.9 MI=0.9 AO=69%

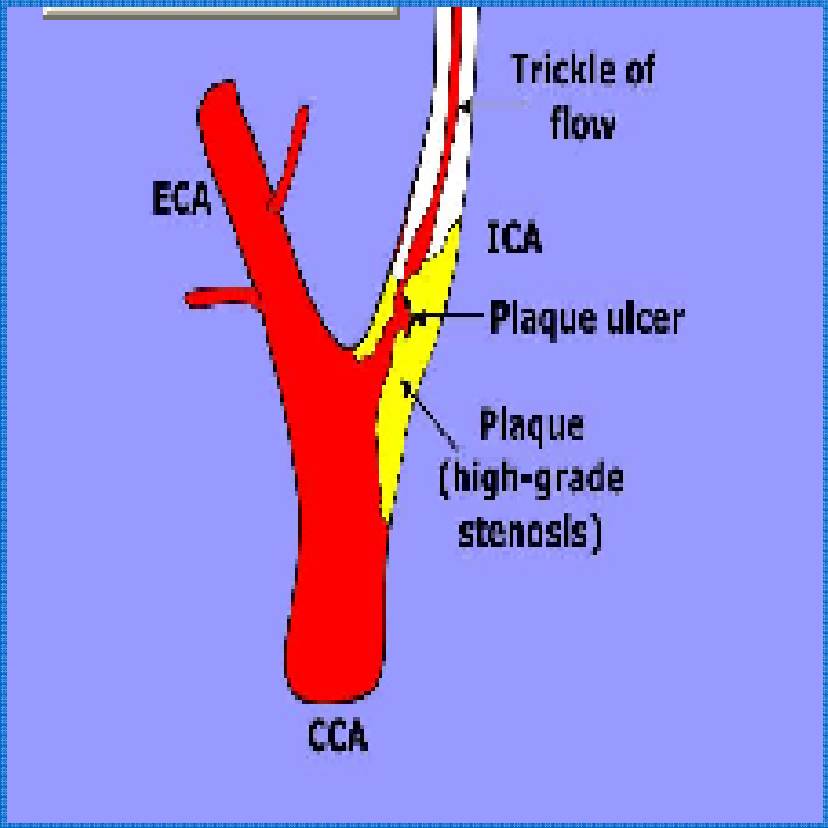
*Table 1:* Doppler criteria for internal carotid artery diameter stenosis detection developed by the Society of Radiologists in Ultrasound consensus conference

| | ICA PSV cm/s | Plaque/diameter | ICA/CCA ratio = $PSV_{ICA}/PSV_{CCA}$ | ICA EDV cm/s |
|---|---|---|---|---|
| Normal | <125 | None | <2 | <40 |
| <50% | <125 | <50% | <2 | <40 |
| 50%–69% | 125–230 | ≥50% | 2–4 | 40–100 |
| ≥70 to near occlusion | >230 | ≥50% | >4 | >100 |
| Near occlusion | High, low, or undetectable | Visible | Variable | Variable |
| Total occlusion | Undetectable | Visible, no detectable lumen | N/A | N/A |

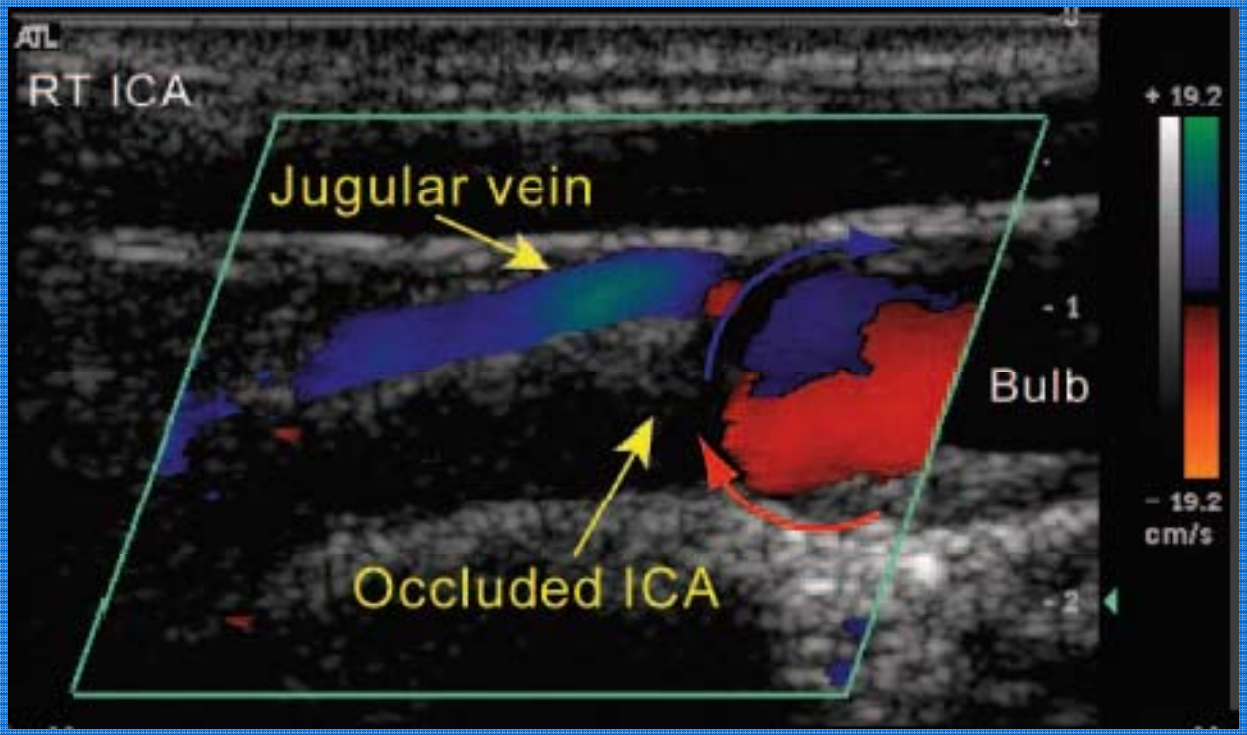
Carotid Stenosis Criteria

| Stenosis | Peak Systolic Velocity (cm/s) | Peak End Diastolic Velocity (cm/s) | Peak Systolic Velocity Ratio |
|---|---|---|---|
| <50 | <150 | <50 | <2.0 |
| 50-59 | 150-200 | 50-70 | 2.0-2.5 |
| 60-69 | 200-250 | 50-70 | 2.5-3.0 |
| 70-79 | 250-325 | 70-90 | 3.0-3.5 |
| 80-89 | 325-400 | 70-100 | 3.5-4.0 |
| 90-99 | >400 | >100 | >4.0 |
| Occlusion | Not applicable | Not applicable | Not applicable |




# String sign - Near Total Occlusion




# Total Occlusion

*Near Total Occlusion or Total*

**Table 2**
**Optimal Color and PW Doppler Imaging Parameters for Enhancing Detection of Trickle Flow in Near Occlusion of the ICA**

| Parameter | Recommended Setting |
|---|---|
| Transducer frequency | <7 MHz |
| Color box | Steer to the center or straight position |
| Sample volume box | Steer to the center or straight position |
| Focal zone | At the level of the diseased segment |
| Color velocity scale | Decrease to <15 cm/sec |
| PW Doppler scale | Decrease to <15 cm/sec |
| Color Doppler gain | Increase to the point of visible background noise |
| PW Doppler gain | Increase to the point of visible background noise |
| Wall filter | Decrease to low |
| Color threshold | Increase to ≥80% |
| Sample volume gate | Increase to ≥2.5 mm |

# *Normal PSVs in ICA always normal ???*

- As the stenotic grade increases PSVs start falling as flow through the tight stenosis reduces

- So measure EDV - which raises
- Measure ratio – ICA, PSVs / CCA PSVs
- Normal to <50% stenosis ratio will be < 2
- As the stenosis increases ratio becomes > 4 or variable, internalization of ECA, opposite ICA PSVs increases

Pitfalls----

Tortuous artery

Plaque which is shadowing

severe stenosis

## *So assess ICA*

- In gray scale for amount of luminal narrowing
- Assess velocities in proper settings
- Should assess PSV, EDV and ratio of PSVs in ICA and CCA
- Assessed proximally, mid and distally
- If no color flow demonstrated in a tight stenotic segment even in power doppler confirm with other modality
- Assess opposite ICA for compensatory flow

# *ECA*

Confirm the ECA

Is there any reversal of flow

Is there any internalization

# *VERTEBRAL ARTERY*

- LOOK AT

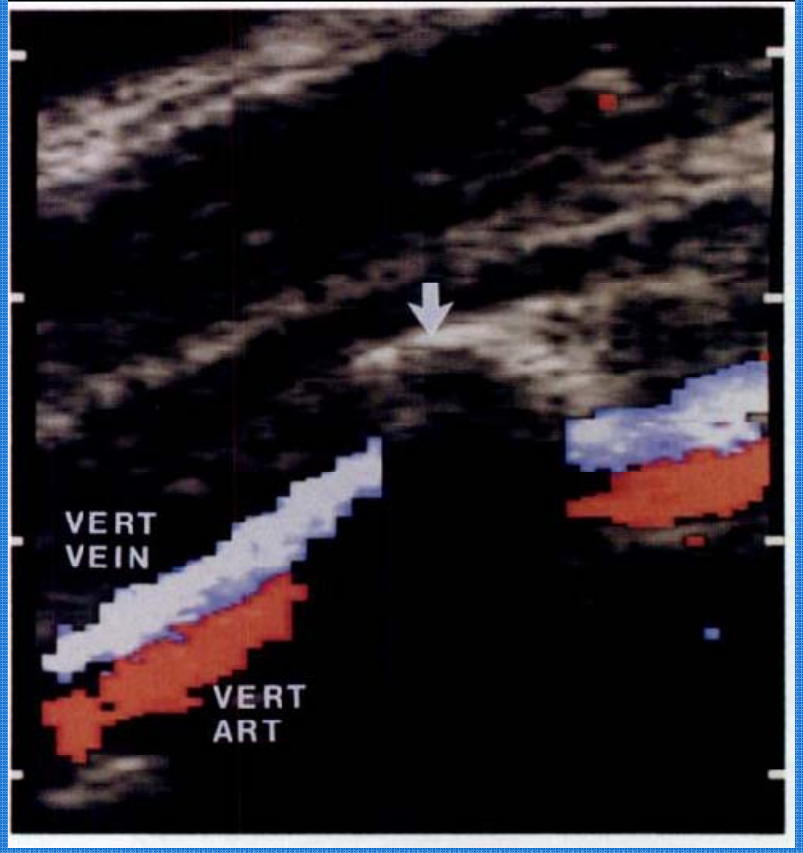
  Normal or hypoplastic or not seen

  Waveform pattern

  Direction of flow

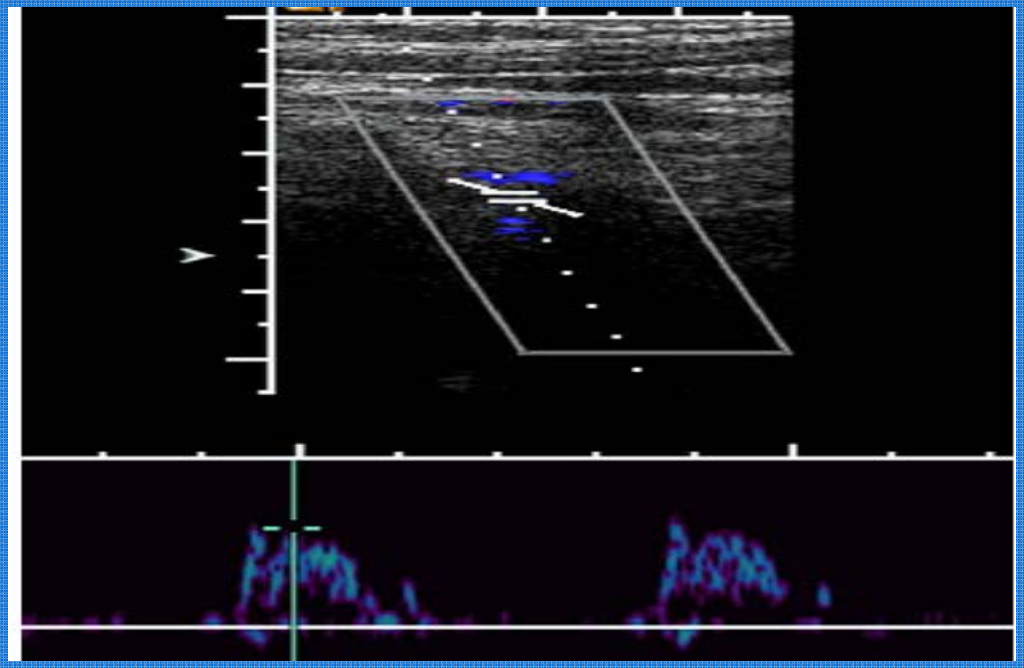
  PSVs

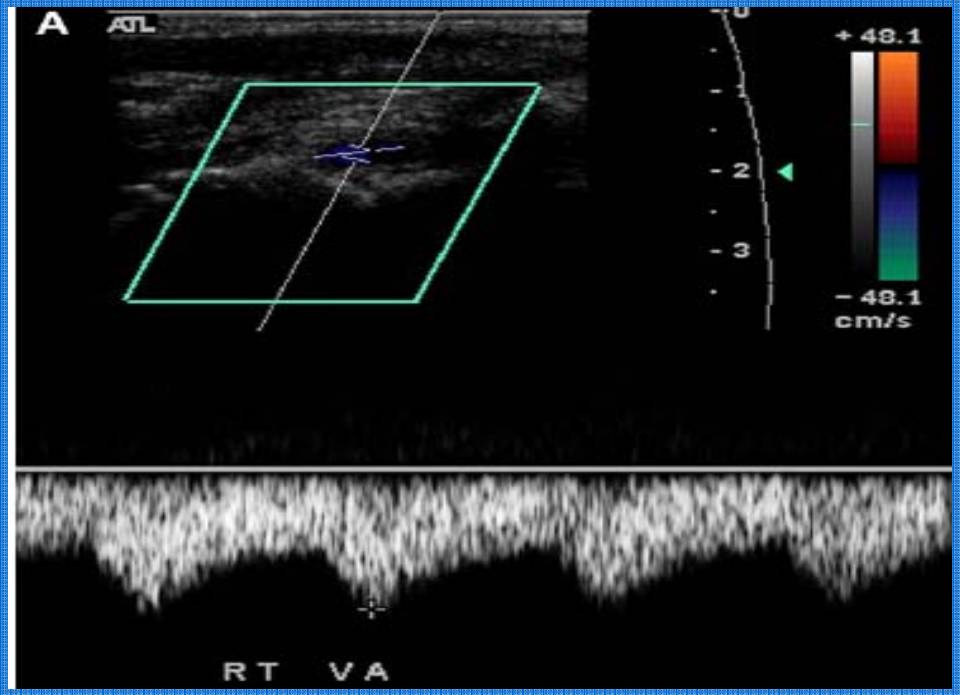
- **Reversal of flow** – stenosis or occlusion at subclavian or brachiocephalic artery
- **Transient systolic reversal** – in lesser digree stenosis
- **High resistance wave pattern** – distal occlusion or stenosis
- **Low resistance wave pattern** – more proximal stenosis




High resistance vertebral artery

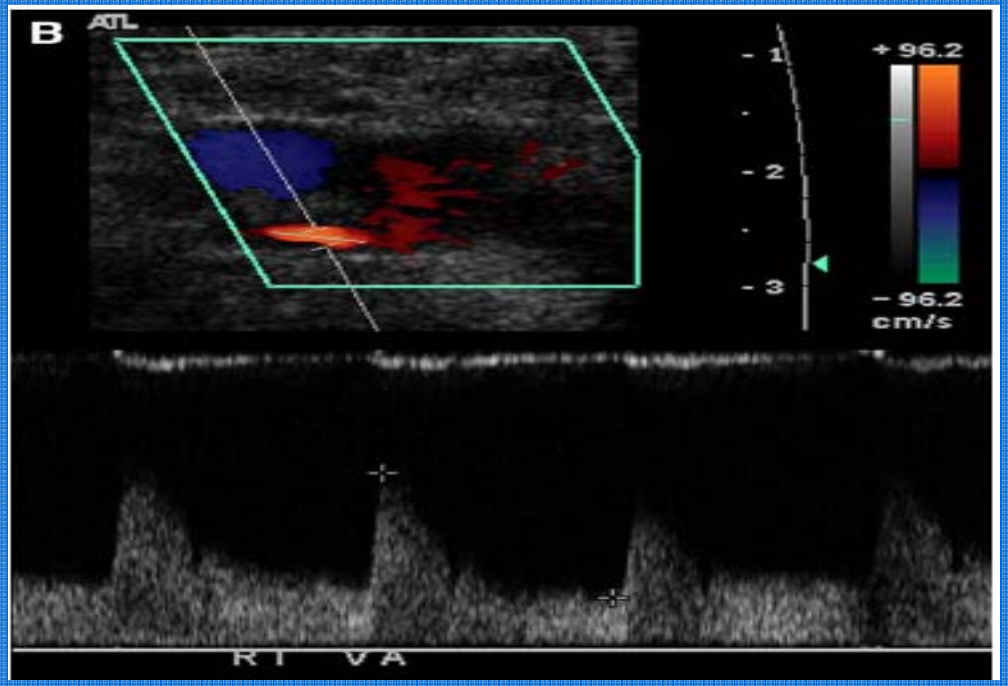
Distal vertebral stenosis






Parvus tardus

Stenosis at vertebral origin- high PSV



# Pitfall--

If not seen

?

Occlusion or small or congenitally absent

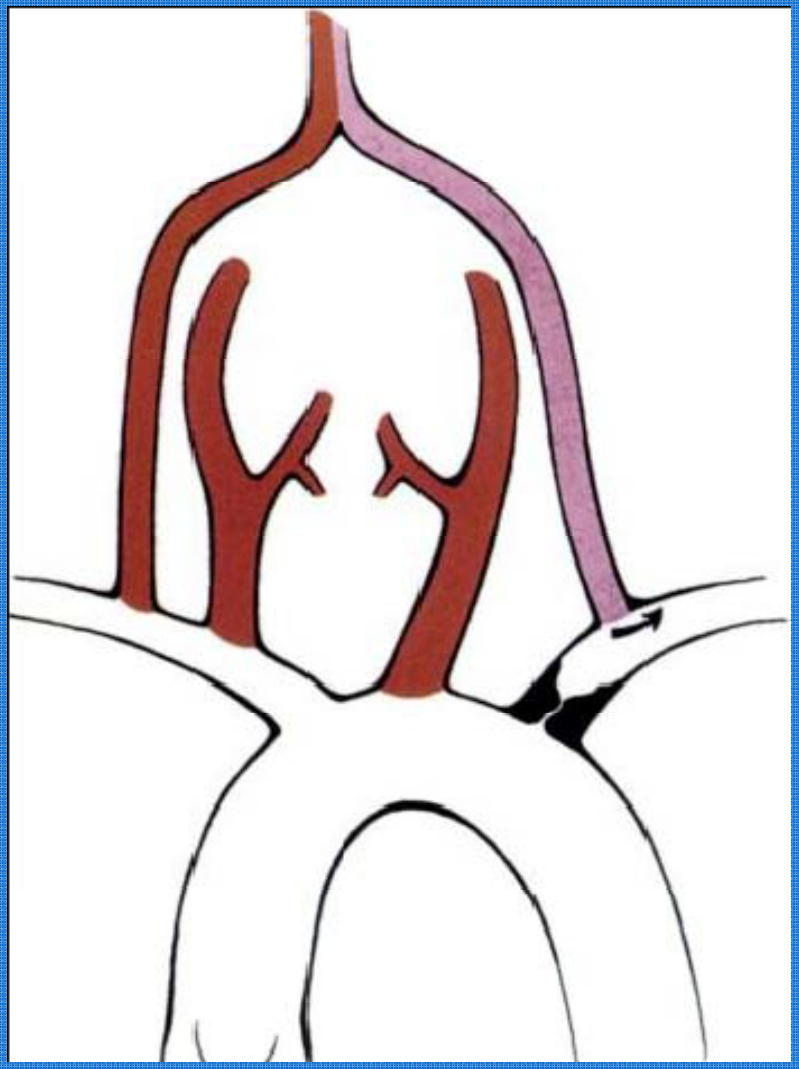
Clinical correlation and other modality helps

# *SUBCLAVIAN STEAL SYNDROME*

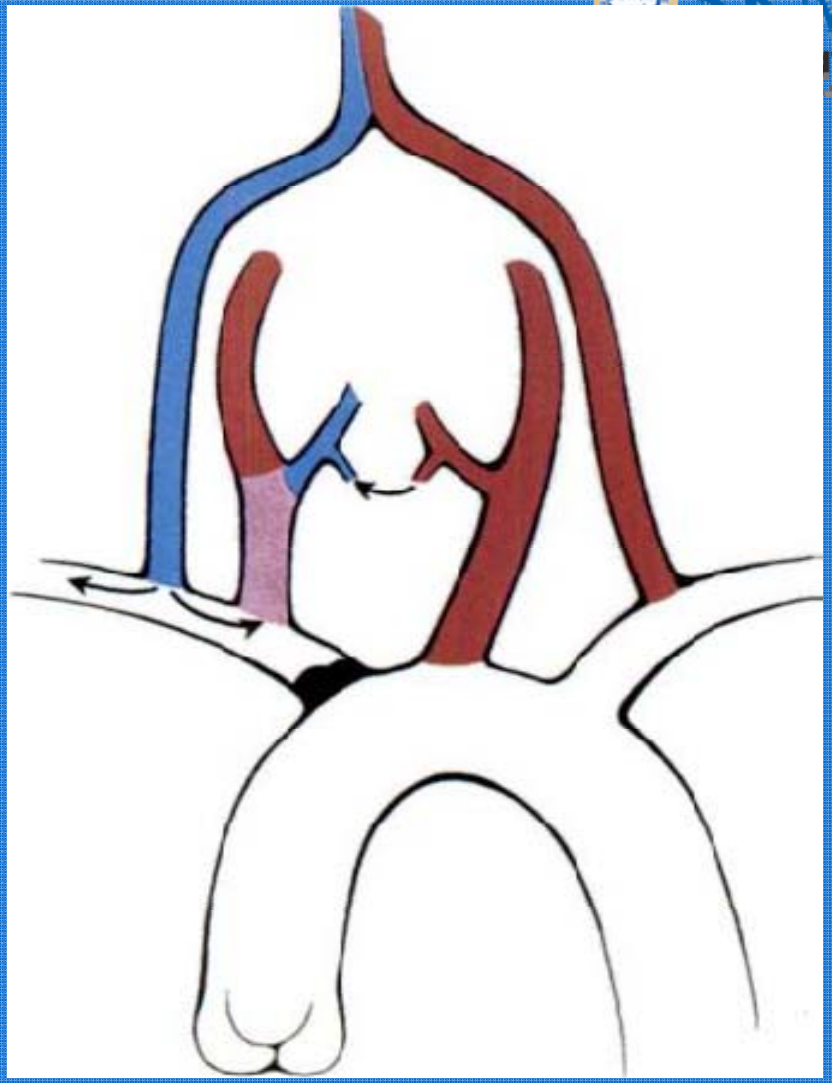
- Subclavian artery steno-occlusive disease **proximal to the origin of the vertebral artery** .

- Resulting in decreased blood pressure in the arm distal to the steno-occlusive disease.
- Causes ipsilateral vertebral artery blood flow alteration

- Severe stenoses, flow reversal occurs in the ipsilateral vertebral artery as compensatory collateral to the vascular territory beyond the subclavian steno-occlusive lesion.



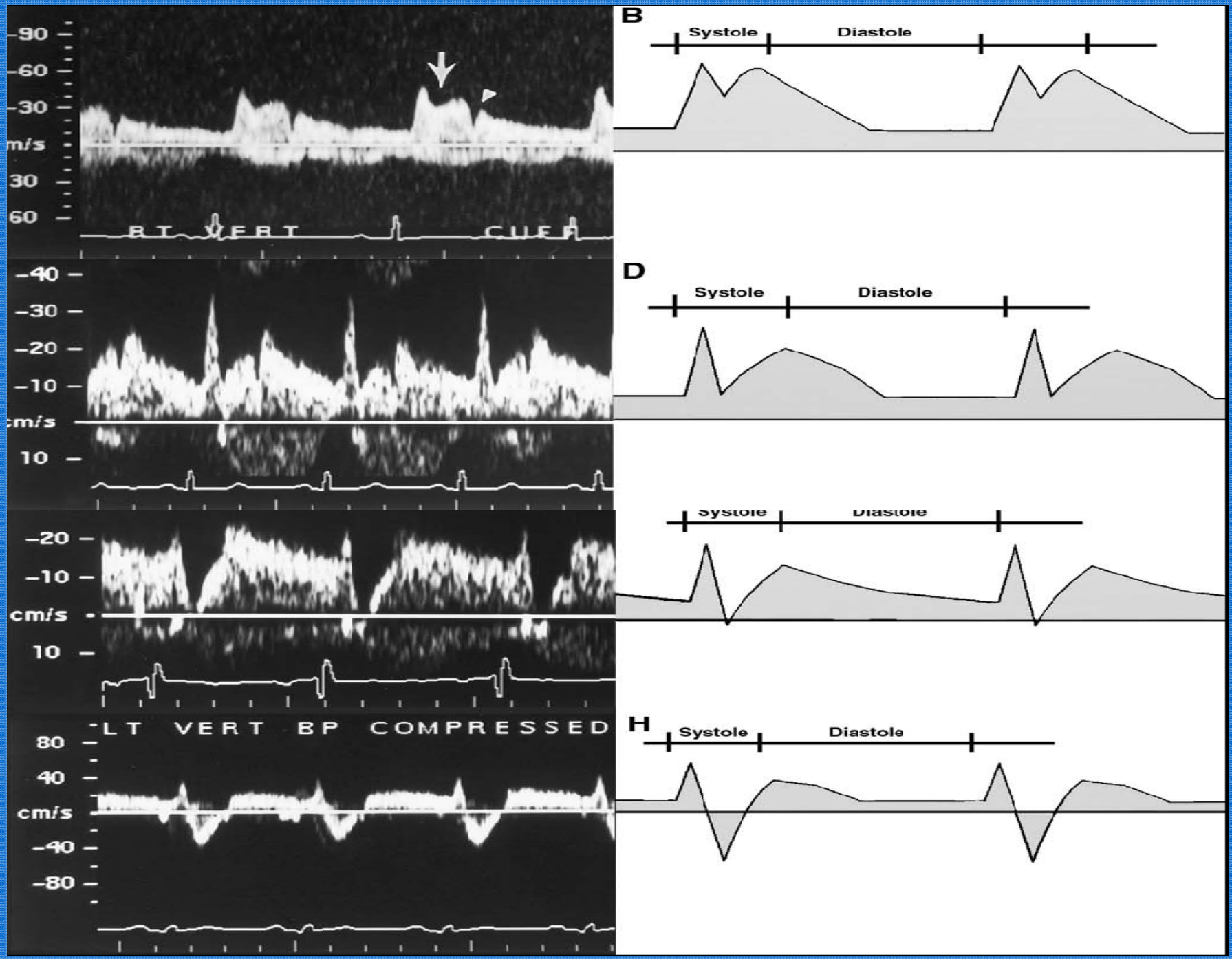
Subclavian artery stenosis

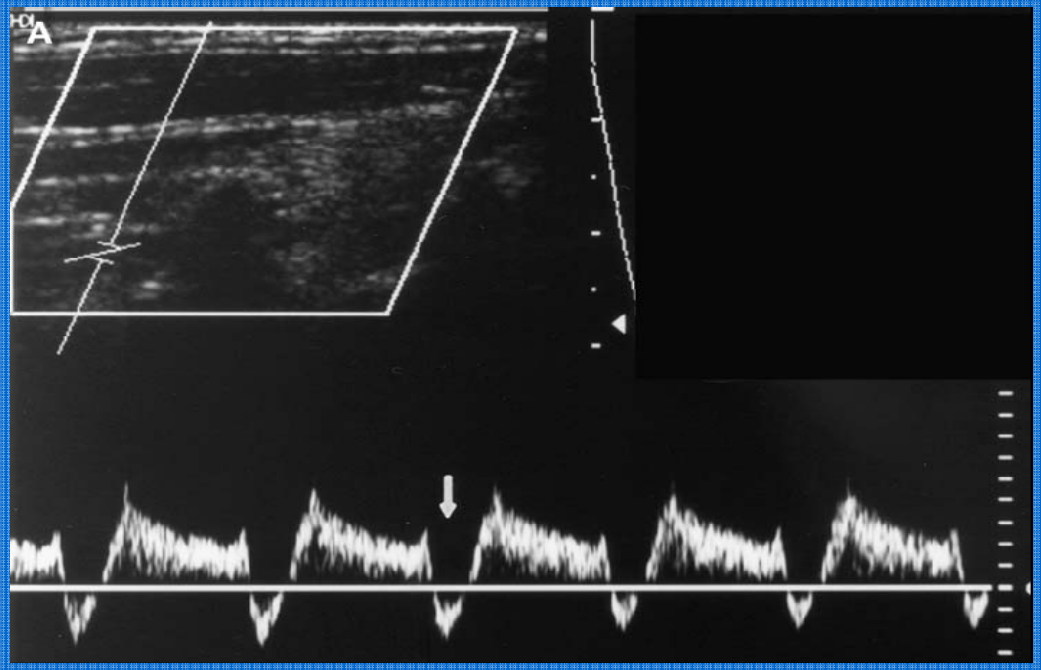


Innominate artery stenosis

# *Classification Based On Vertebral Artery Hemodynamics*

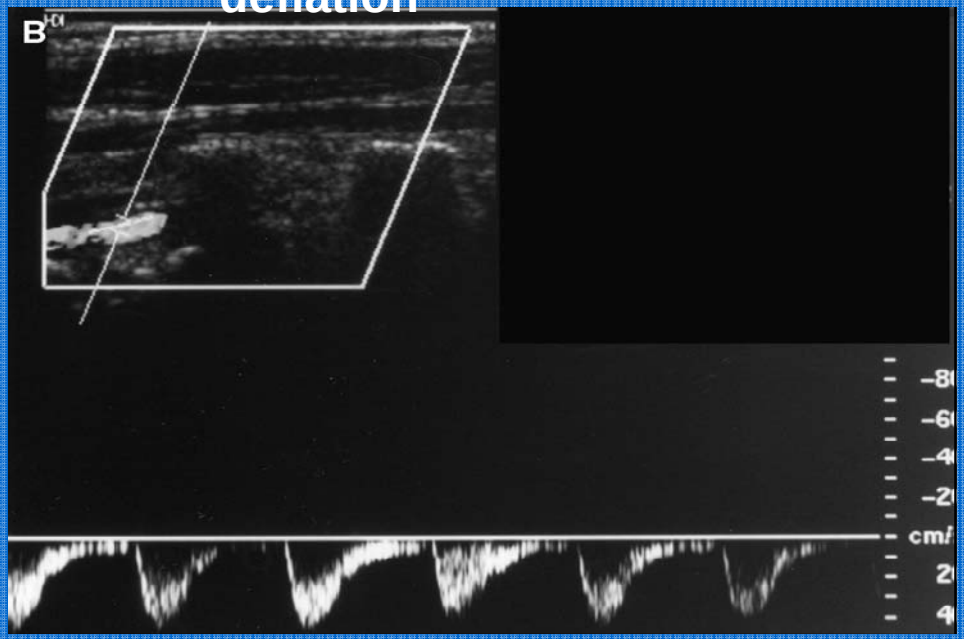
- reduced antegrade vertebral flow (stage I)
- reversal of flow during reactive hyperemia testing of the arm (stage II)
- permanent retrograde vertebral flow (stage III).


-90
-60
-30
m/s
30
60
-40
-30
-20
-10
cm/s
10
-20
-10
cm/s
10
LT VERT BP COMPRESSED
80
40
cm/s
-40
-80
B
Systole
Diastole
D
Systole
Diastole
Systole
Diastole
H
Systole
Diastole

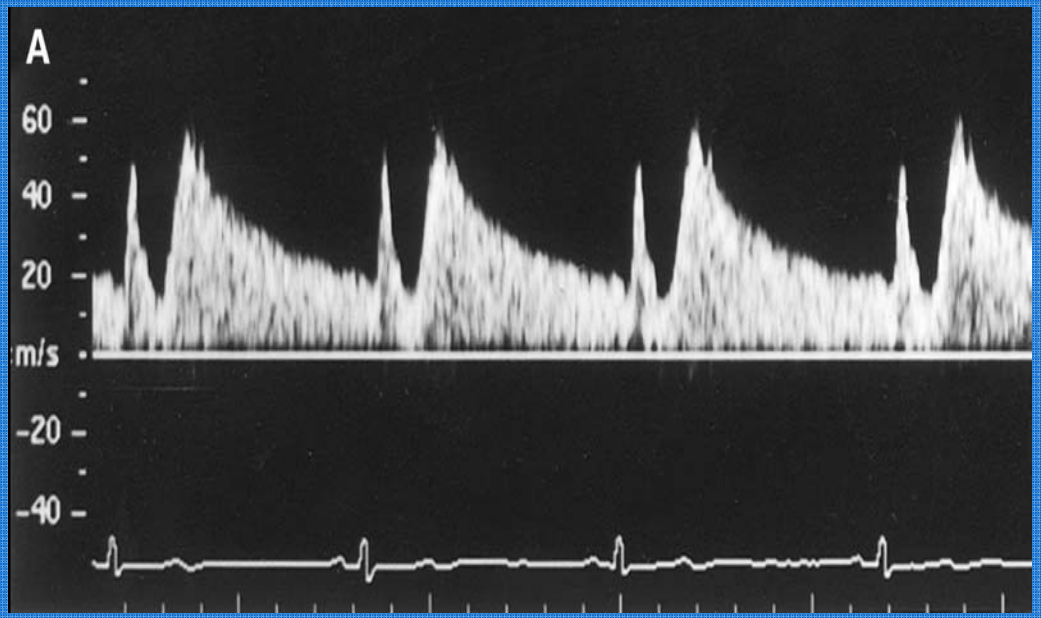



at rest

After inflation of a blood Pressure cuff on the left arm and rapid deflation

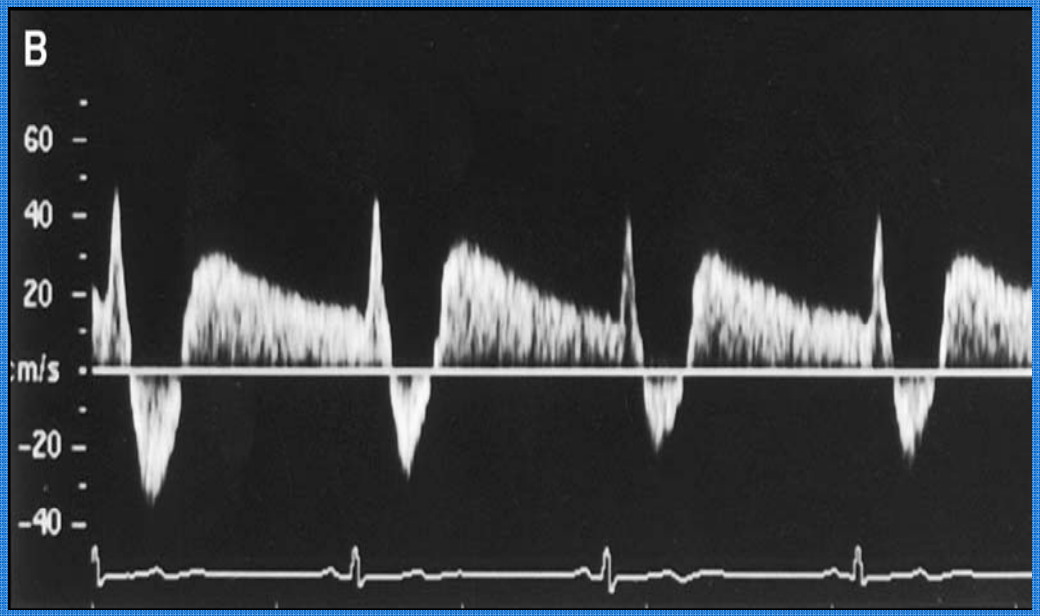



Conversion of a presteal waveform to a complete steal following provocative maneuvers.



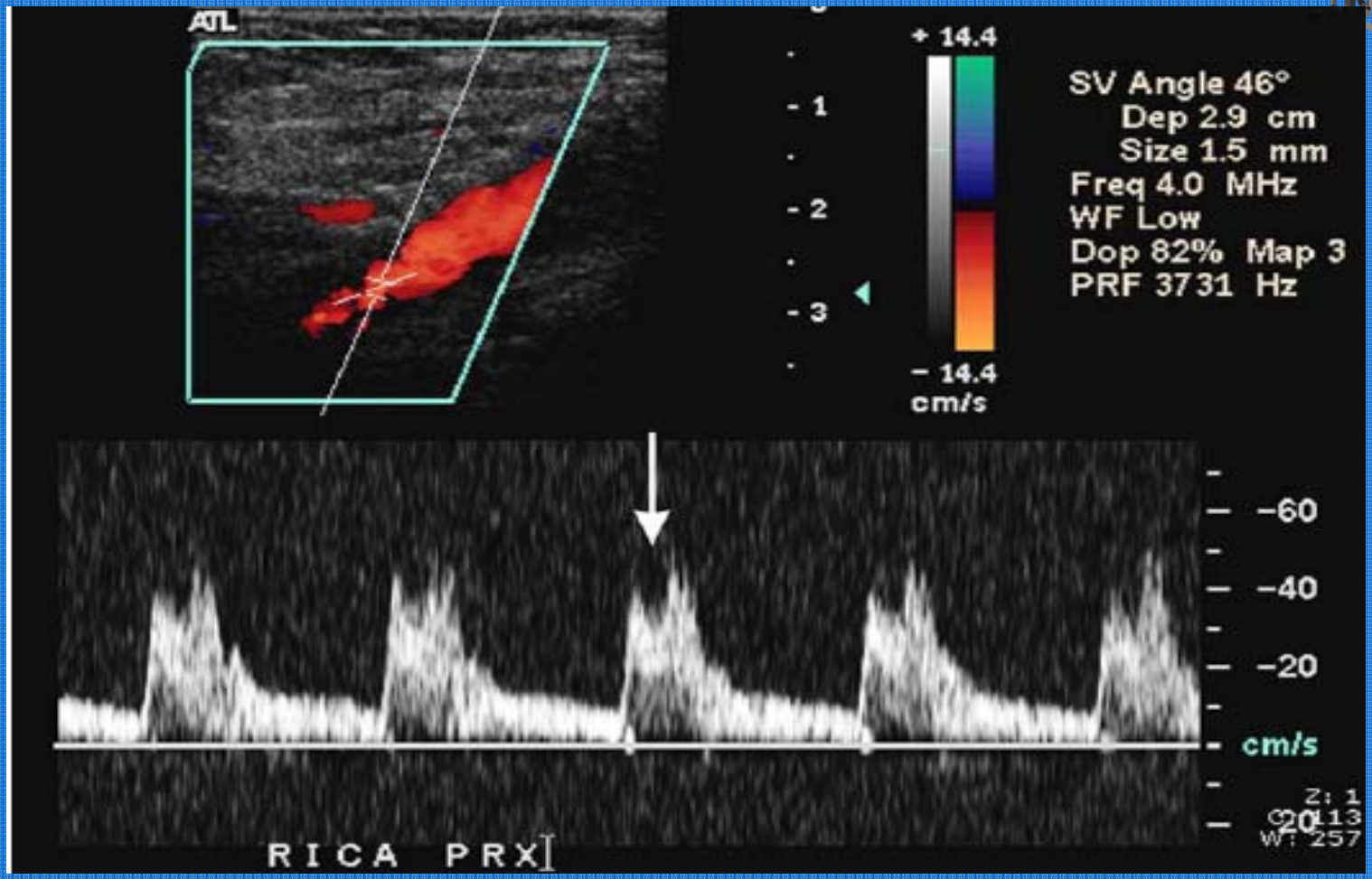

at rest

After inflation of a blood Pressure cuff on the left arm and rapid deflation



- The blood pressure cuff maneuver induces reactive hyperemia in the distal arm and increases blood flow across the subclavian stenosis, resulting in a complementary pressure drop and change in direction of blood flow in the ipsilateral vertebral artery towards the lower pressure subclavian origin.

# *Other wave patterns*




**Mid Systolic Retraction – Pulsus Bisferience**

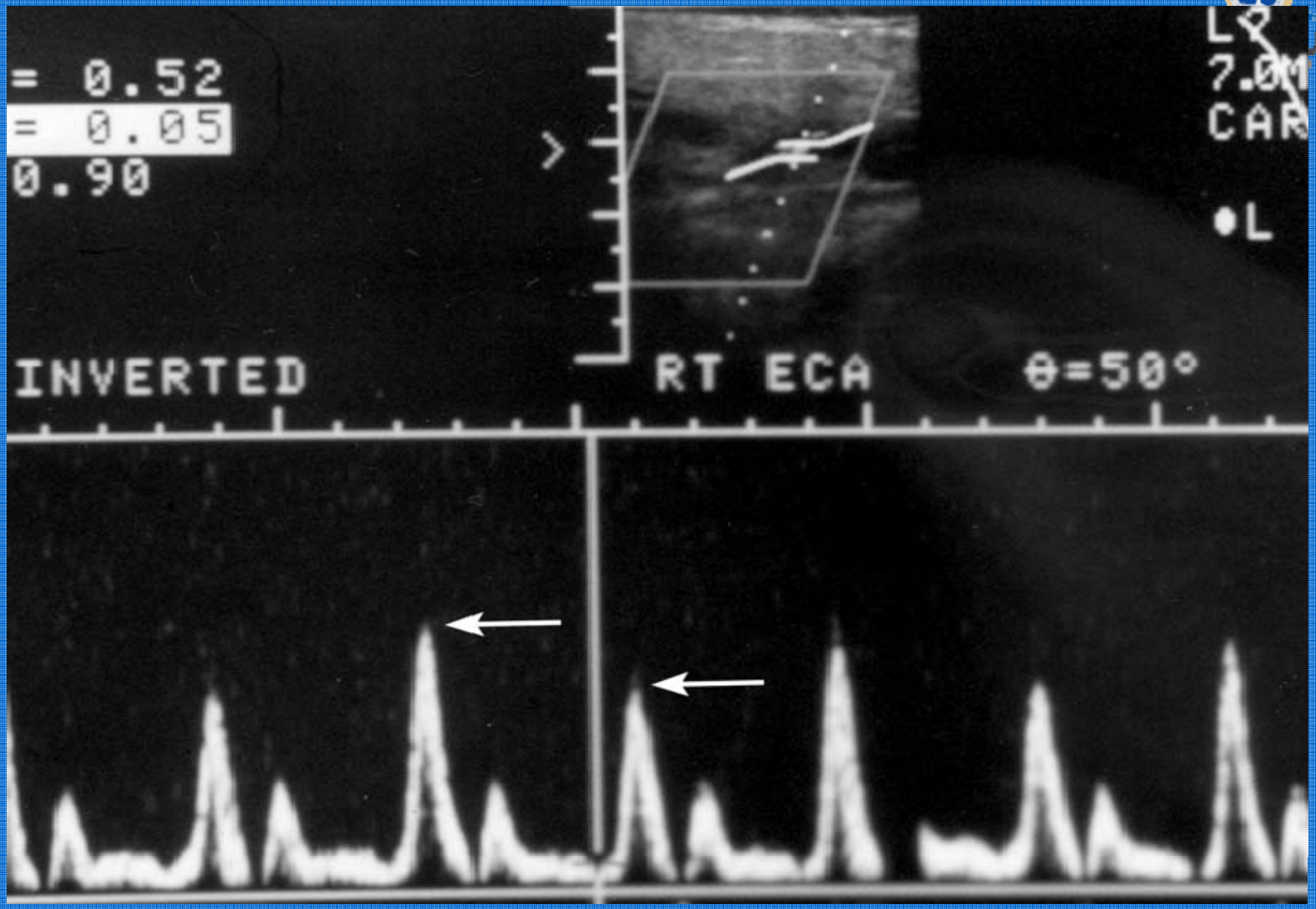
# *PULSUS BISFERIENCE*

"beat twice,"

- Characterized by two systolic peaks with an interposed midsystolic retraction
- Seen in

  AR with or without concomitant AS

  Hypertophic obstructive cardiomyopathy
- Occasionally, may be seen in healthy, athletic, young individuals or in older patients.




**Alternating systolic peak - Pulsus Alternans**

# *PULSUS ALTERNANS*

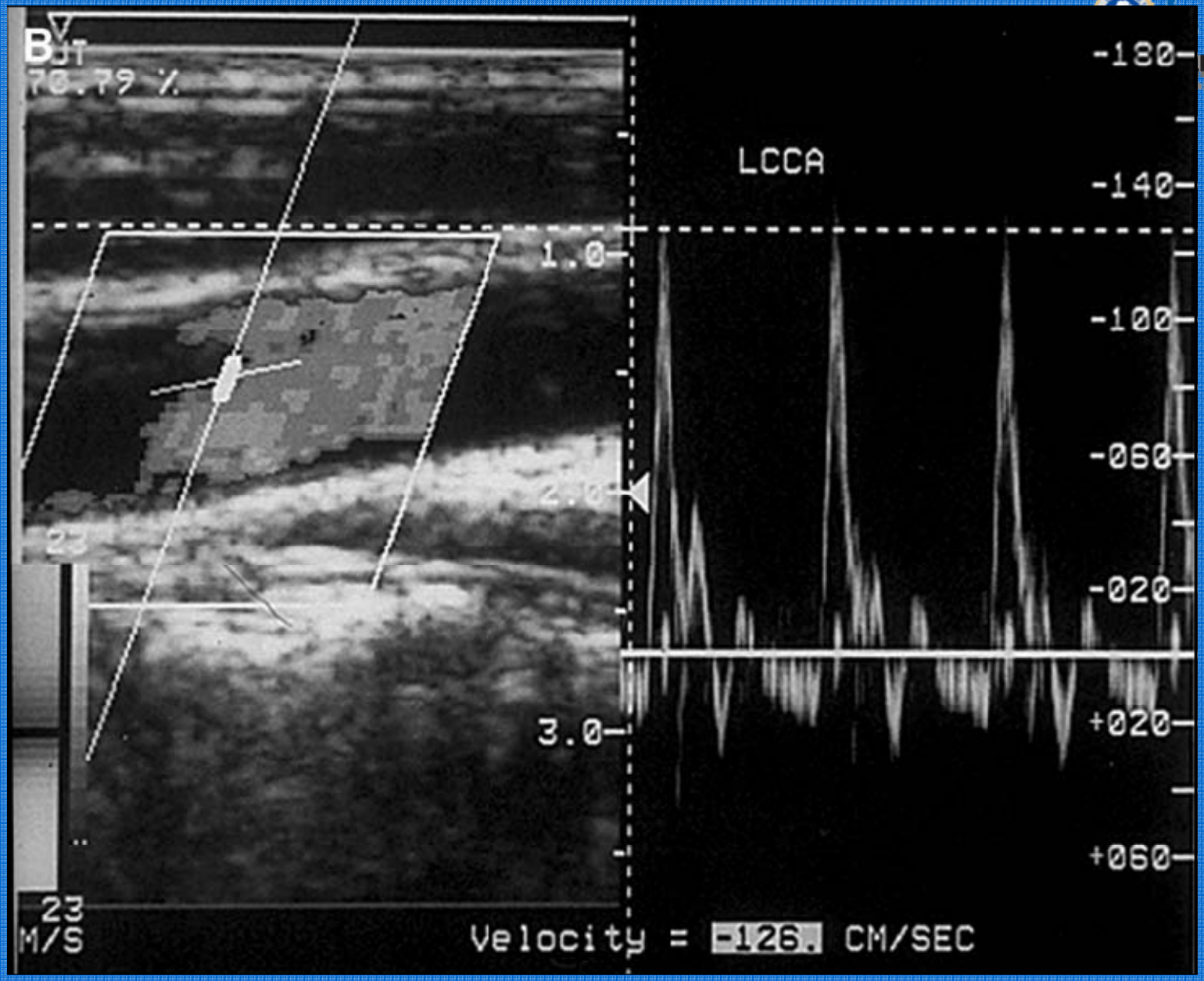
- Alternating peak systolic heights on sequential beats in a regular normal sinus rhythm
- Clinical conditions

  Intrinsic myocardial disease

  Ischemia

  Cardiomyopathies

  Valvular heart disease

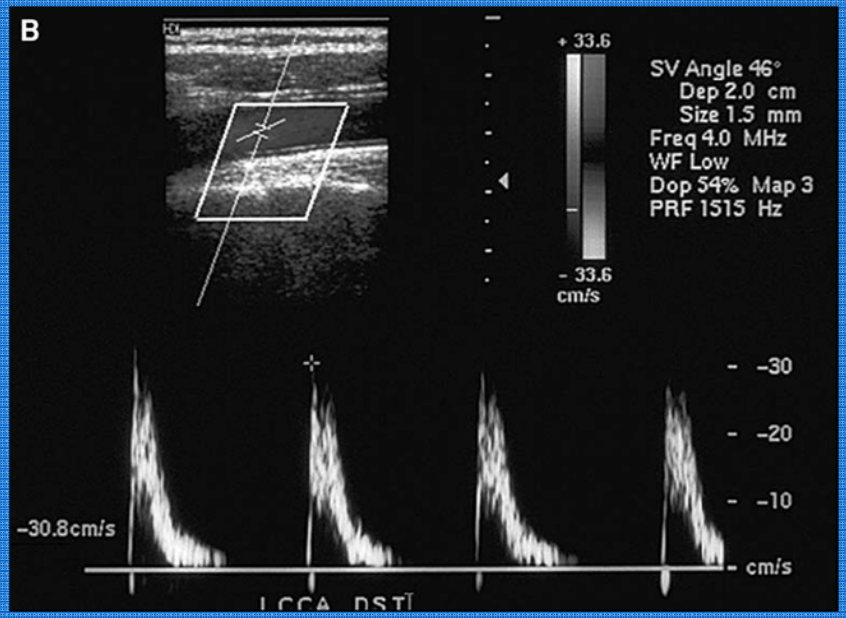

LCCA
-180
-140
-100
-060
-020
+020
+060
1.0
3.0
23
M/S
Velocity = -126. CM/SEC

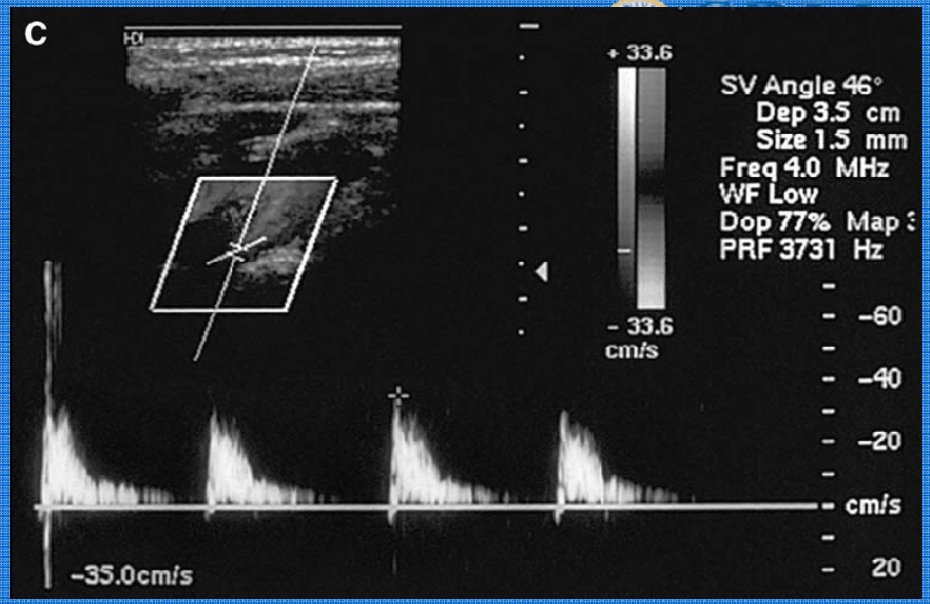
## *"water hammer pulse"*

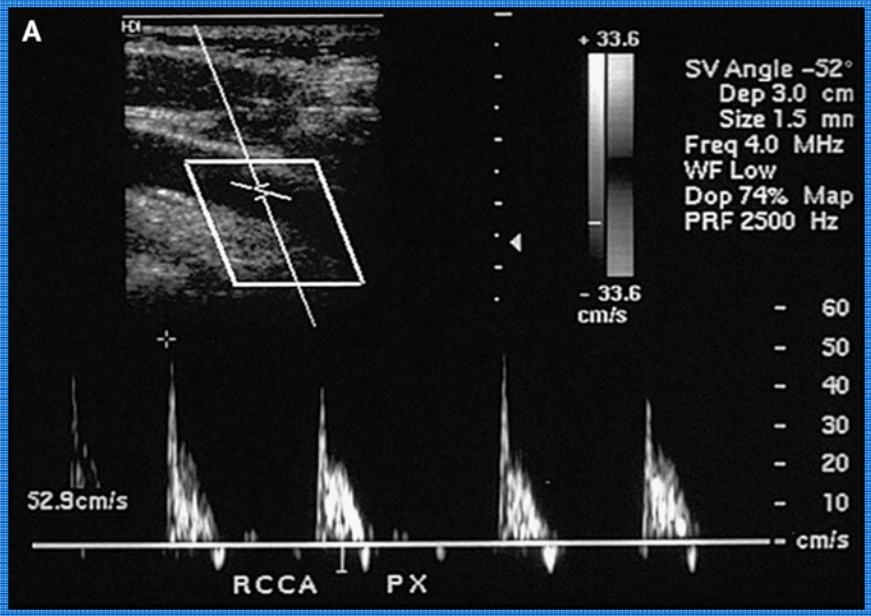
- In aortic regurgitation – reversed early diastolic flow in both CCAs with elevation of PSV and a sharp systolic upstroke

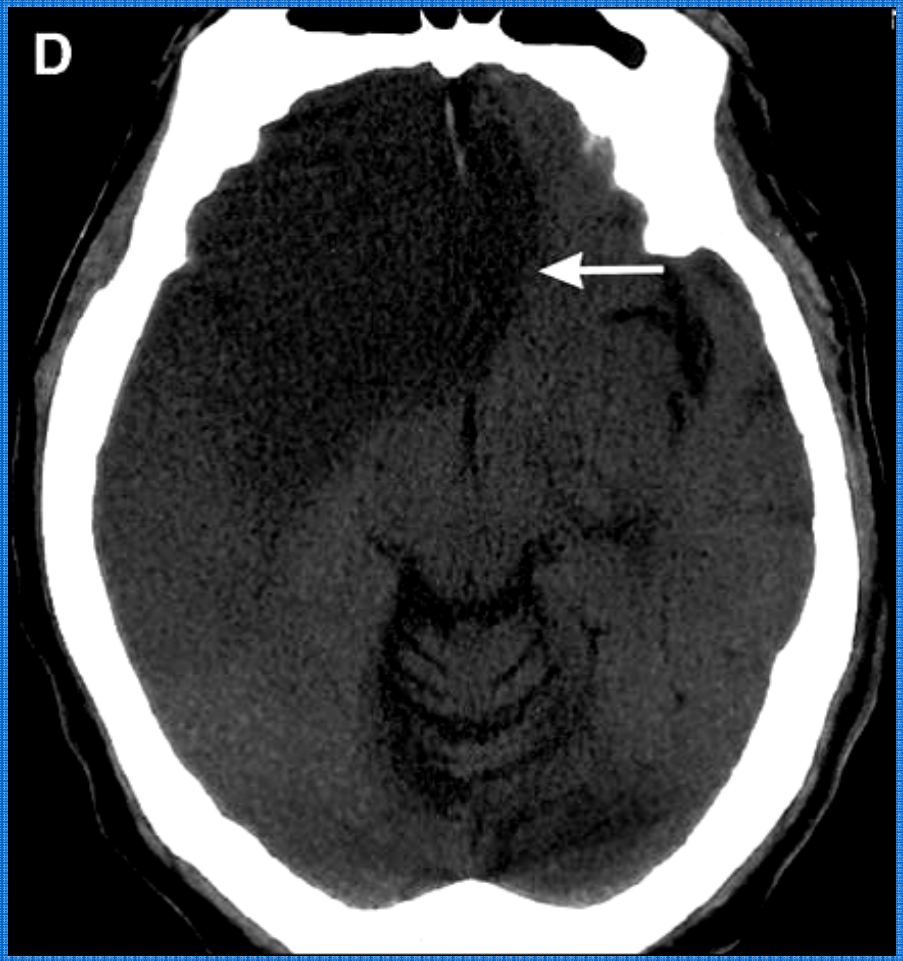
- Depending on the severity, the reversal of flow may be limited to early diastole with normalization of forward flow in end Diastole or may persist throughout diastole.

# Appearance is Bilateral


B
+ 33.6
SV Angle 46°
Dep 2.0 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 54% Map 3
PRF 1515 Hz
- 33.6
cm/s
-30
-20
-10
cm/s
-30.8cm/s


C
+ 33.6
SV Angle 46°
Dep 3.5 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 77% Map 3
PRF 3731 Hz
- 33.6
cm/s
-60
-40
-20
cm/s
20
-35.0cm/s


A
+ 33.6
SV Angle -52°
Dep 3.0 cm
Size 1.5 mn
Freq 4.0 MHz
WF Low
Dop 74% Map
PRF 2500 Hz
- 33.6
cm/s
60
50
40
30
20
10
cm/s
52.9cm/s
RCCA
PX




Large cerebral infarct with uncal herniation

# CAROTID DISSECTION

# DISSECTION

- Trauma - seat belt injury or repetitive trauma.
- Occasionally, spontaneous and isolated to the carotid arteries in Marfan syndrome, Ehlers-Danlos syndrome, fibromuscular dysplasia, hypertension, or drug abuse
- Also - direct extension of an aortic dissection.
- Rare but, dissection of the ICA is the most common cause of stroke in young patients.
- Most ICA dissections occur at the level of the carotid bifurcation.

- Wave pattern is extremely bizarre in configuration: low PSV velocity with a highly irregular waveform contour with many spikes or fluttering with reversed or bidirectional of flow, such that it may be difficult to distinguish systole from diastole

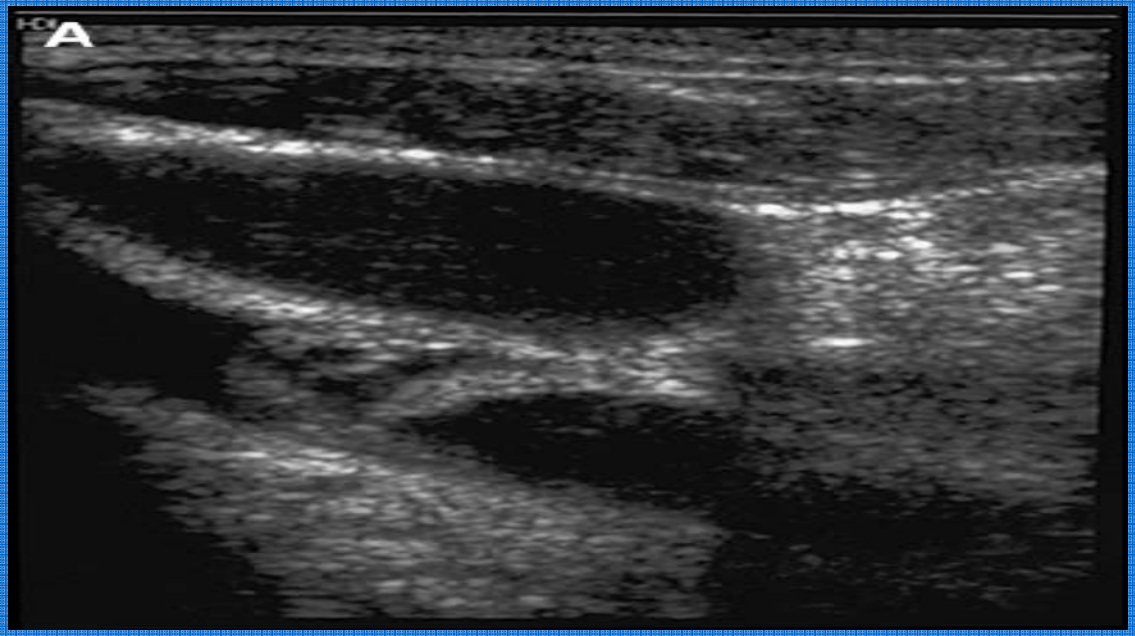
- an intramural hematoma, causing a long-segment tapering of the ICA without a break in the intima
- The residual lumen may be narrowed markedly, creating a ‘‘string sign.’’

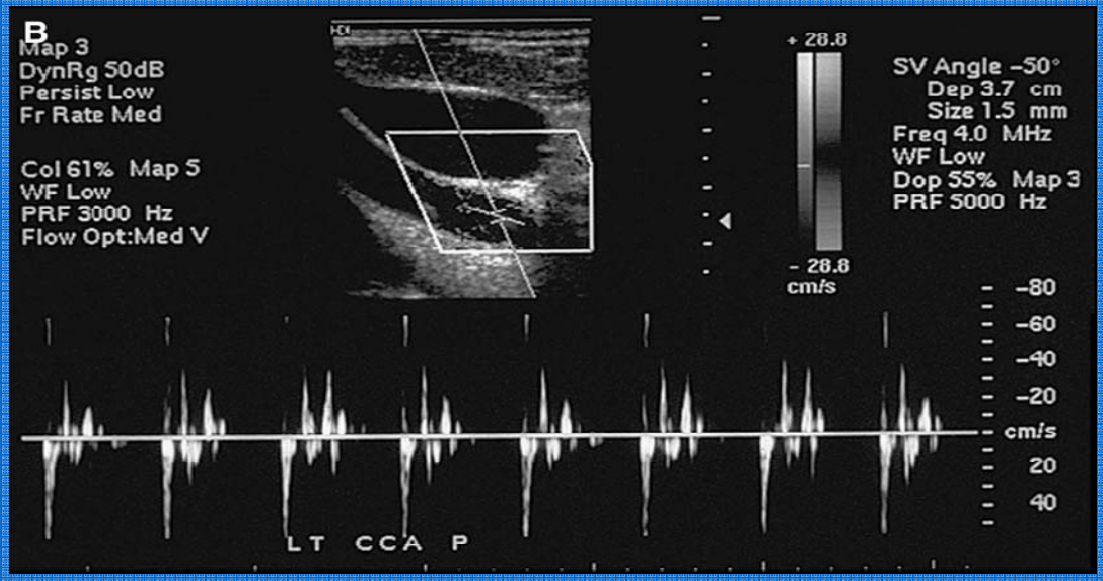
- Thrombosis of the false lumen - mimic stenosis

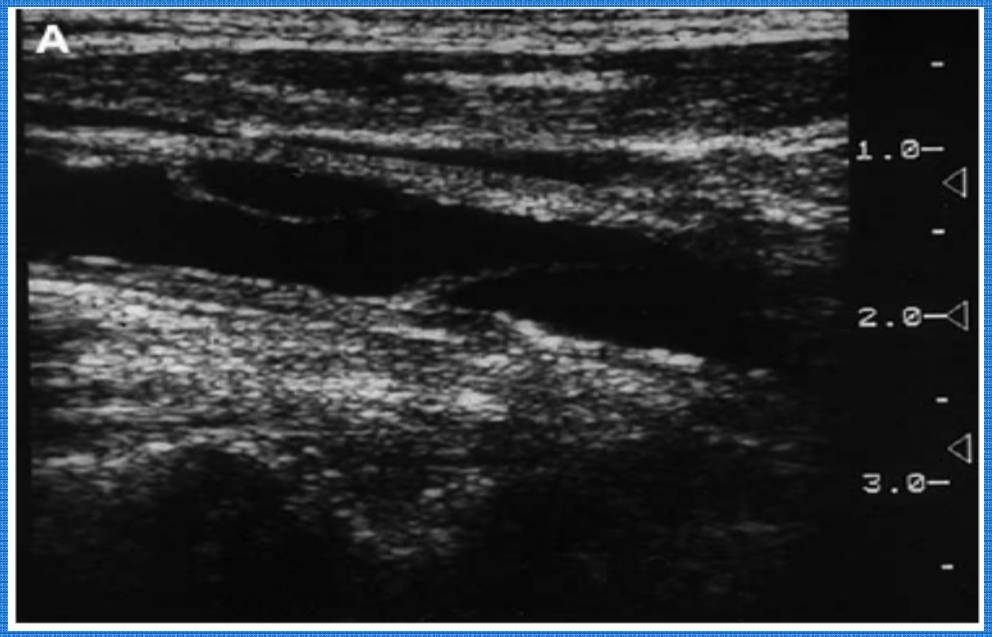
- The waveform may be indistinguishable from a stenosis except that typically it extends over a much longer segment and often no plaque is visualized.

- The presence of early diastolic flow reversal in the ipsilateral CCA
- reduced peak systolic and diastolic velocities in the ipsilateral ICA

are non-specific, but warrant a search for a cause of increased peripheral vascular resistance.

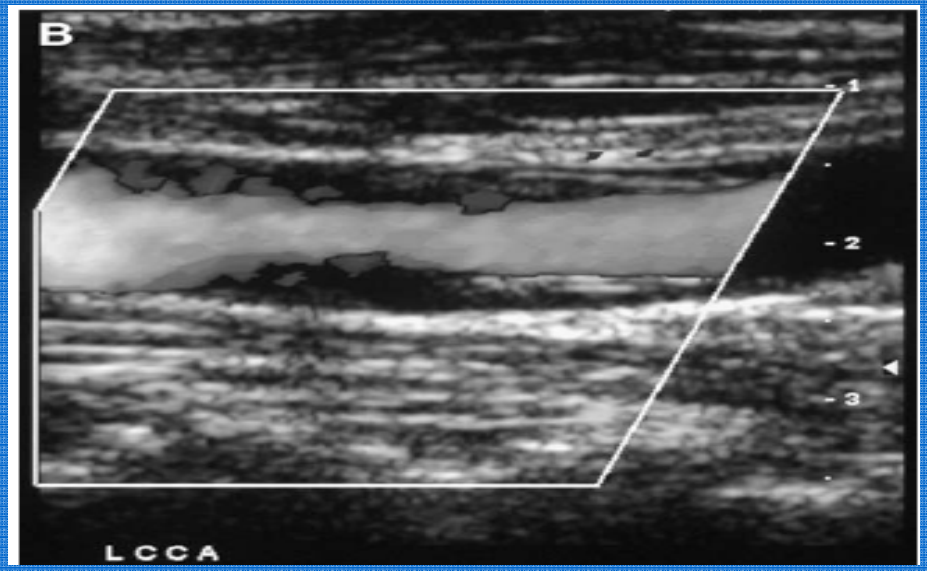

A

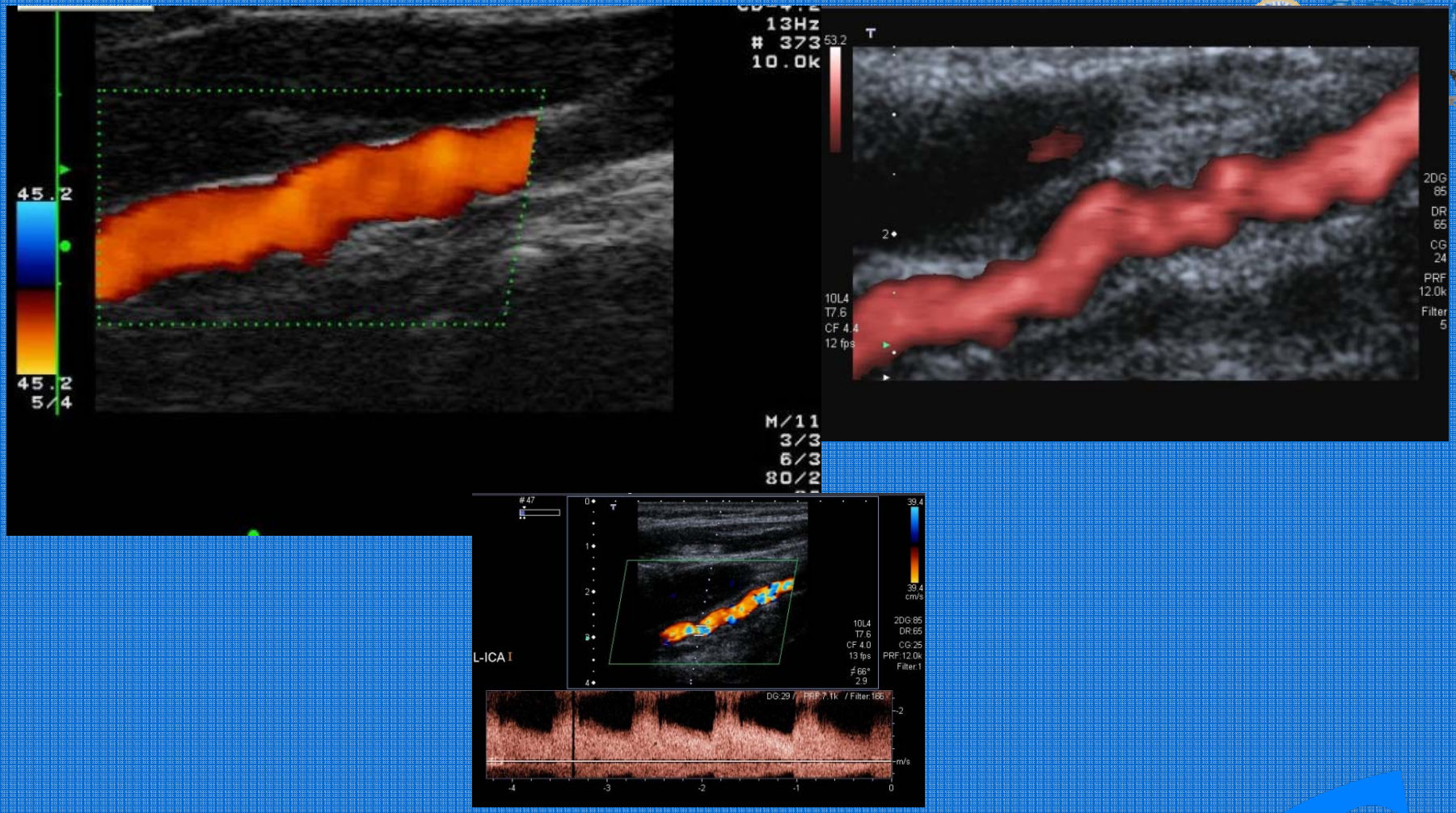

B
Map 3
DynRg 50dB
Persist Low
Fr Rate Med
Col 61% Map 5
WF Low
PRF 3000 Hz
Flow Opt:Med V
+ 28.8
- 28.8
cm/s
SV Angle -50°
Dep 3.7 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 55% Map 3
PRF 5000 Hz
-80
-60
-40
-20
cm/s
20
40
LT CCA P




Hematoma with dissection

Echogenic flap









*So -------*

*What is this ???*

*Thank you*