BASIC CONCEPTS IN ULTRASONOGRAPHY

بسم الله

BASIC ULTRASOUND PHYSICS

- The source of the ultrasound wave is the piezoelectric crystal, which is placed in the transducer.
- This crystal has the ability to transform an electrical current into mechanical pressure waves (ultrasound waves) and vice versa.
- Once the ultrasound wave is generated and travels through the medium, the crystal switches from ‘sending’ into ‘listening’ mode and awaits returning ultrasound echoes.

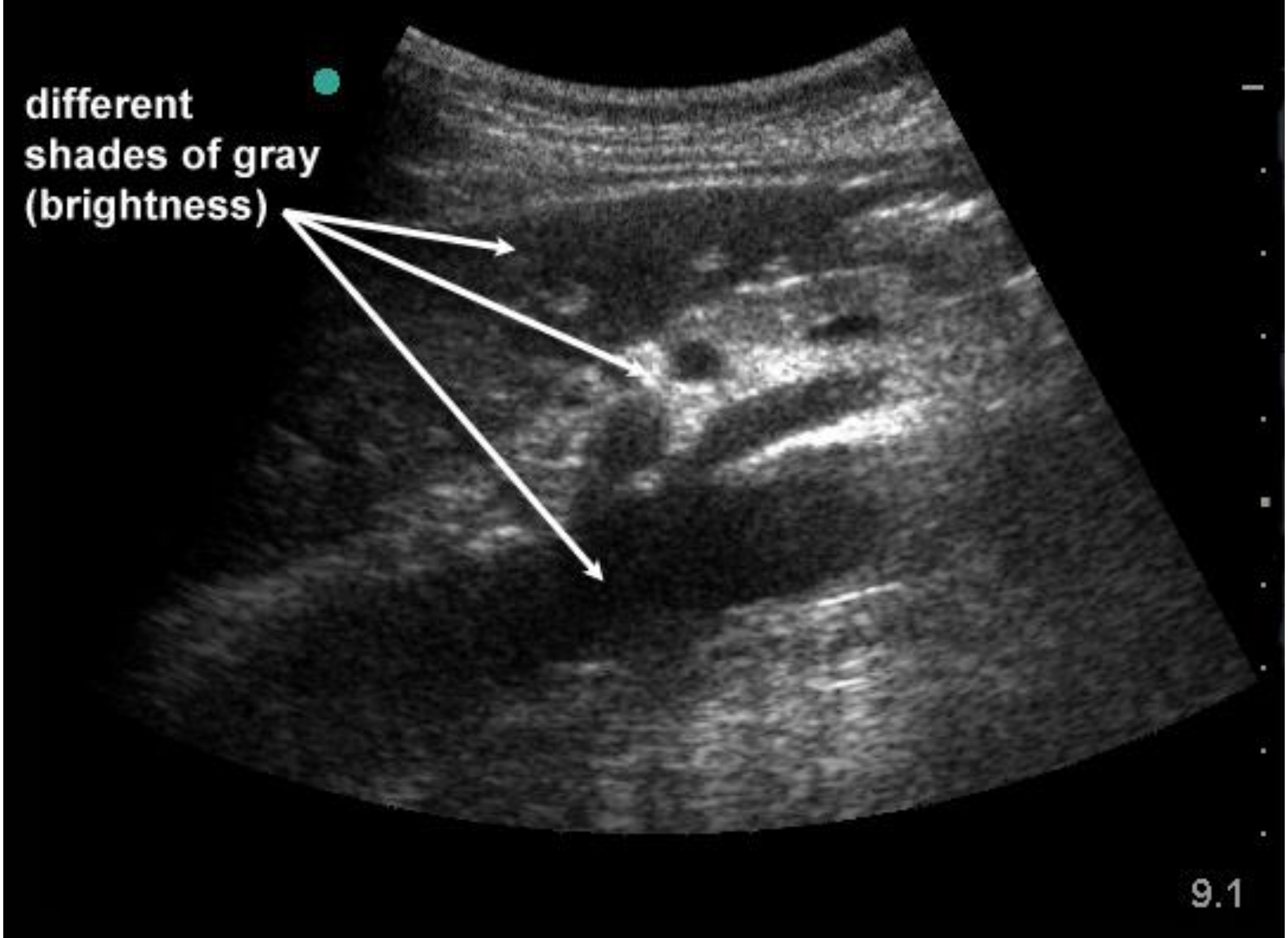
- Actually over 99% of the time is spent “listening”.
- This cycle is repeated several million times per second. This principle is called “pulsed-echo” principle.
- Returning sound waves are converted into images on the ultrasound monitor.
- Diagnostic ultrasound used for common medical imaging uses frequencies between 2 and 20 million Hertz (Megahertz, MHz).

PROBES

- **Lower frequencies** are able to penetrate **deeper** into tissue but show **poorer resolution**.
- In contrary **higher frequency** ultrasound will display more detail with a **higher resolution** in exchange for **less depth** penetration.
- This is a very important principle when choosing your probes and frequencies.

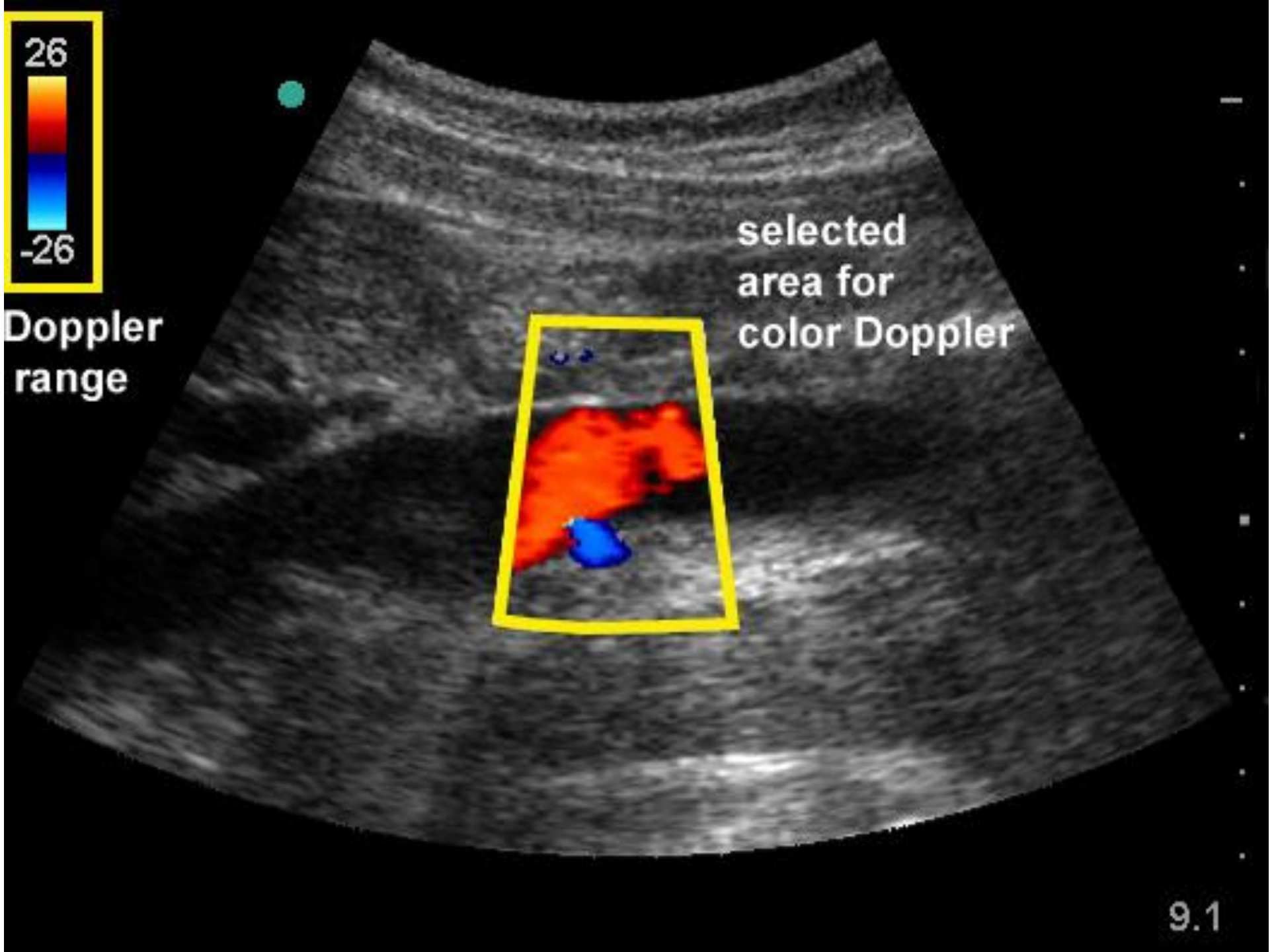
ULTRASOUND MODES

- **B-mode** stands for ‘brightness mode’ and provides structural information utilizing different shades of gray (or different ‘brightness’) in a two-dimensional image.


different
shades of gray
(brightness)
9.1

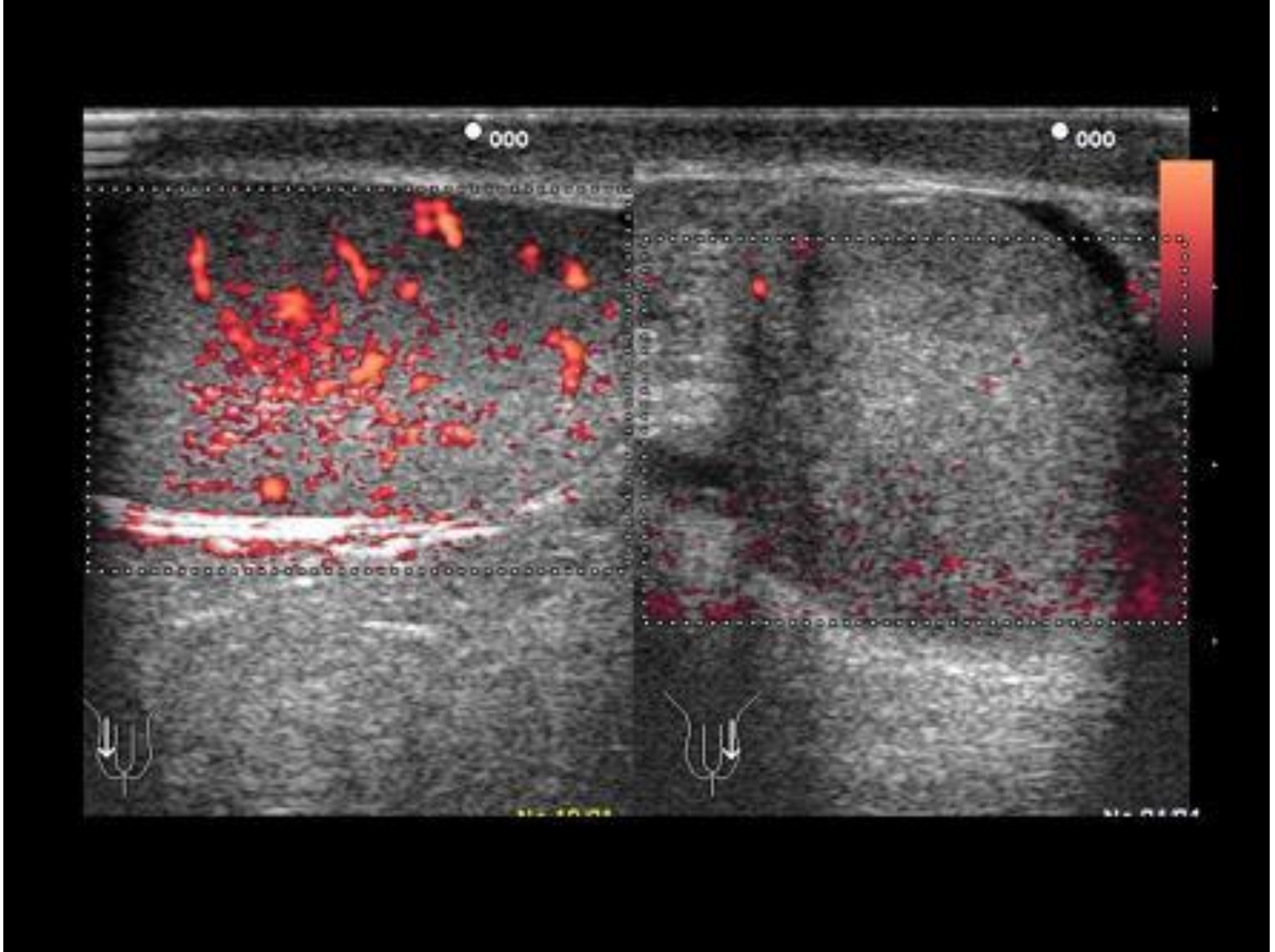
THE DOPPLER MODE

- It utilizes a phenomenon called 'Doppler shift', which is a change in frequency from the sent to the returning sound wave.
- **Color Doppler** ultrasound is also called color-flow ultrasound. It is able to show blood flow or tissue motion in a selected two-dimensional area. Direction and velocity of tissue motion and blood flow are color coded and superimposed on the corresponding B-mode image.


26
-26
Doppler range
selected area for color Doppler
9.1

POWER DOPPLER

- Unlike color Doppler, common power Doppler does not examine flow velocity or the direction of flow.
- It looks at the amplitudes of the returning frequency shifts and is able to detect even states of very low flow.
- **This is of use when examining vascular emergencies such as testicular or ovarian torsion.**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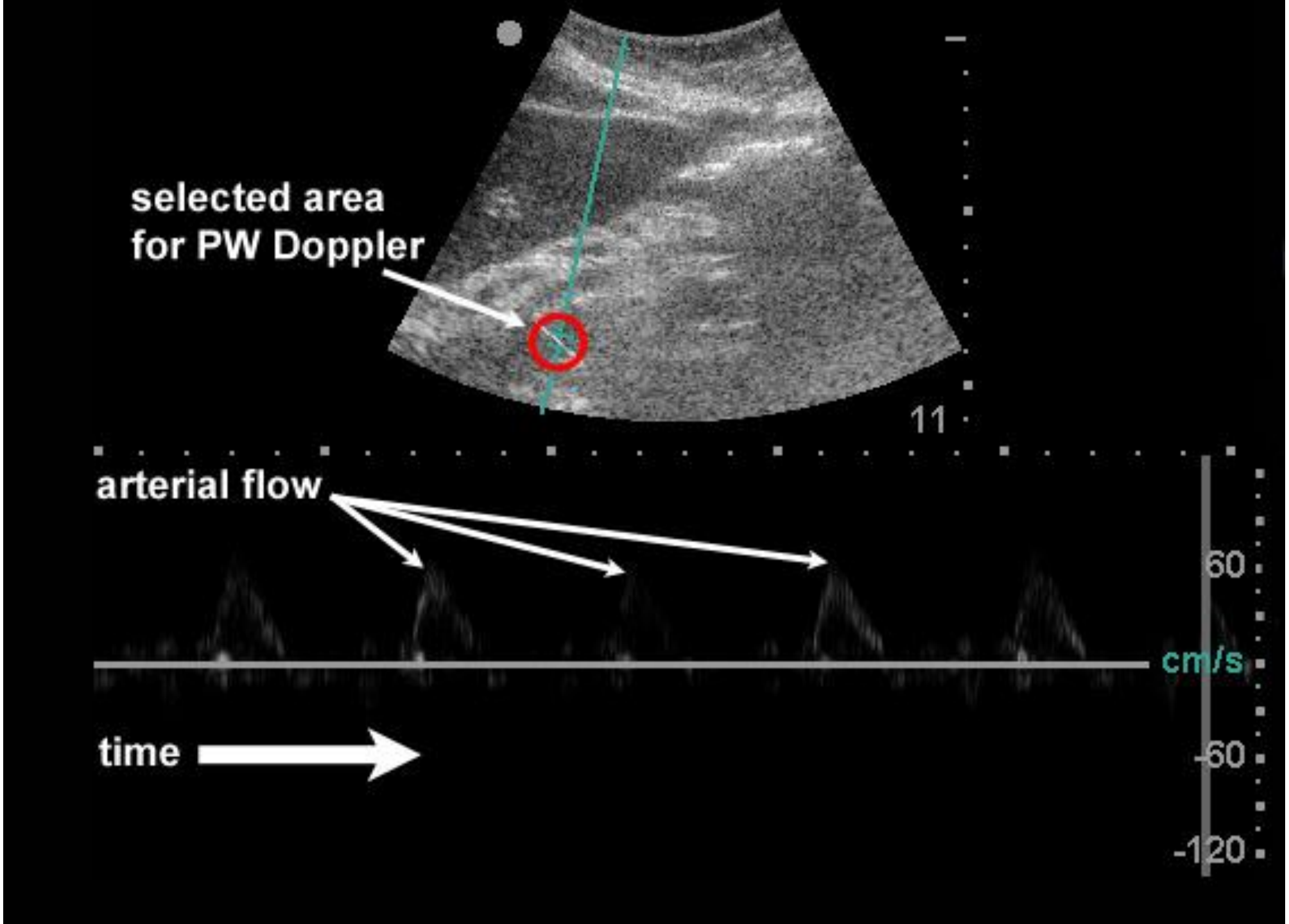
Spectral doppler (pulsed-wave form)

- Pulsed-wave spectral Doppler shows the “spectrum” of the returned Doppler frequencies in a characteristic two-dimensional display.
- Venous flow demonstrates a more continuous, band like shape.
- Arterial flow shows a more triangular shape

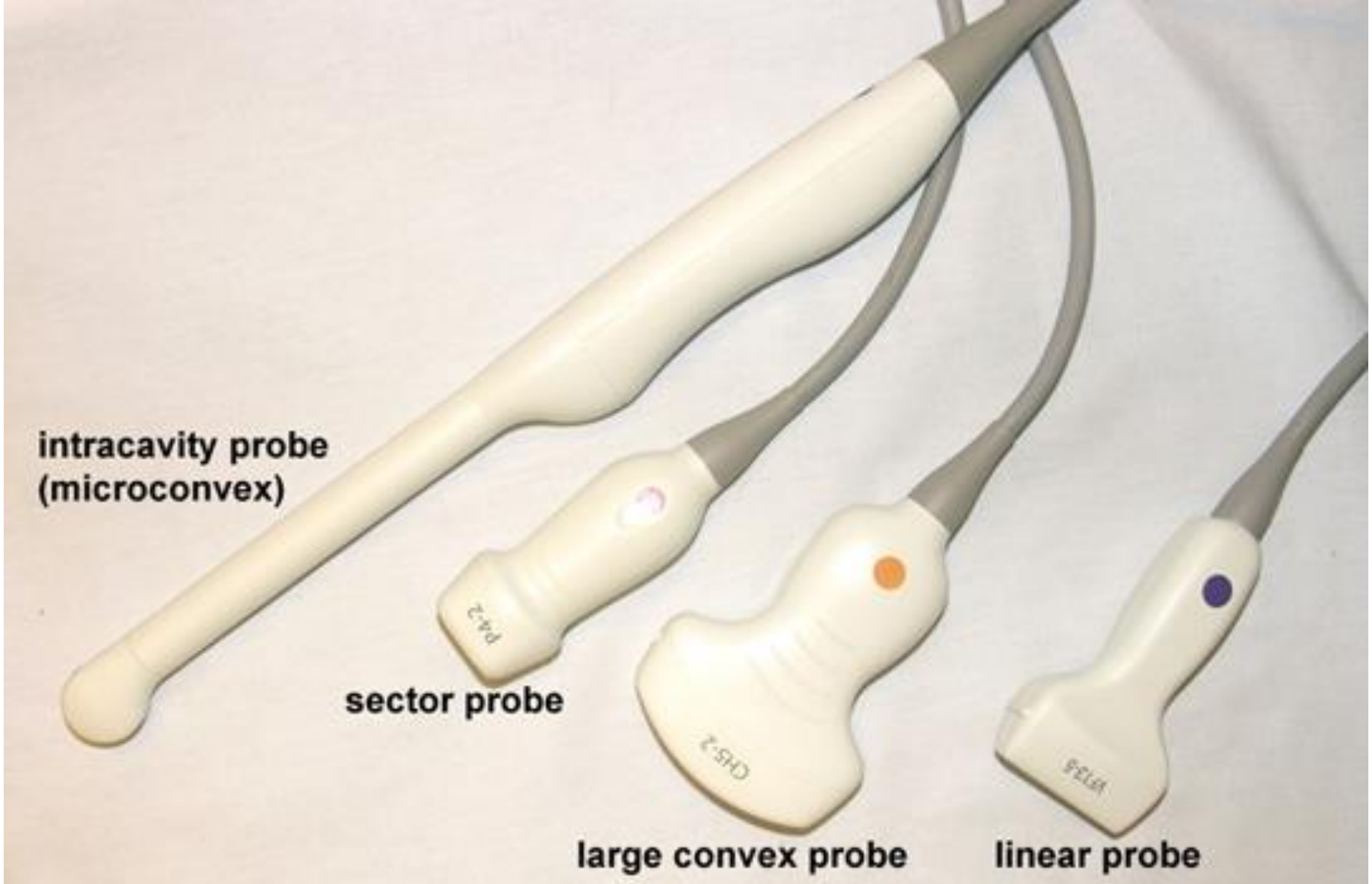

selected area
for PW Doppler
11
arterial flow
60
cm/s
-60
-120
time

PROBES

The most common transducers utilized in the emergency department are:

- Large Convex Probe:
  - Main ED utilization is transabdominal sonography. Produces a sector shaped image with a large curved top. The active element is arranged in a large curved line, also called large curved probe or transducer.

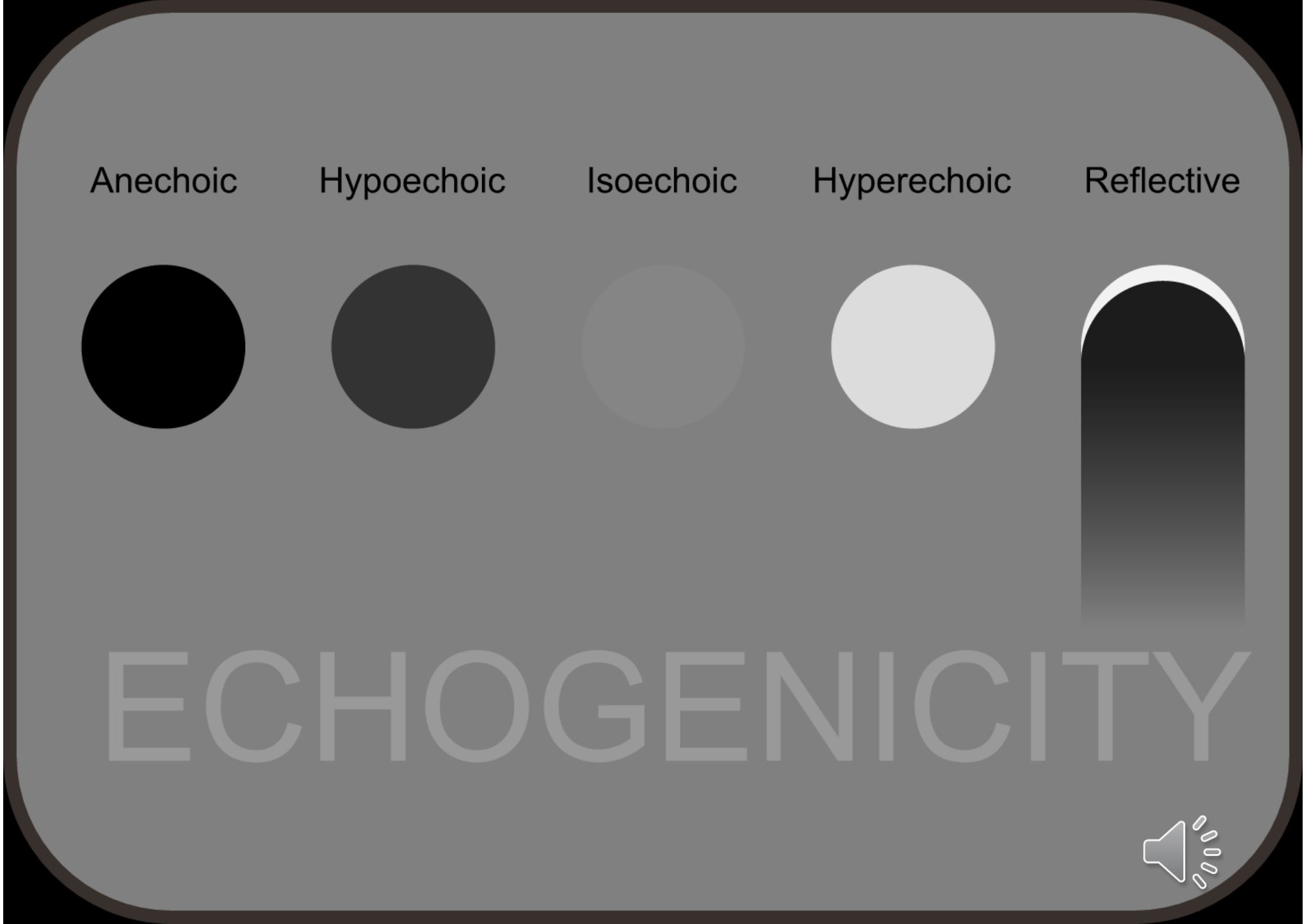
- Linear Probe:
  - Main utilization is vascular sonography or evaluation of superficial soft tissue structures. The active element is arranged in a straight line.


intracavity probe
(microconvex)
sector probe
large convex probe
linear probe

COMMON TERMINOLOGY

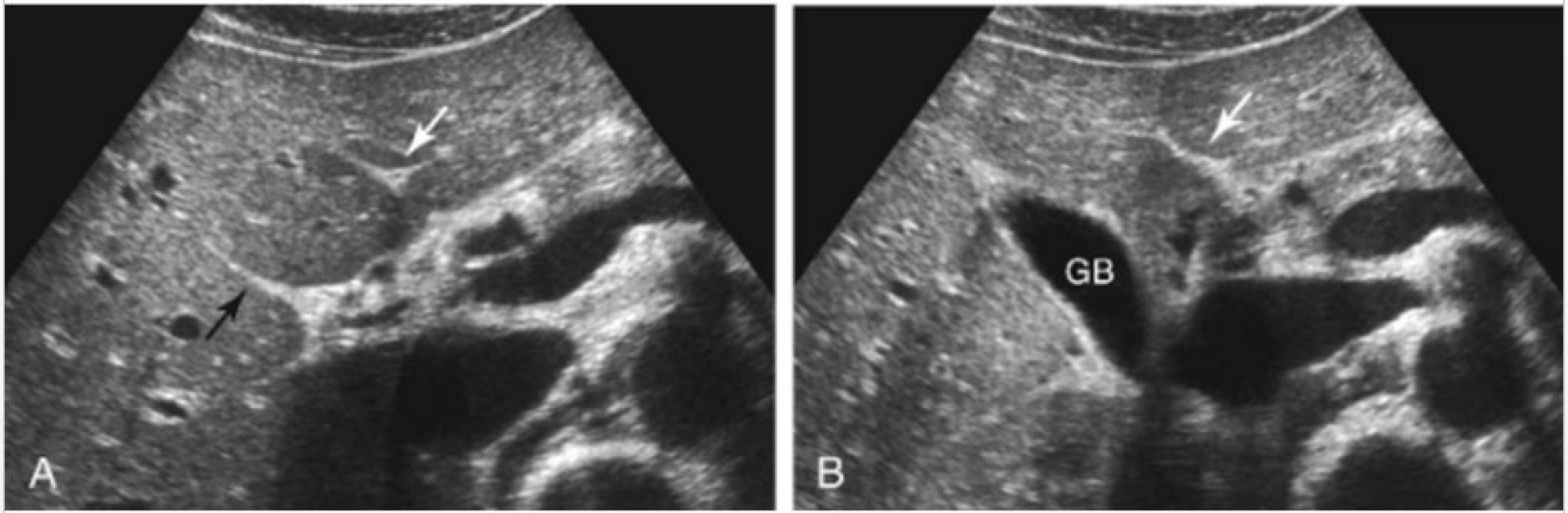
Image Interpretation:

- Anechoic / Echolucent - Complete absence of returning sound waves, area is black.
- Hypoechoic - Structure has very few echoes and appears darker than surrounding tissue.
- Hyperechoic / Echogenic - Opposite of hypoechoic, structure appears brighter than surrounding tissue.


Anechoic
Hypoechoic
Isoechoic
Hyperechoic
Reflective
ECHOGENICITY

THE GALLBLADDER

Characteristic	Appearance
Location	Inferior to interlobar fissure Between left and right hemiliver
Size	<4 cm transverse <10 cm longitudinal
Wall thickness	<3 mm
Lumen	Anechoic


A
GB
B

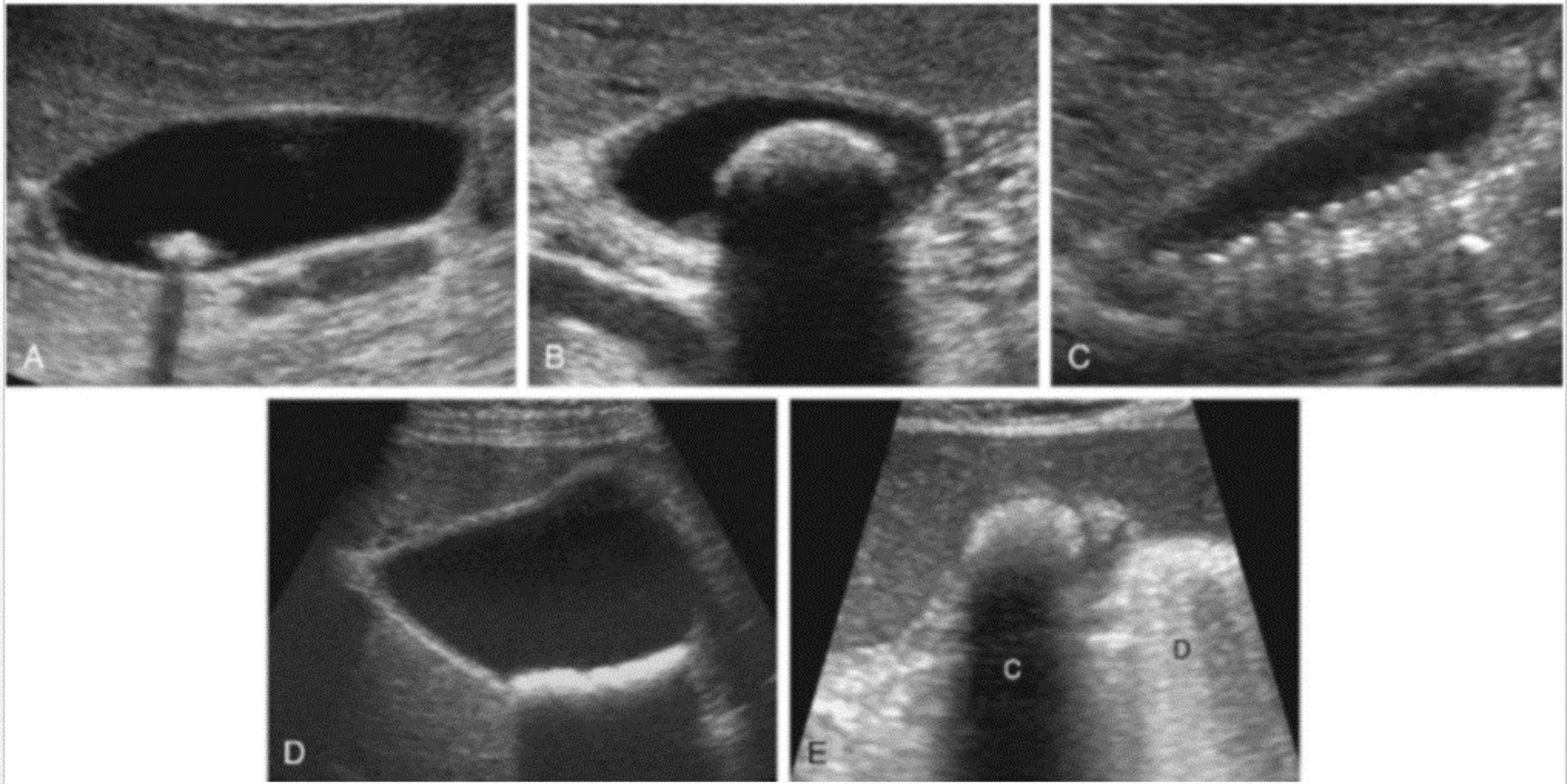
TECHNIQUE

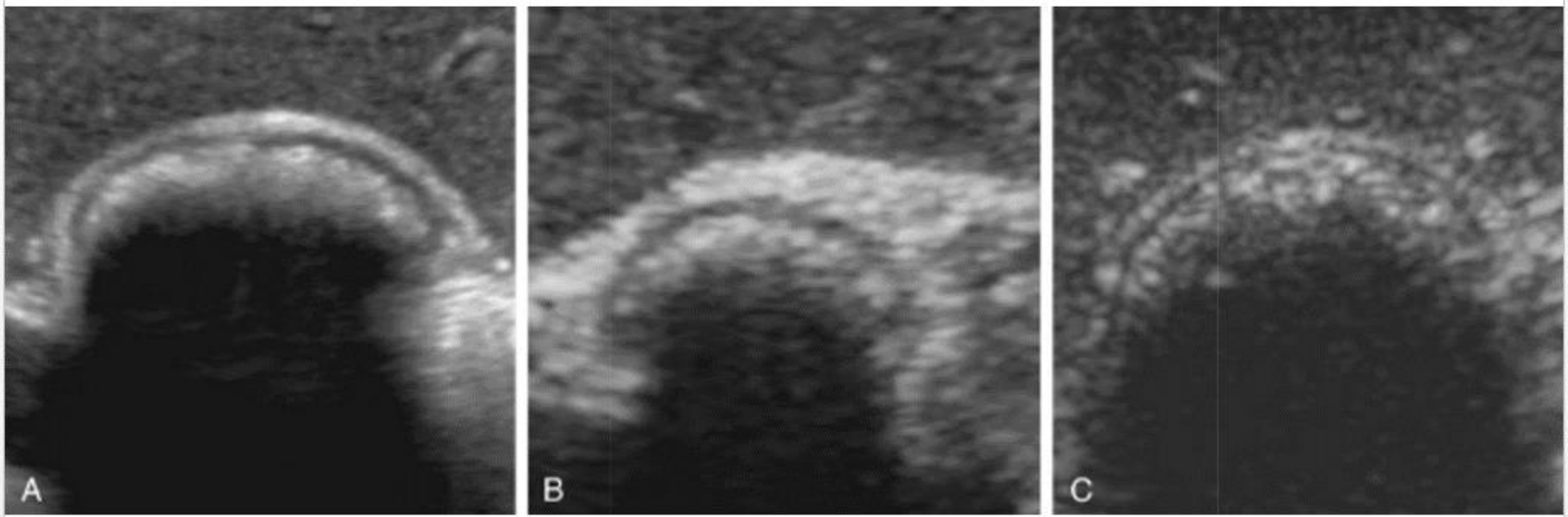
- Ideally, patients should fast 8 hours after midnight before they undergo a gallbladder sonogram to ensure adequate gallbladder distention and to reduce upper abdominal bowel gas.
- Most gallbladder examinations start with the patient in the supine position using a 3- to 5-MHz sector transducer.

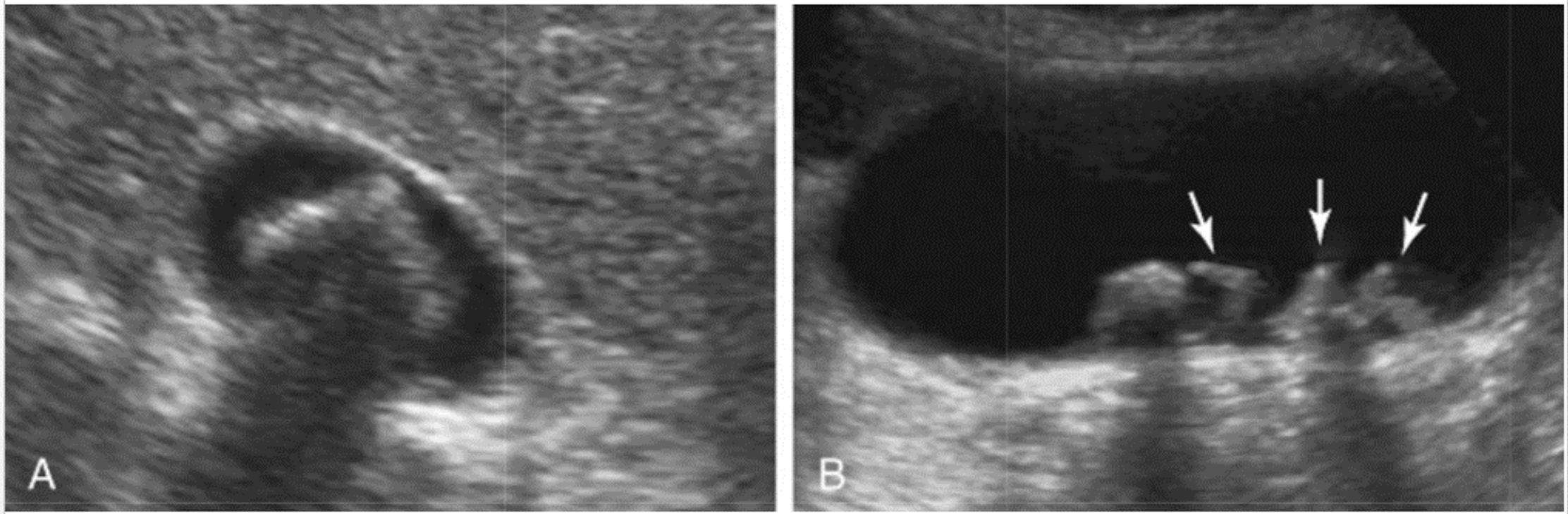
GALLSTONES

- Gallstones are present in up to 10% of the population.
- The majority (60% to 80%) of gallstones are asymptomatic (silent).
- Approximately 30% of patients with gallstones will have only a single episode of pain.
- The most common symptom of gallstones is biliary colic, which manifests as acute right upper quadrant (RUQ) or epigastric pain lasting for up to 6 hours and ending when the stone disimpacts from the gallbladder neck or passes completely through the cystic duct.

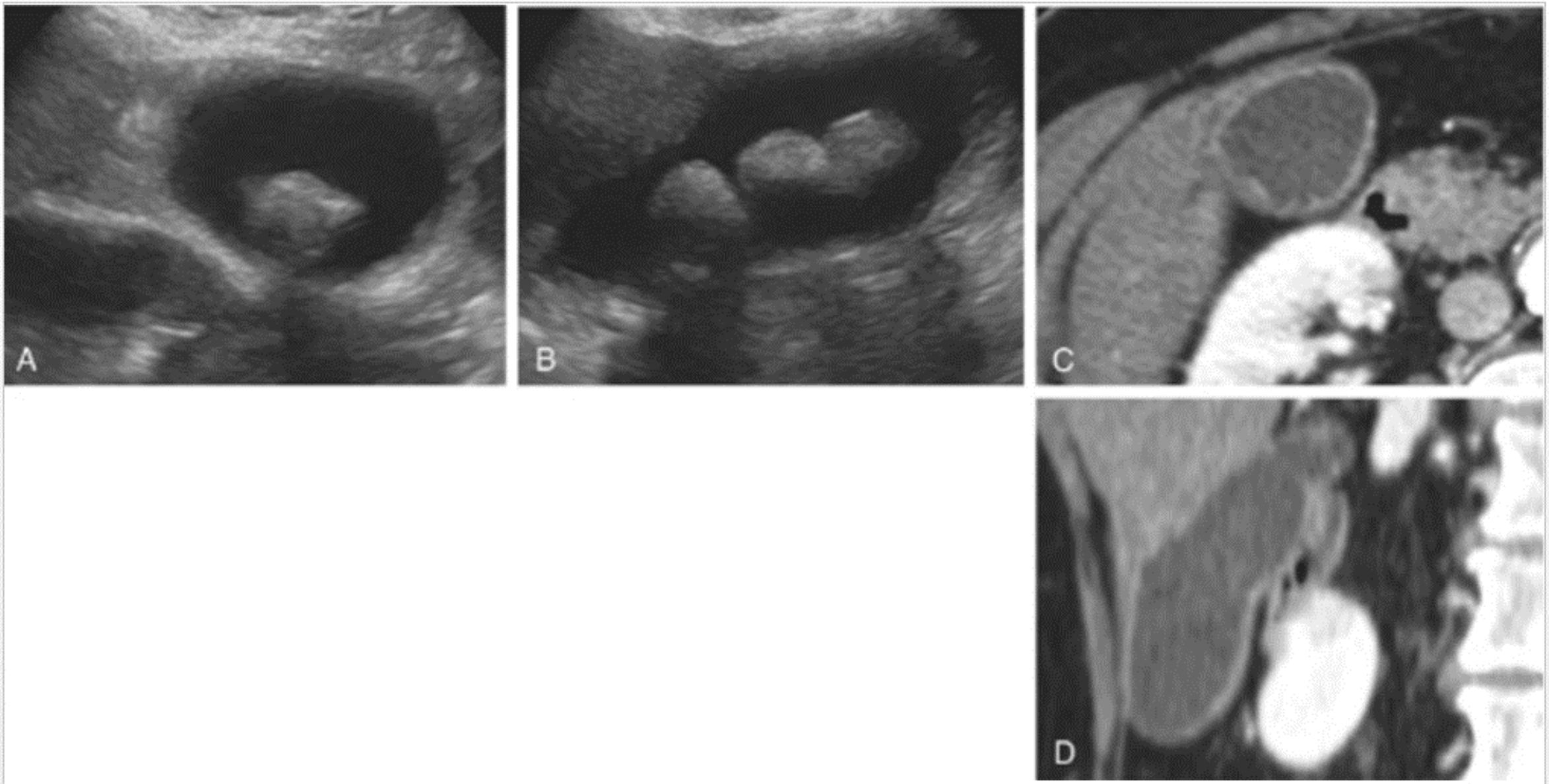
- Gallstones appear as mobile, echogenic, intraluminal structures that cast acoustic shadows.
- Shadowing occurs because of sound beam absorption by the stone.
- Demonstration of shadowing is important in distinguishing stones from other intraluminal abnormalities.
- Shadowing primarily depends on the size of the stone.
- Stones smaller than 3 mm may not cast a detectable shadow.


A
B
C
D
C
D
E


A
B
C


A
B

- Multiple studies have documented sensitivities of greater than 95% and positive and negative predictive values that are close to 100%.
- Approximately 15% of gallstones are visible on abdominal radiographs.
- CT is significantly better in detecting gallstones than radiography, but is significantly less sensitive than sonography.
- This is because noncalcified cholesterol stones may have the same attenuation value as bile and be occult on CT.
- At best, CT has sensitivity of approximately 80%.

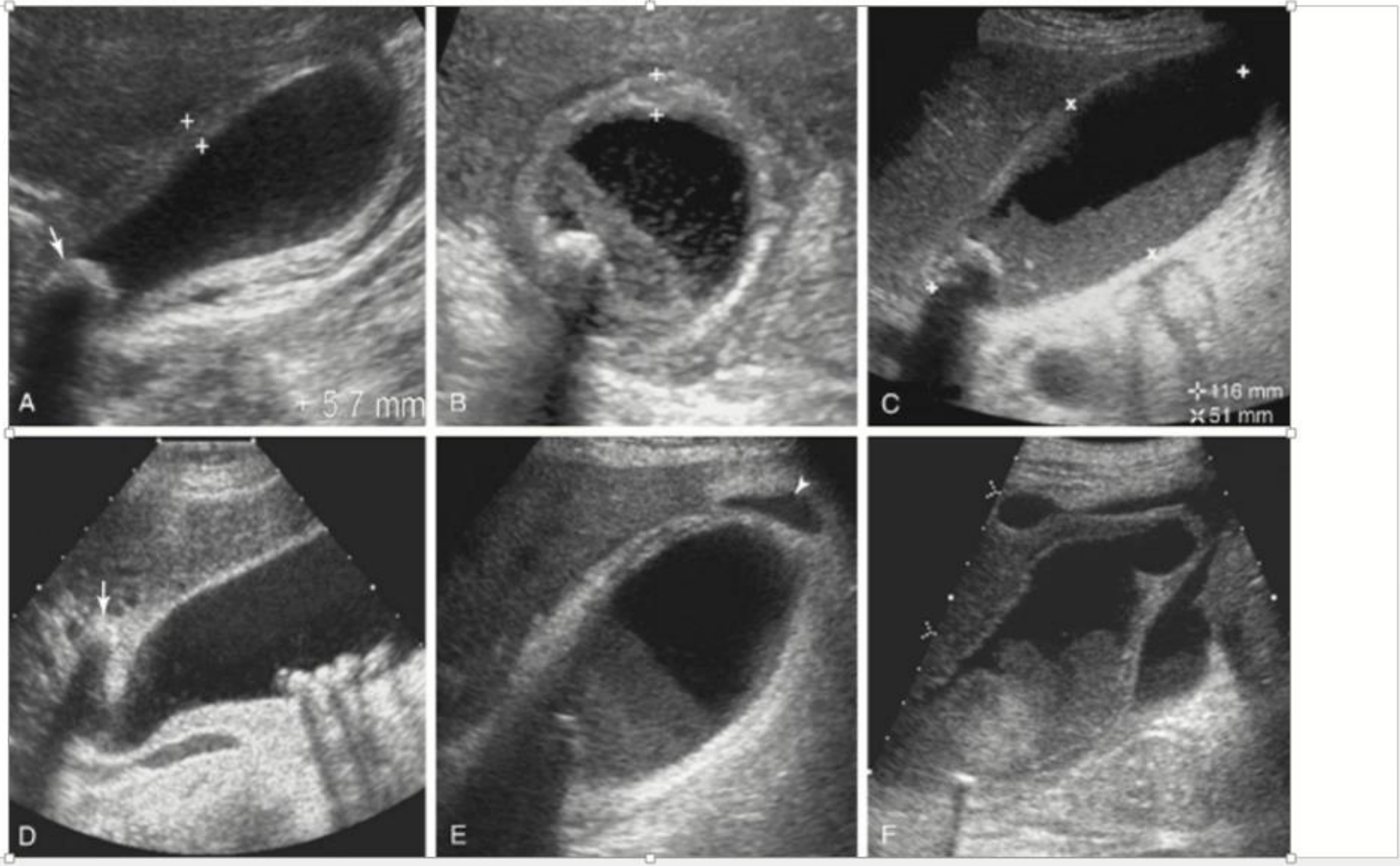

A
B
C
D

ACUTE CHOLECYSTITIS

Box 2-1

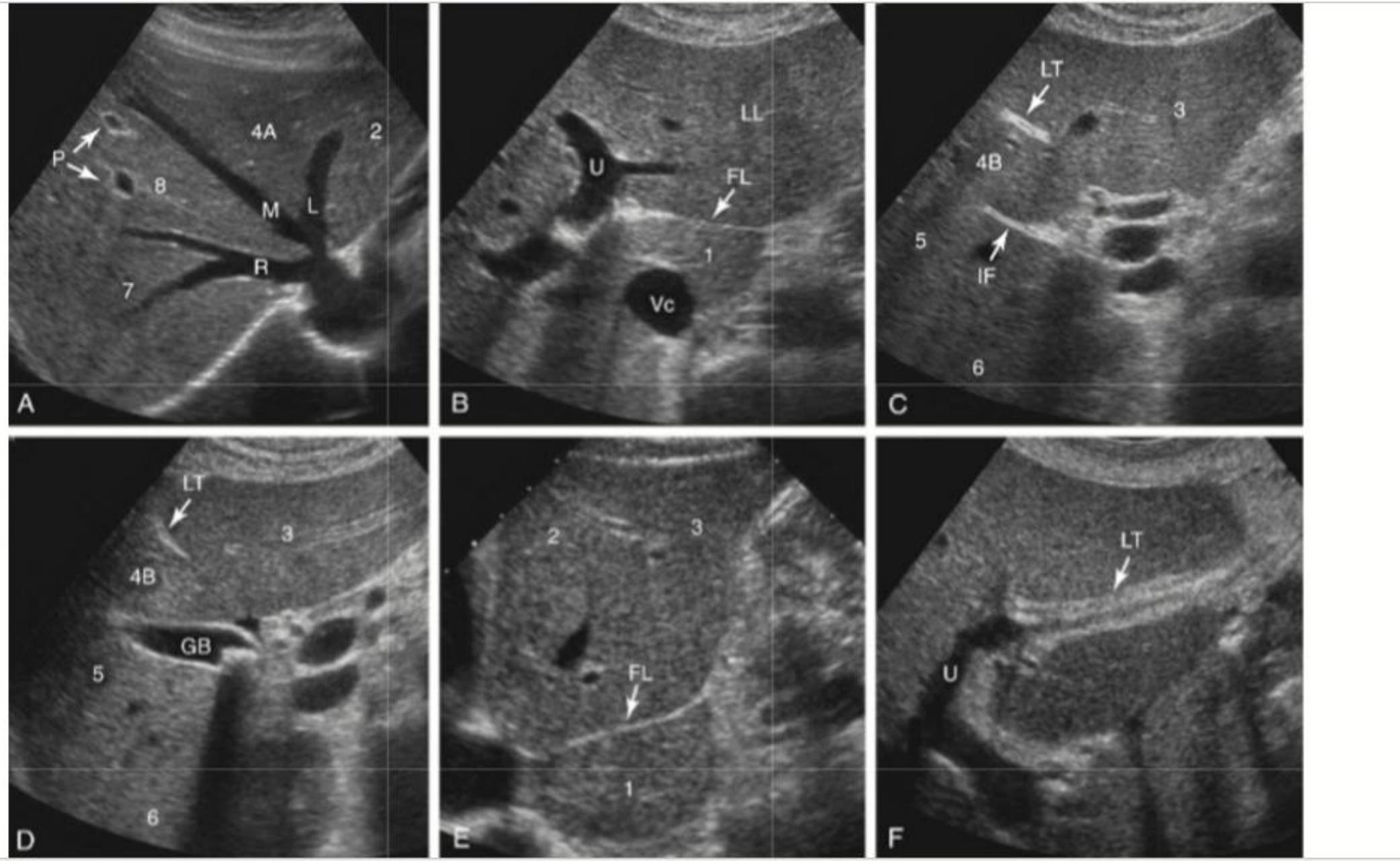
Sonographic Signs of Acute Cholecystitis

- Gallstones
- Wall thickening (≥3 mm)
- Gallbladder enlargement
- Pericholecystic fluid
- Impacted stone
- Sonographic Murphy's sign


A
+ 5 7 mm
B
C
+ 116 mm
x 51 mm
D
E
F

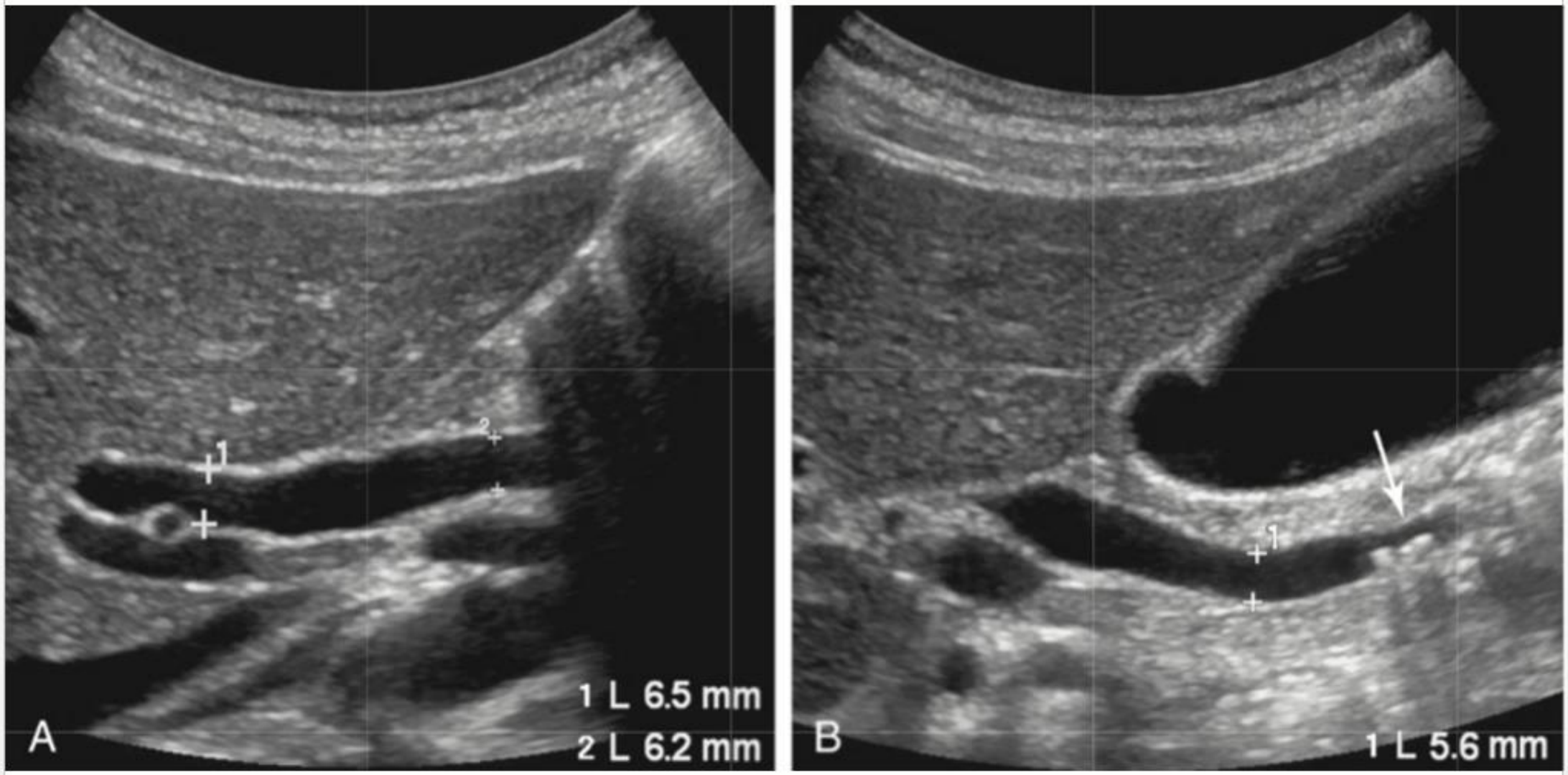
LIVER

Characteristic	Appearance
Size	<15 cm
Echogenicity	≥Right kidney, ≤pancreas, <spleen
Parenchyma	Homogeneous
Surface	Smooth


4A
2
P
8
M
L
R
7
A
LL
U
FL
1
Vc
B
LT
3
4B
5
IF
6
C
LT
3
4B
GB
5
6
D
2
3
FL
1
E
LT
U
F

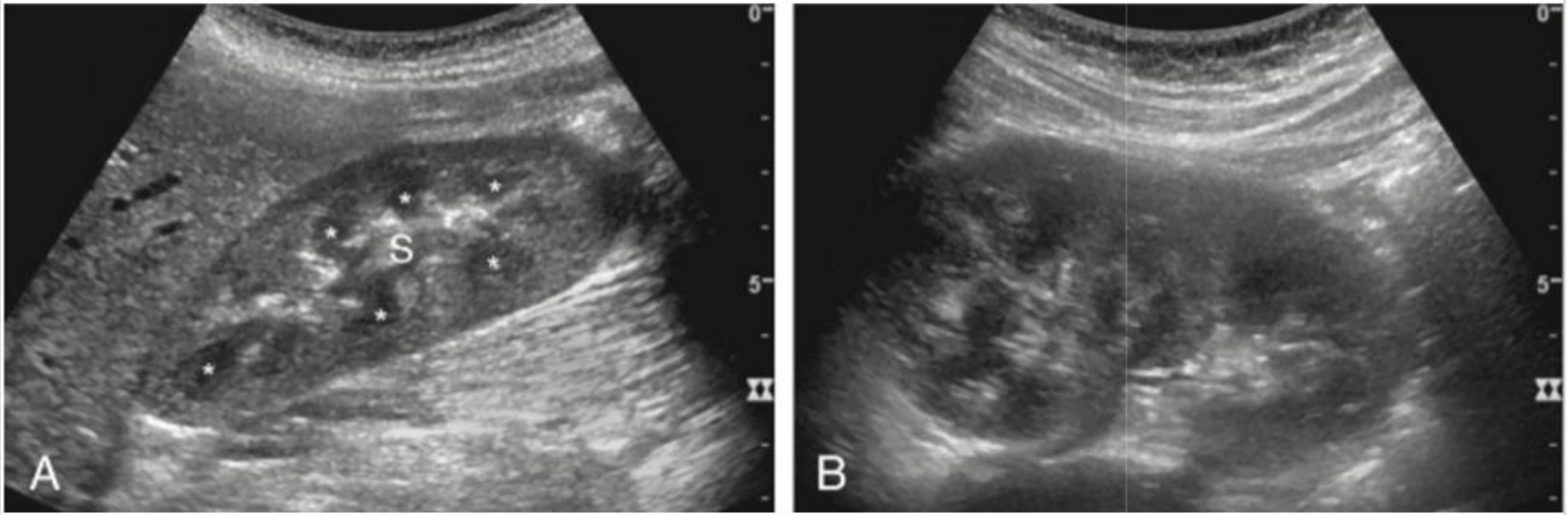
BILIARY OBSTRUCTION

- The least restricted segment of the bile duct is the mid segment (between the right hepatic artery and the pancreas), and therefore this segment dilates first in the setting of obstruction.
- This segment is generally considered dilated when it is 7 mm or greater in diameter, with the measurement taken from the inner to the inner wall.
- The common duct enlarges with age and most sonologists believe that the duct enlarges following a cholecystectomy.


1
2
1 L 6.5 mm
2 L 6.2 mm
A
1
B
1 L 5.6 mm

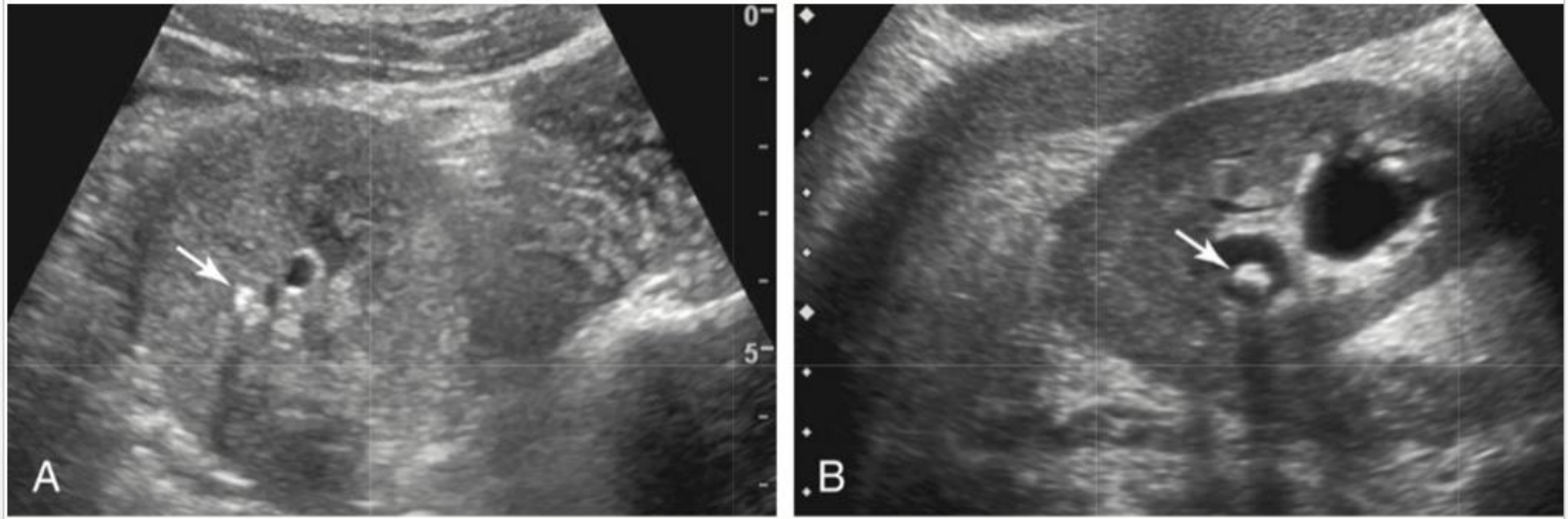
THE KIDNEYS

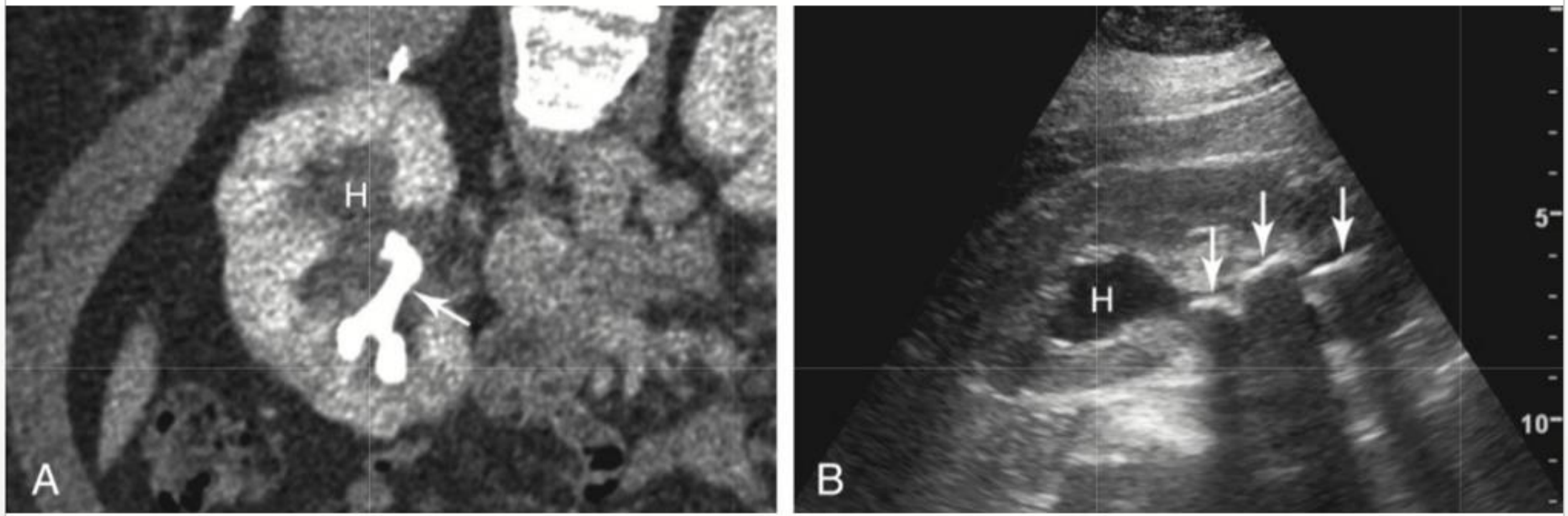
Characteristic	Appearance
Size	Average 11 cm (range, 9-13 cm)
Echogenicity	Right, less than or equal to that of the liver; left, less than that of the spleen
Parenchyma	Homogeneous (except for hypoechoic pyramids)
Renal sinus	Hyperechoic
Surface	Smooth


A
S
B

RENAL STONES

- Stones of sufficient size produce an echogenic focus in the renal sinus with an associated acoustic shadow.
- Stones that are 3 mm or smaller are a diagnostic problem because they are hard to separate from the echogenic renal sinus itself.
- Despite optimized technique small stones may not be seen with gray-scale sonography.
- A pitfall in the sonographic diagnosis of stones is refractive shadowing arising from the renal sinus.
- Sensitivity depends primarily on the size of the stones, with stones that are larger than 5 mm detected with a high sensitivity, whereas smaller stones are detected less reliably.


0
5
A
B


H
A
H
B
5
10

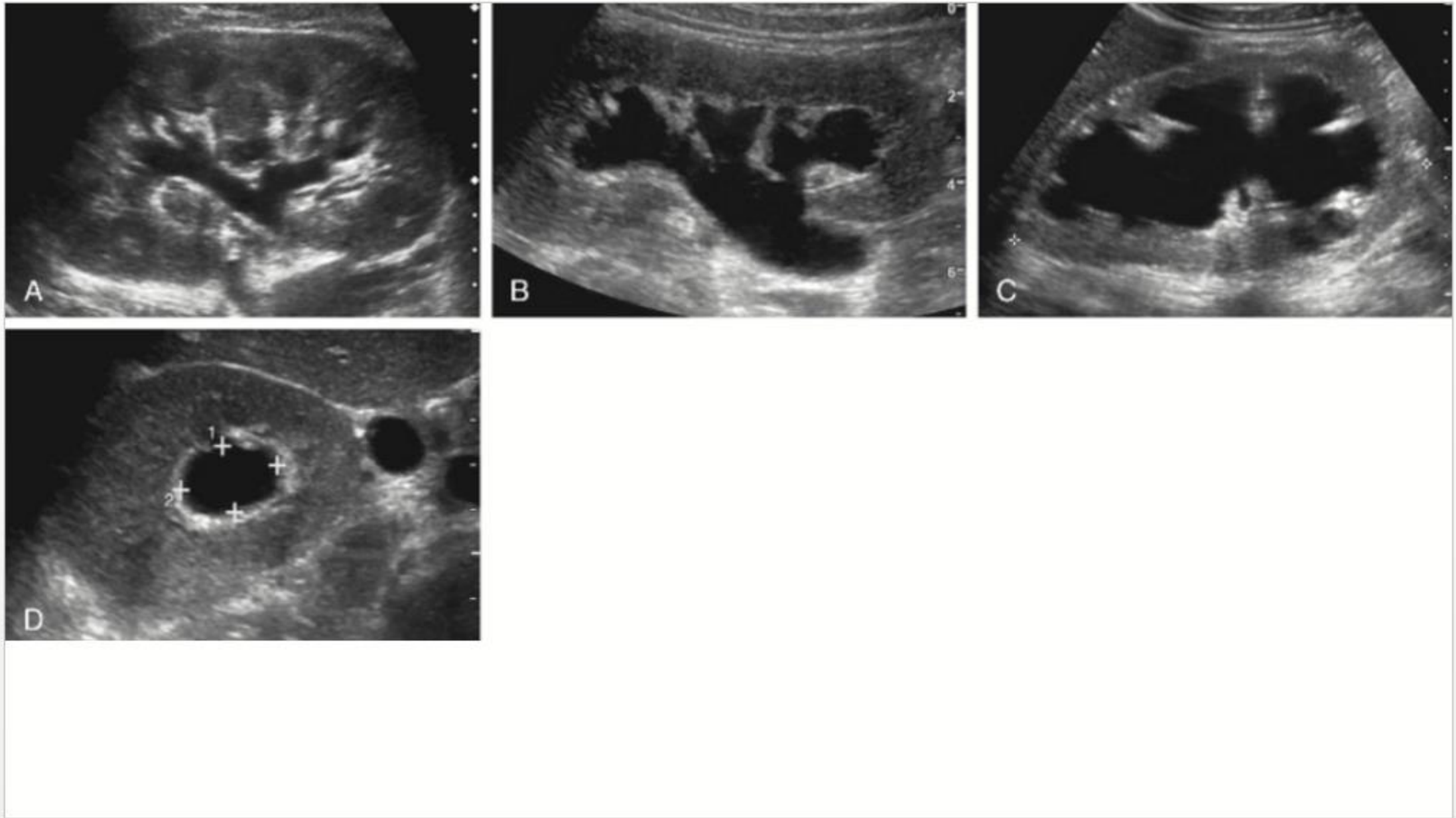
OBSTRUCTION

- Approximately 5% of patients with renal failure suffer from urinary obstruction.
- In most cases bilateral obstruction is required for renal insufficiency to develop.
- Early detection is important, as untreated obstruction can lead to irreversible renal damage.
- Patients with signs of infection who are suspected to have renal obstruction should be treated as emergencies, with immediate renal sonography and urgent drainage performed if hydronephrosis is detected.
- In general, uninfected patients with suspected renal obstruction are not considered emergencies and are scanned as soon as is reasonable.

- The likelihood of sonographic detection of hydronephrosis in patients with renal failure depends on the patient's history.
- In many of these low-risk patients an ultrasound finding of hydronephrosis will ultimately prove to be incorrect, or the patient will receive no therapy despite the ultrasound results.
- approximately 30% of the patients with known risk factors such as a known pelvic tumor, a palpable abdominal or pelvic mass, a history of renal stone disease, renal colic, sepsis, recent surgery, or a history of bladder outlet obstruction will have hydronephrosis.

- The sonographic diagnosis of obstruction relies on the detection of a dilated collecting system.
- Marked hydronephrosis (sometimes called grade 3) refers to severe dilatation that is associated with cortical thinning.
- Moderate hydronephrosis (grade 2) refers to dilatation of the collecting system that is readily evident but is not associated with cortical thinning.
- Mild hydronephrosis (grade 1) refers to minimal amounts of urine producing slight distention of the collecting system.

- Detecting the various grades of hydronephrosis is much less difficult than determining their significance.
- Repeated or long-standing obstruction may cause a dilated, ectatic collecting system that persists even when obstruction is relieved.
- Acute obstruction may produce minimal hydronephrosis or may be imaged before any hydronephrosis develops.
- For this reason, comparison with old studies is extremely valuable.


A
B
C
D
1
2

Box 5-1

Causes of Hydronephrosis

Common

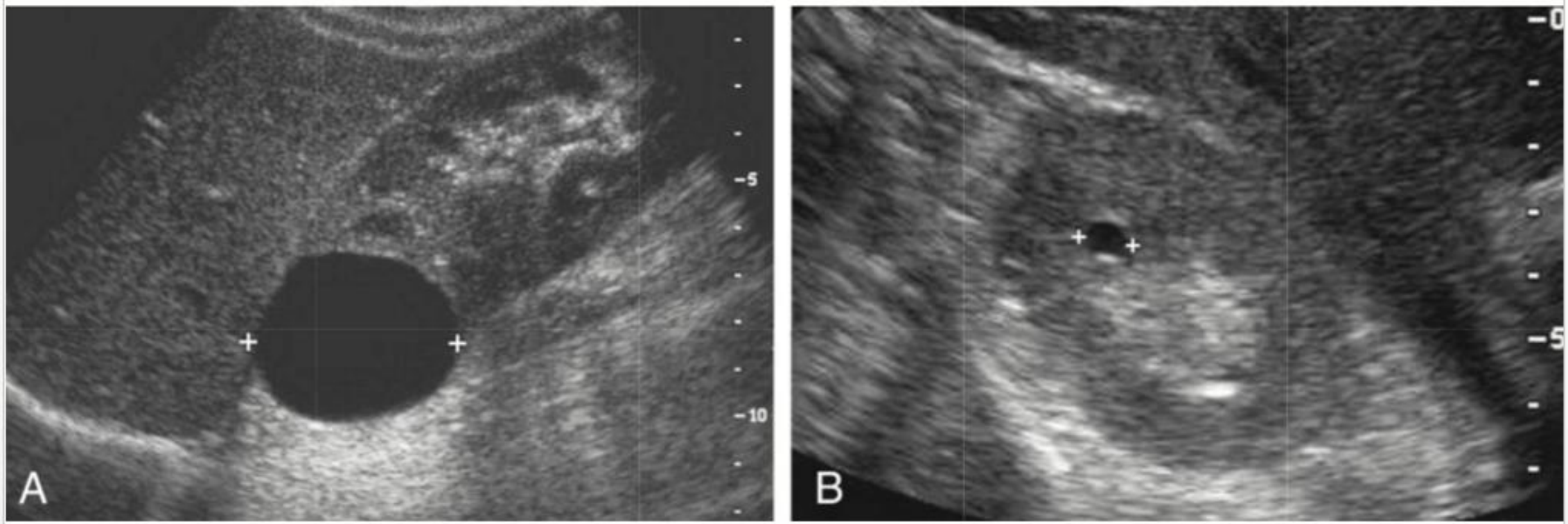
- Obstruction
- Previous obstruction
- Extrarenal pelvis
- Distended bladder
- Pregnancy

Uncommon

- Active diuresis
- Diabetes insipidus
- Reflux nephropathy

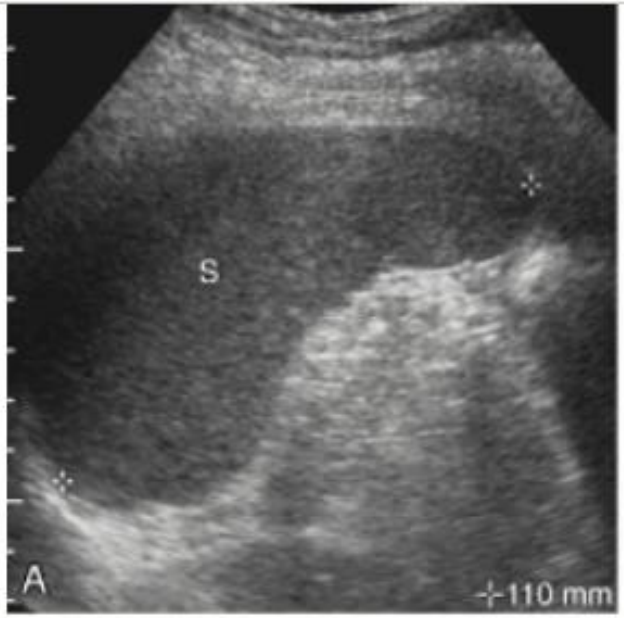
RENAL CYSTS

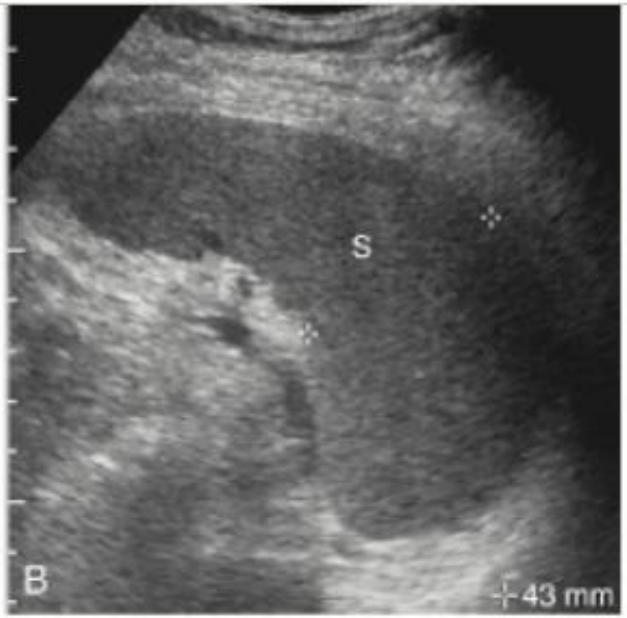
- Sonography is the most accurate way to evaluate cystic lesions in the kidney.
- To qualify as a simple cyst, the lesion should have the following characteristics:
  - Anechoic lumen
  - Well-defined back wall
  - Acoustic enhancement deep to the lesion
  - No measurable wall thickness

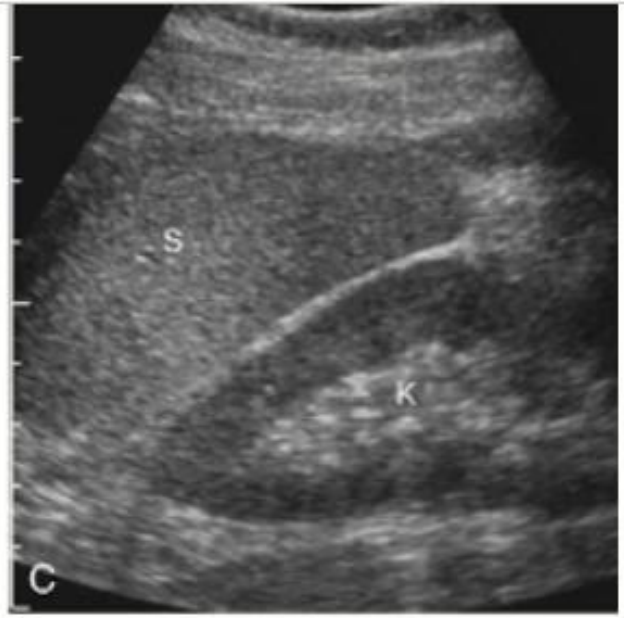

A
B

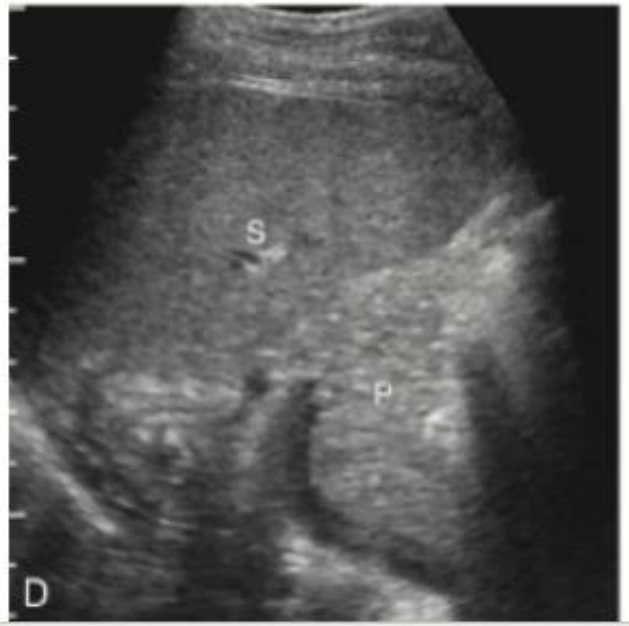
SPLEEN

Characteristic	Normal finding
Size	≤13 cm long, ≤6 cm thick
Echogenicity	>Kidney; >Liver; >, =, or <Pancreas
Echotexture	Homogeneous
Surface	Smooth
Shape	Crescentic


S
A
110 mm


S
B
43 mm


S
K
C


S
P
D

APPENDICITIS

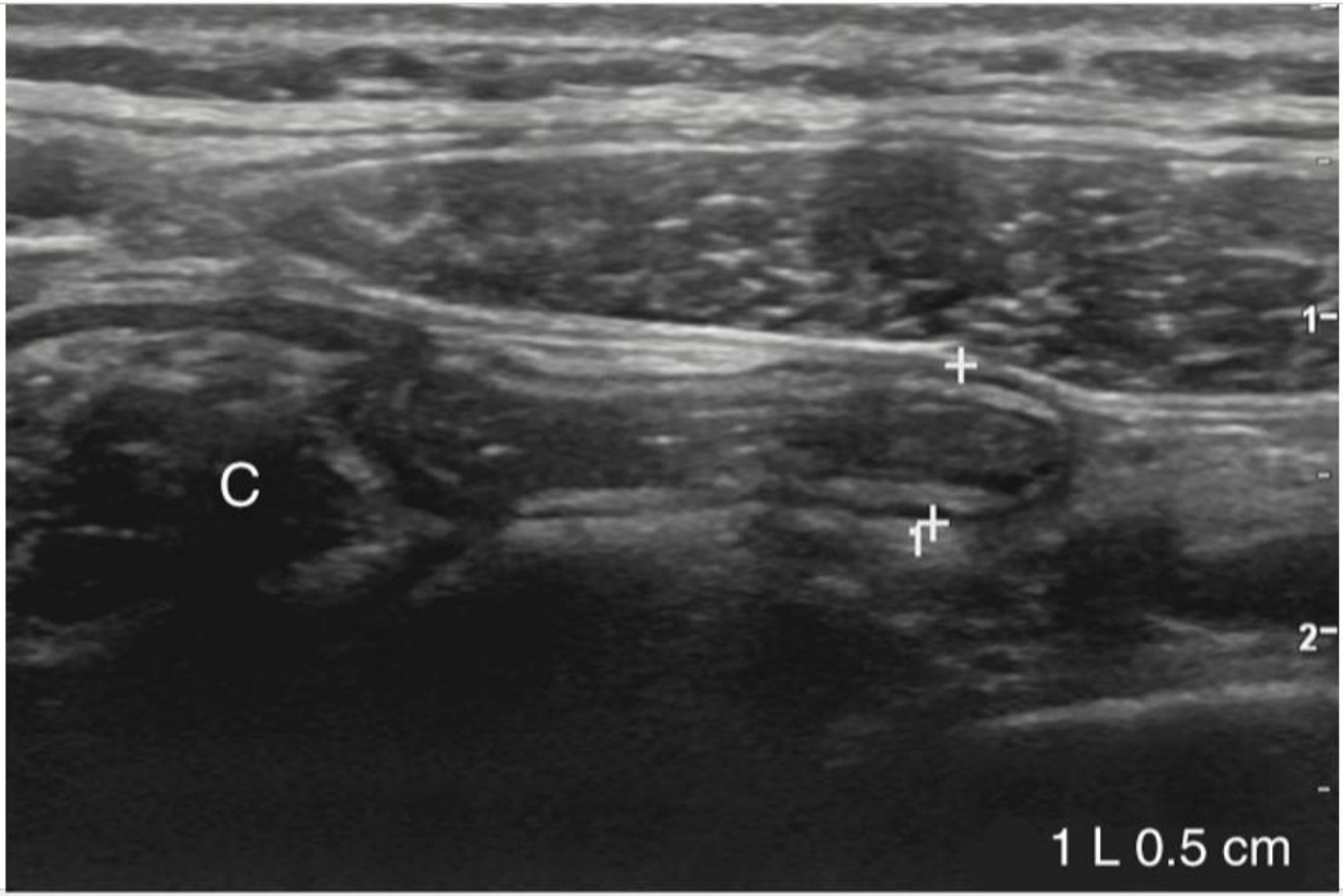
- Appendicitis is a common cause of acute abdominal pain and is the most common condition requiring urgent abdominal surgery.
- CT is the primary imaging modality used to image patients with suspected appendicitis, with sensitivity and specificity of approximately 90%.
- Sonography has sensitivity and specificity of approximately 80%.
- Sonography is used as the primary test in children and pregnant women to avoid radiation exposure, and in young women because of the frequency of gynecologic causes of pain.

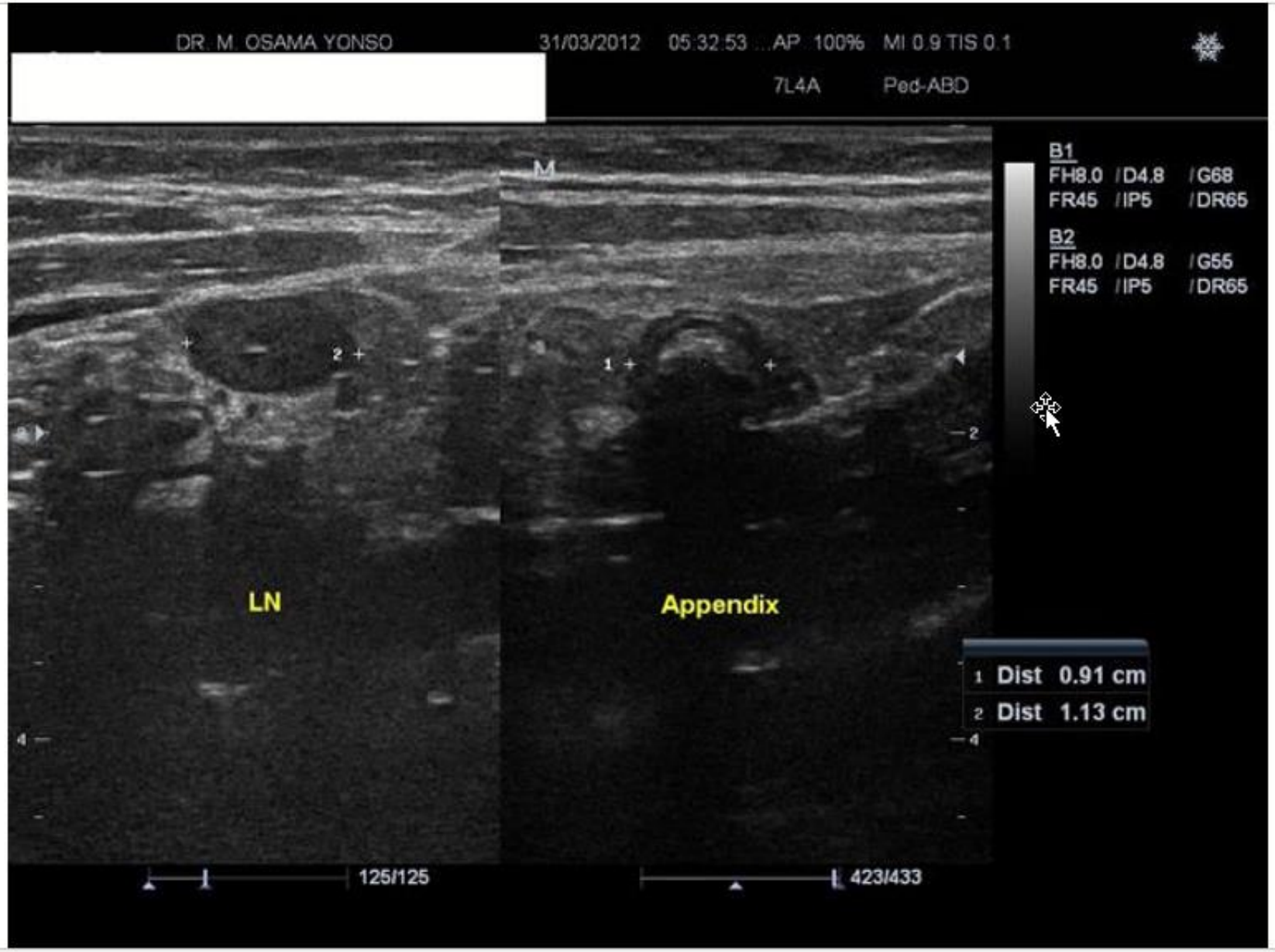
- The appendix should be blind ending and noncompressible, and peristalsis should be absent or very minimal.
- It is important to realize that the normal appendix can be seen only by experienced sonographers, and usually only in thin patients.
- It is not necessary to see a normal appendix to exclude appendicitis.

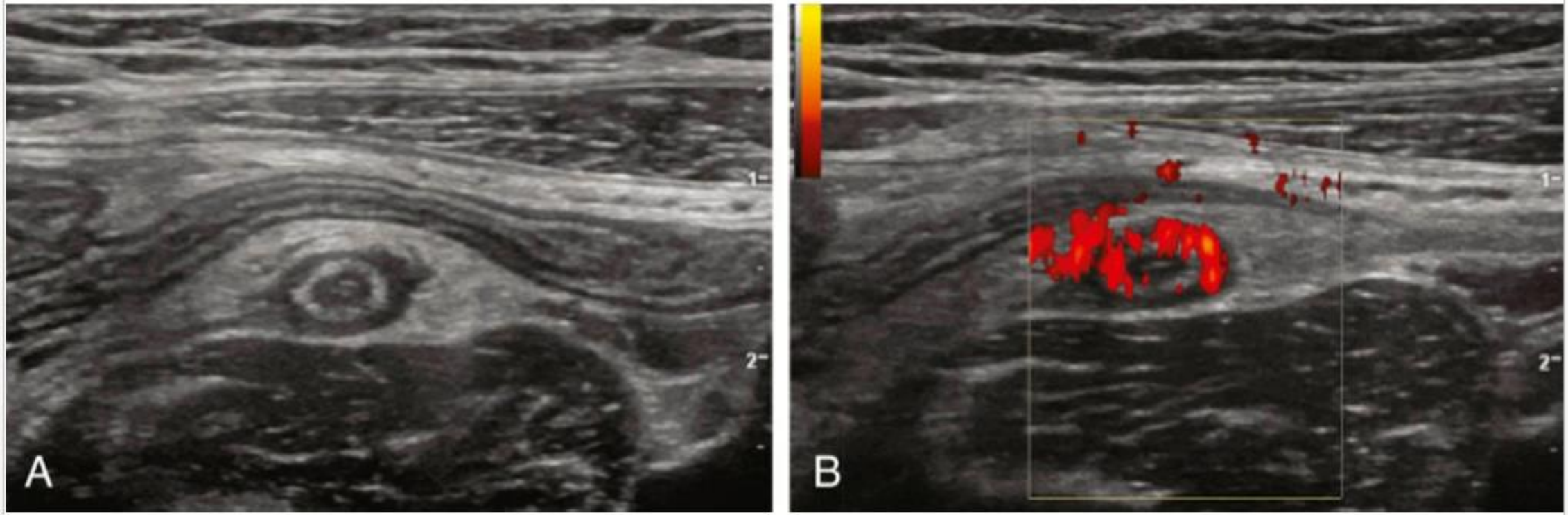
Box 9-2

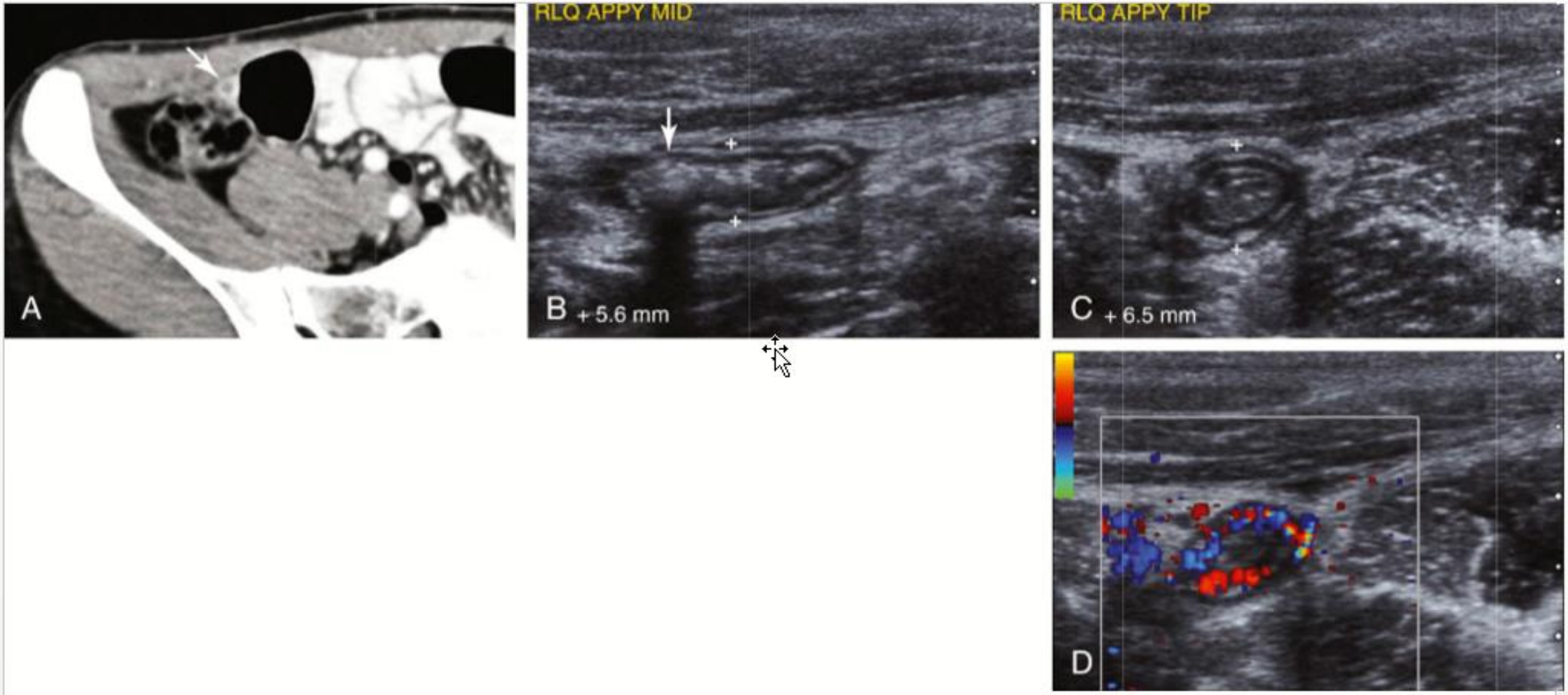
Sonographic Signs of Appendicitis

- Diameter > 6 mm
- Lack of compressibility
- Inflamed, echogenic periappendiceal fat
- Hyperemia
- Appendicolith
- Adjacent fluid collections


C
1
2
1 L 0.5 cm


DR. M. OSAMA YONSO
31/03/2012 05:32:53 ...AP 100% MI 0.9 TIS 0.1
7L4A Ped-ABD
B1
FH8.0 /D4.8 /G68
FR45 /IP5 /DR65
B2
FH8.0 /D4.8 /G55
FR45 /IP5 /DR65
LN
Appendix
1 Dist 0.91 cm
2 Dist 1.13 cm
125/125
423/433


A
B

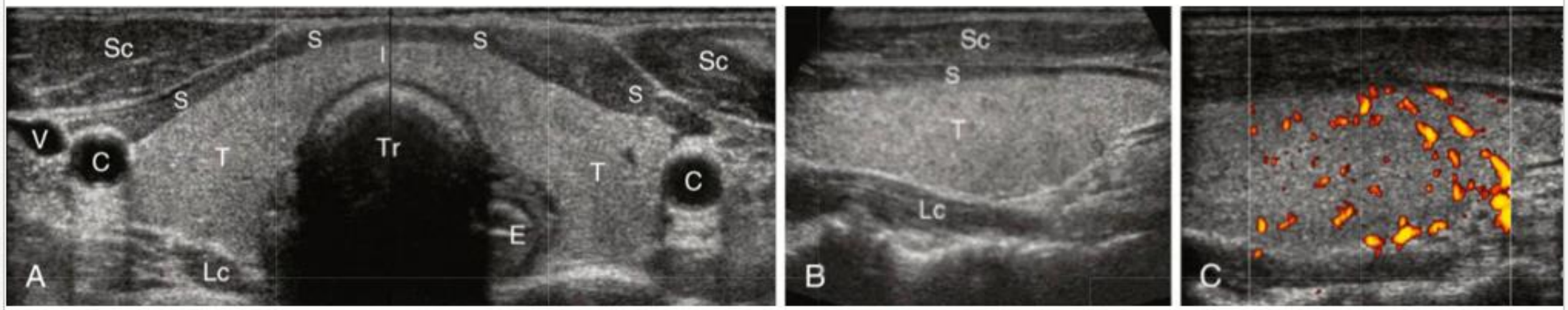

A
RLQ APPY MID
B + 5.6 mm
RLQ APPY TIP
C + 6.5 mm
D

THYROID

Box 10-1
Characteristics of the Normal Thyroid

Hyperechoic to adjacent muscles
Homogeneous
Scattered readily detectable internal vessels
Diameter of lobes less than 2 cm in AP and transverse views
Isthmus less than 4 mm

AP, Anteroposterior.


Sc
S
I
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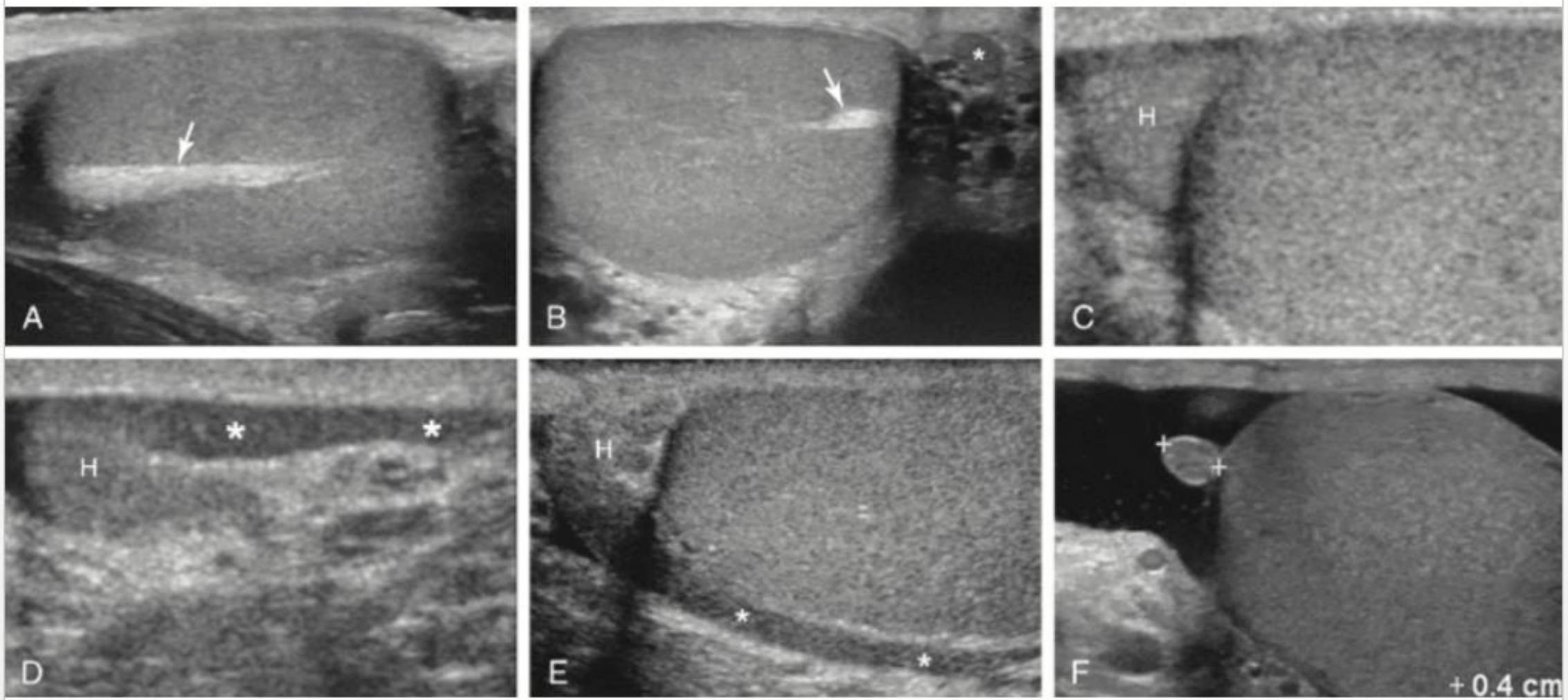
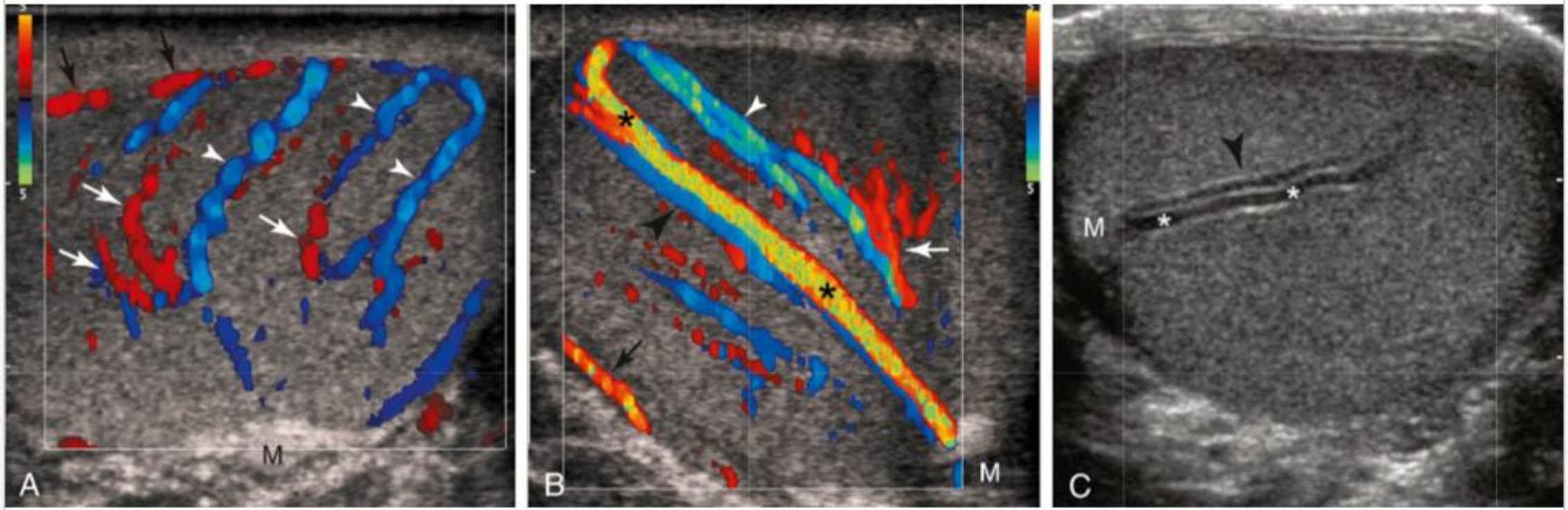
Sc
S
S
V
C
T
Tr
T
C
E
Lc
A
Sc
S
T
Lc
B
C

SCROTUM

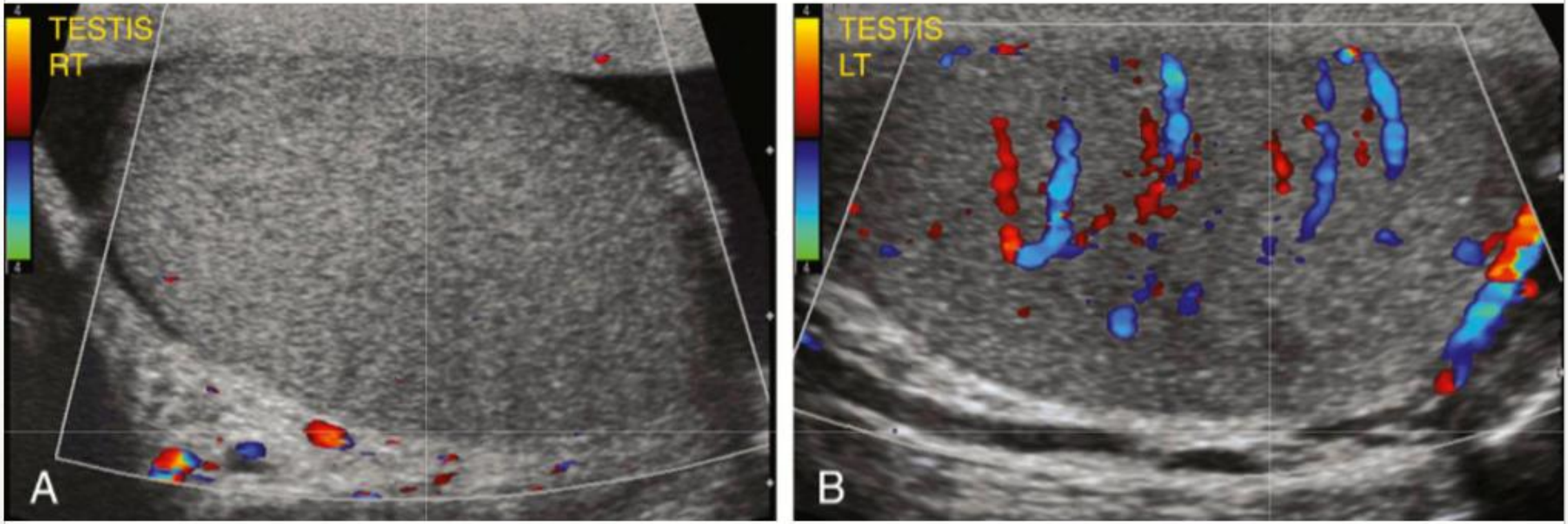
Characteristic	Appearance
Echogenicity	Medium level (except echogenic mediastinum)
Texture	Homogeneous
Surface	Smooth
Vascularity	Largest vessels on surface
Size	15-20 cm^3 (average 4-5 × 2-3 × 2-2.5 cm)


A
B
C
H
D
H
E
H
F
+ 0.4 cm


A
M
B
M
C
M

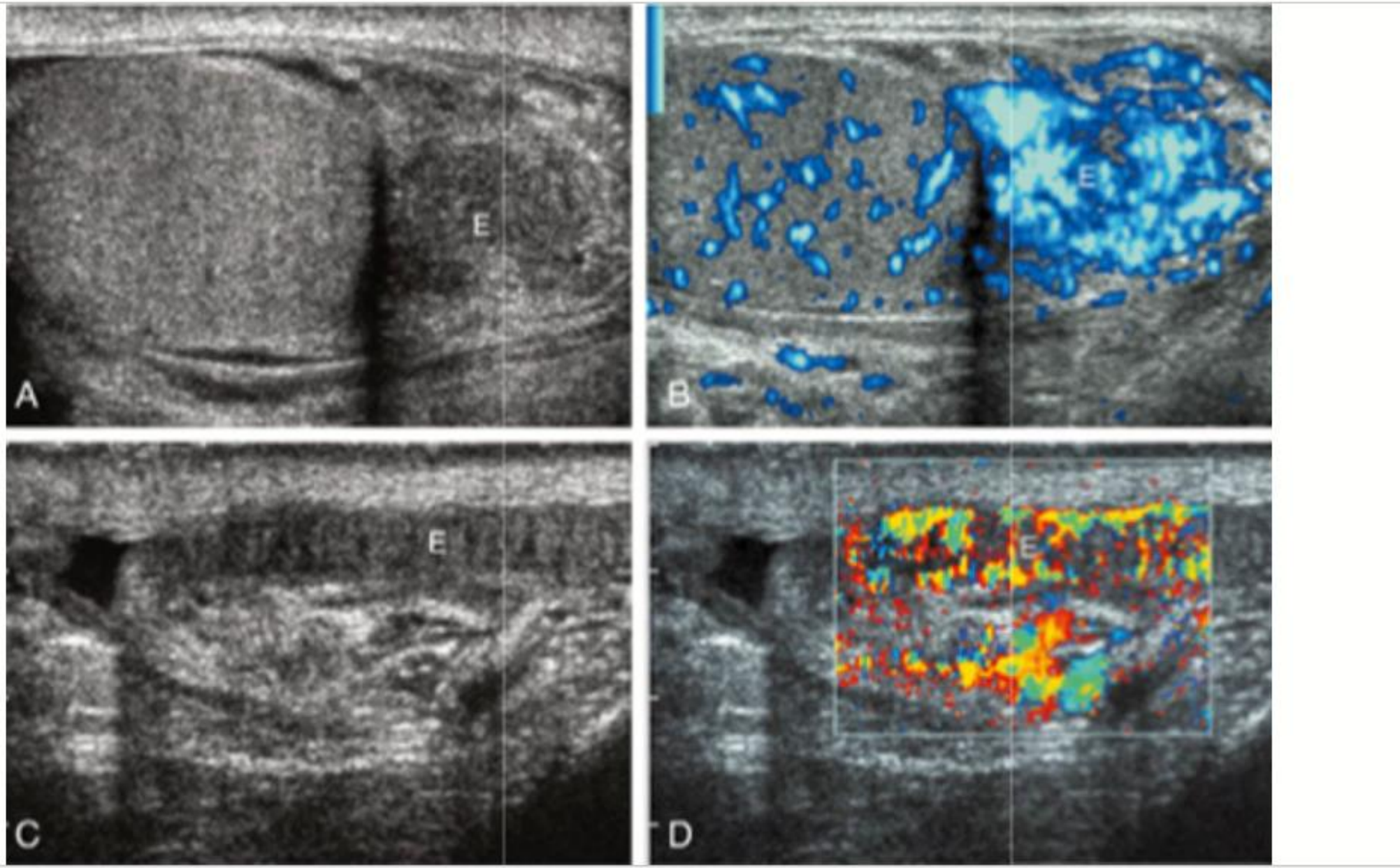
TESTICULAR TORSION

- Color Doppler is an effective way to detect testicular ischemia in the setting of torsion.
- This is primarily done by comparing the vascularity of the normal and abnormal testes.
- In most cases a torsed testis will have no detectable flow.
- In a smaller percentage of cases there will be detectable flow that is clearly asymmetrically decreased compared with the other testis

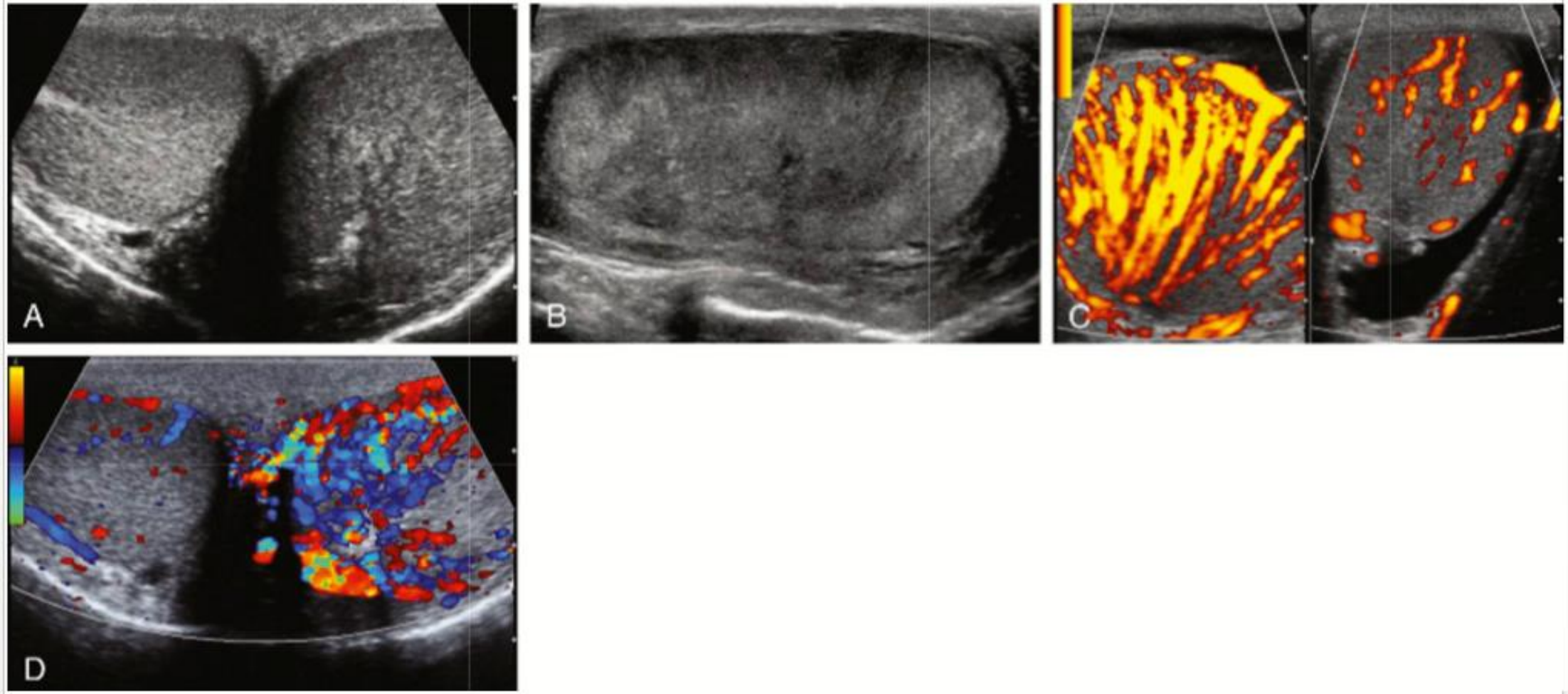

TESTIS
RT
A
TESTIS
LT
B

EPIDIDYMO-ORCHITIS

- Scrotal inflammatory disease usually involves the epididymis initially and spreads from there to the testis, scrotal sac, or scrotal wall.
- The hallmark of epididymitis on gray-scale studies is enlargement and, to a lesser degree, decreased echogenicity of the epididymis.
- Color Doppler imaging is valuable when the gray-scale findings are equivocal or normal because it can detect inflammatory hyperemia as increased epididymal vascularity.

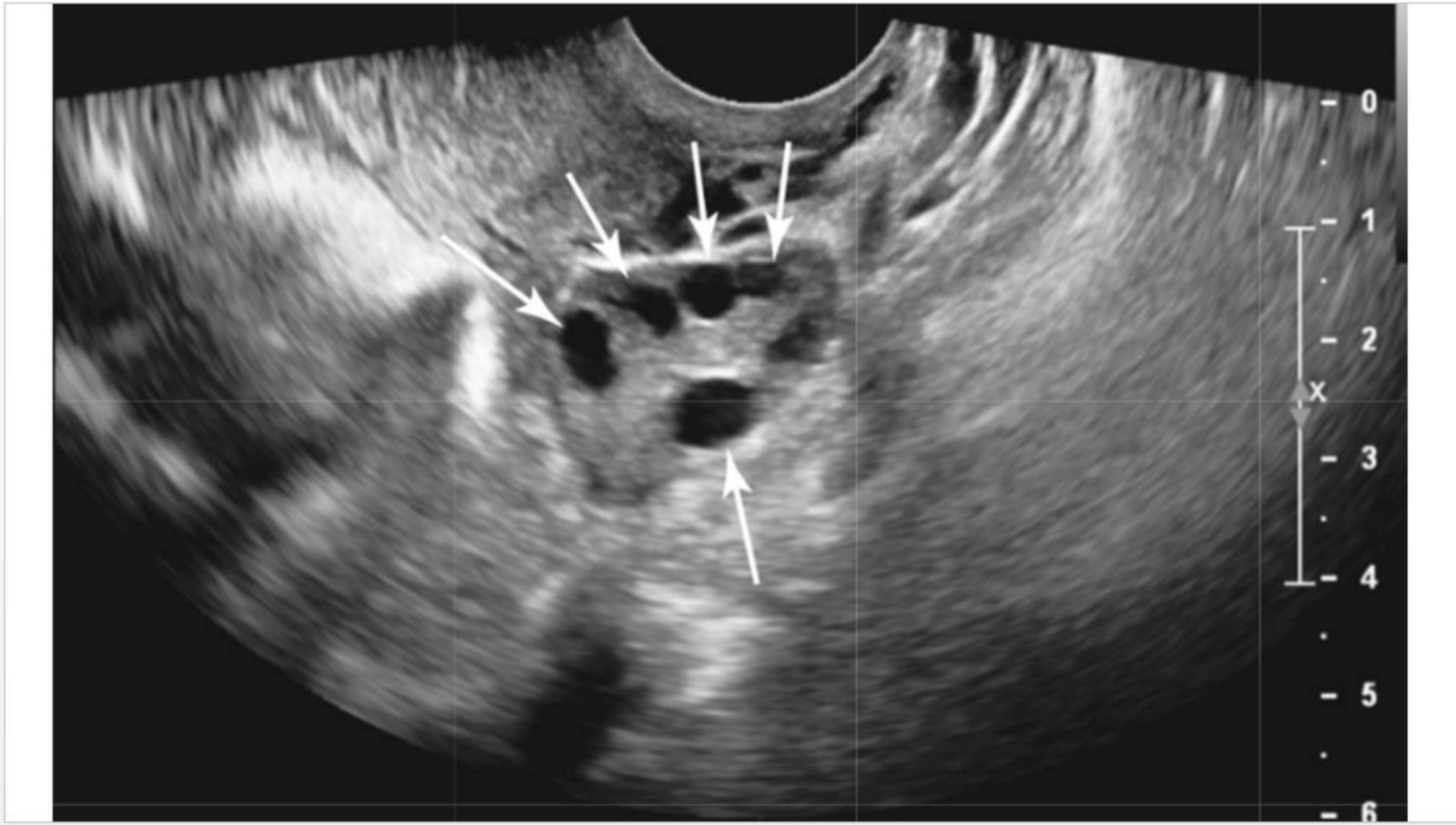

A
E
B
E
C
E
D
E

- Orchitis usually occurs in conjunction with epididymitis.
- Isolated orchitis is less common and generally viral in nature (i.e., mumps).
- Testicular enlargement, decreased echogenicity, heterogeneity, and hypervascularity are all typical findings


A
B
C
D

NORMAL OVARY

- The ovaries are ovoid or teardrop in configuration and elongated in contour.
- Follicles are depicted as rounded, thin-walled anechoic cystic structures in the ovary.
- Identification of follicles distinguishes the ovary from adjacent structures such as bowel loops and uterine masses.
- The ovaries are typically positioned lateral to the uterus and anteromedial to the internal iliac blood vessels.
- Ovarian volume can be estimated by multiplying length × width × depth and dividing by 2 (a simplified version of the formula for the volume of an ellipse).


0
1
2
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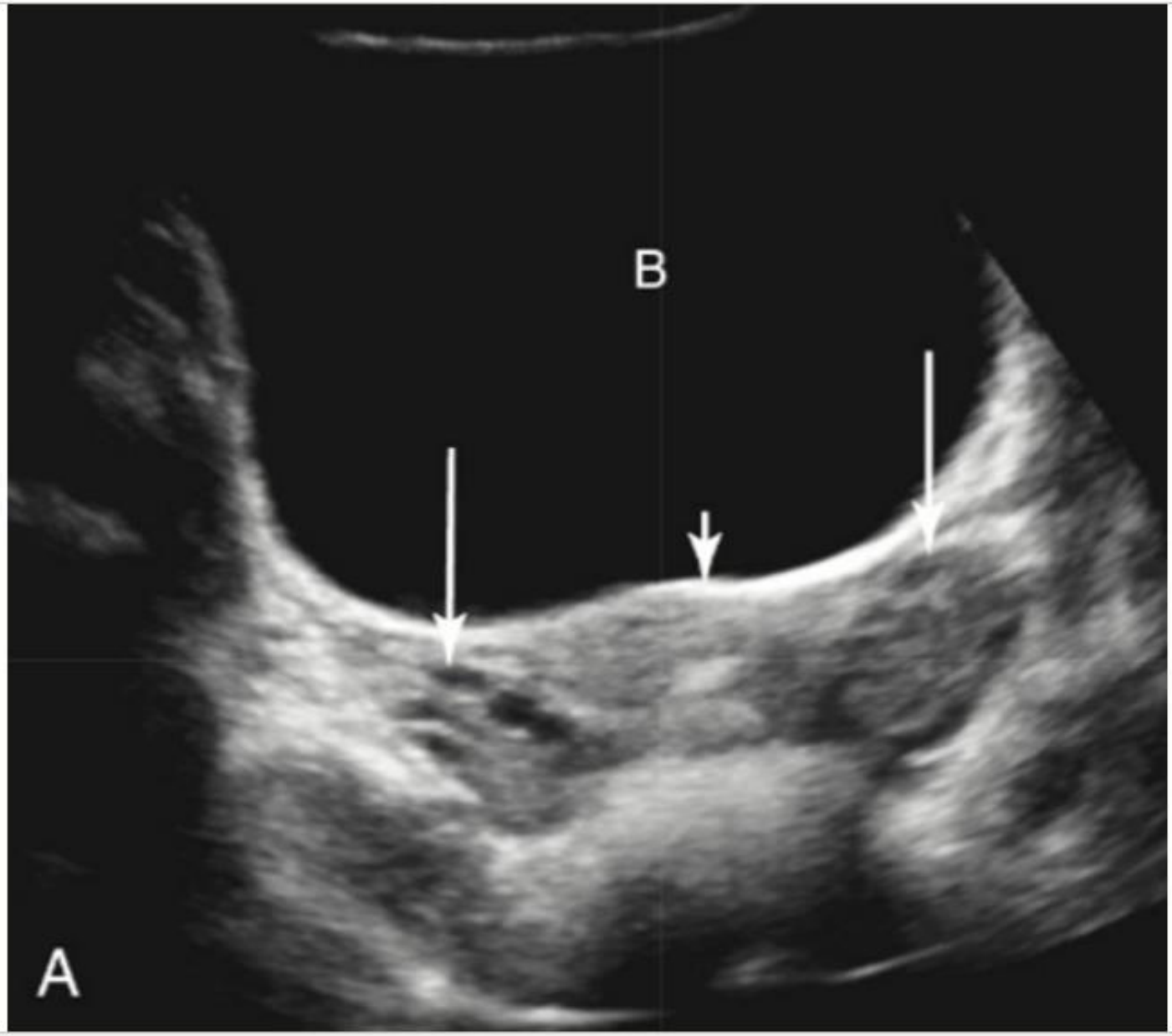
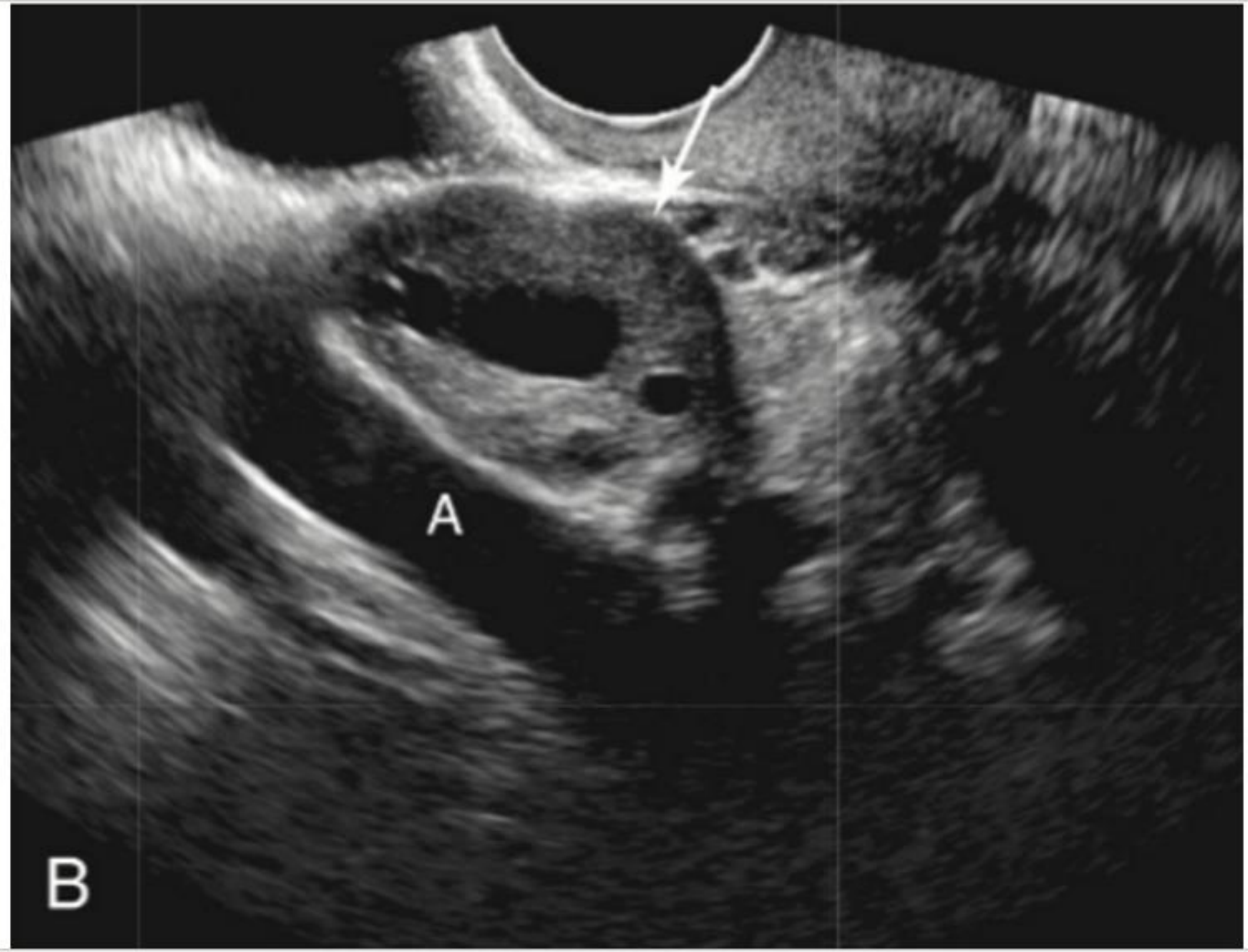

B
A


A
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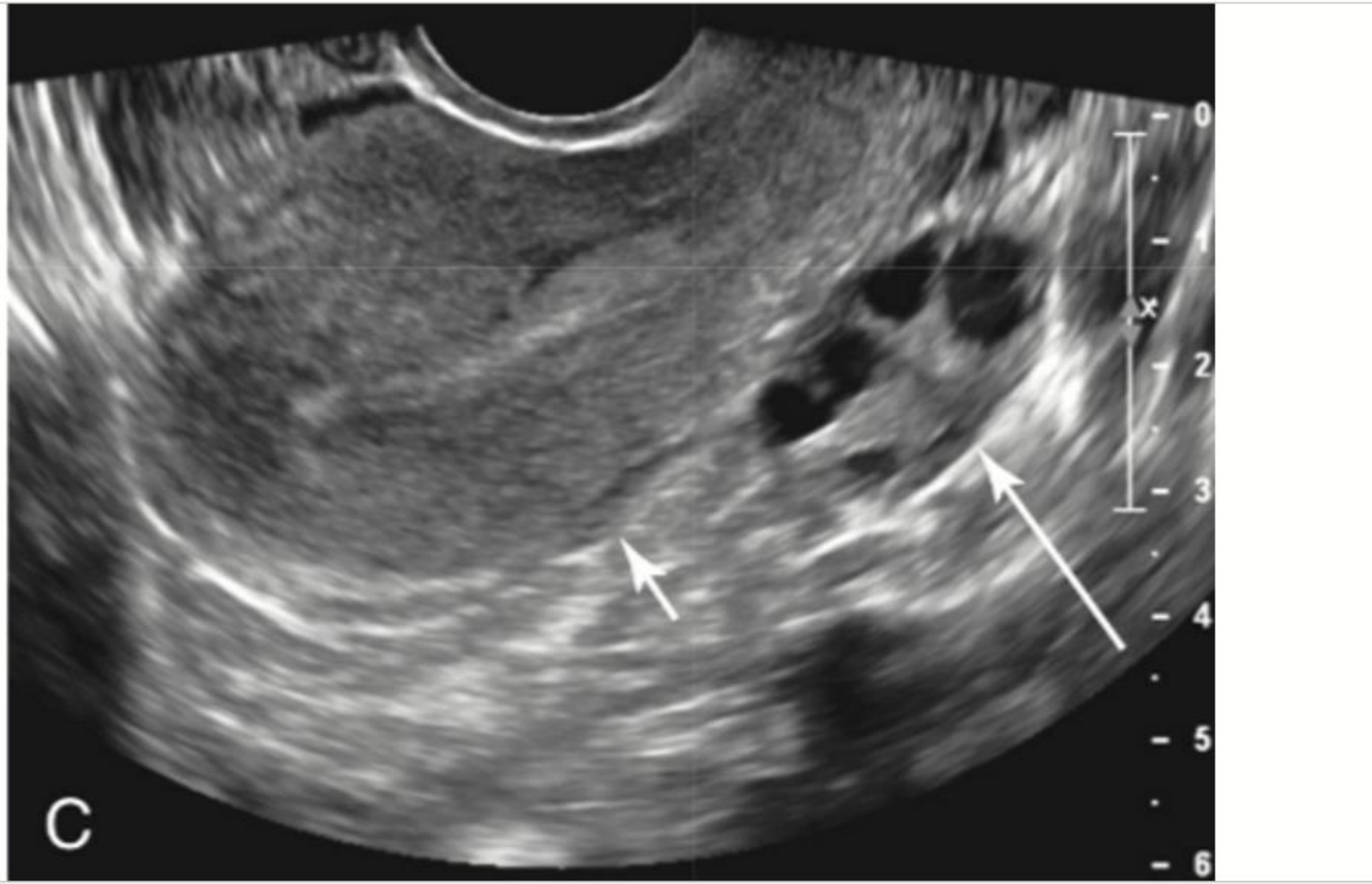
C
0
1
2
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4
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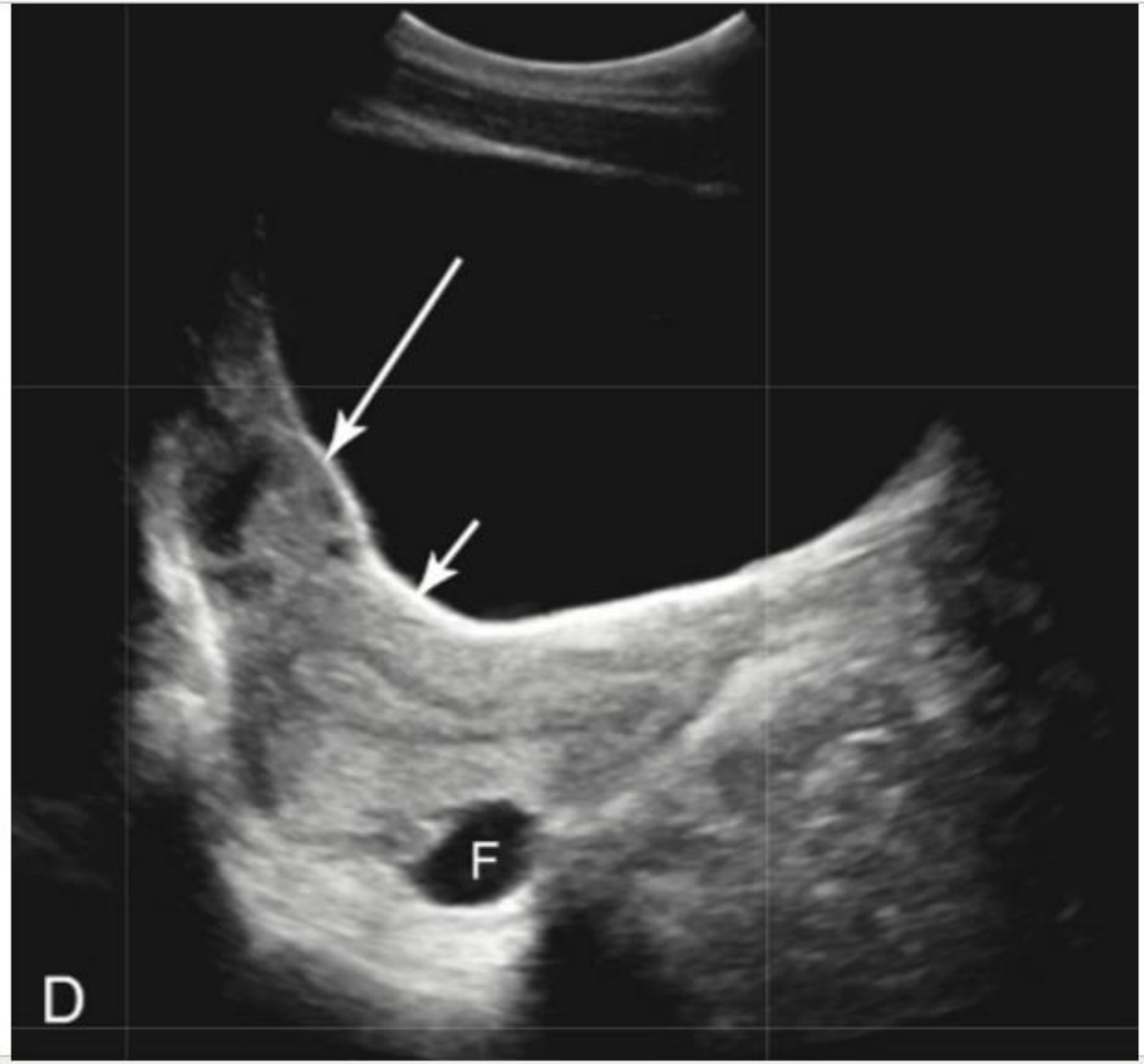

F
D

OVARIAN TORSION

- Patients with ovarian torsion typically present with acute onset of severe unilateral pain, often in conjunction with nausea and vomiting.
- Intermittent pain may precede the acute pain by weeks.
- Torsion may present at any time in life from the neonatal to the postmenopausal period, although it is relatively uncommon following menopause.
- There is an increased risk of ovarian torsion during pregnancy.
- When ovarian torsion is strongly suspected, rapid surgical intervention is important to improve the likelihood of a viable ovary following detorsion.

Box 24-4

Ovarian Torsion: Ultrasound Findings

Ovarian enlargement: especially asymmetric enlargement on side of pain compared with contralateral ovary

Heterogeneous ovarian echotexture

Relative paucity of follicles

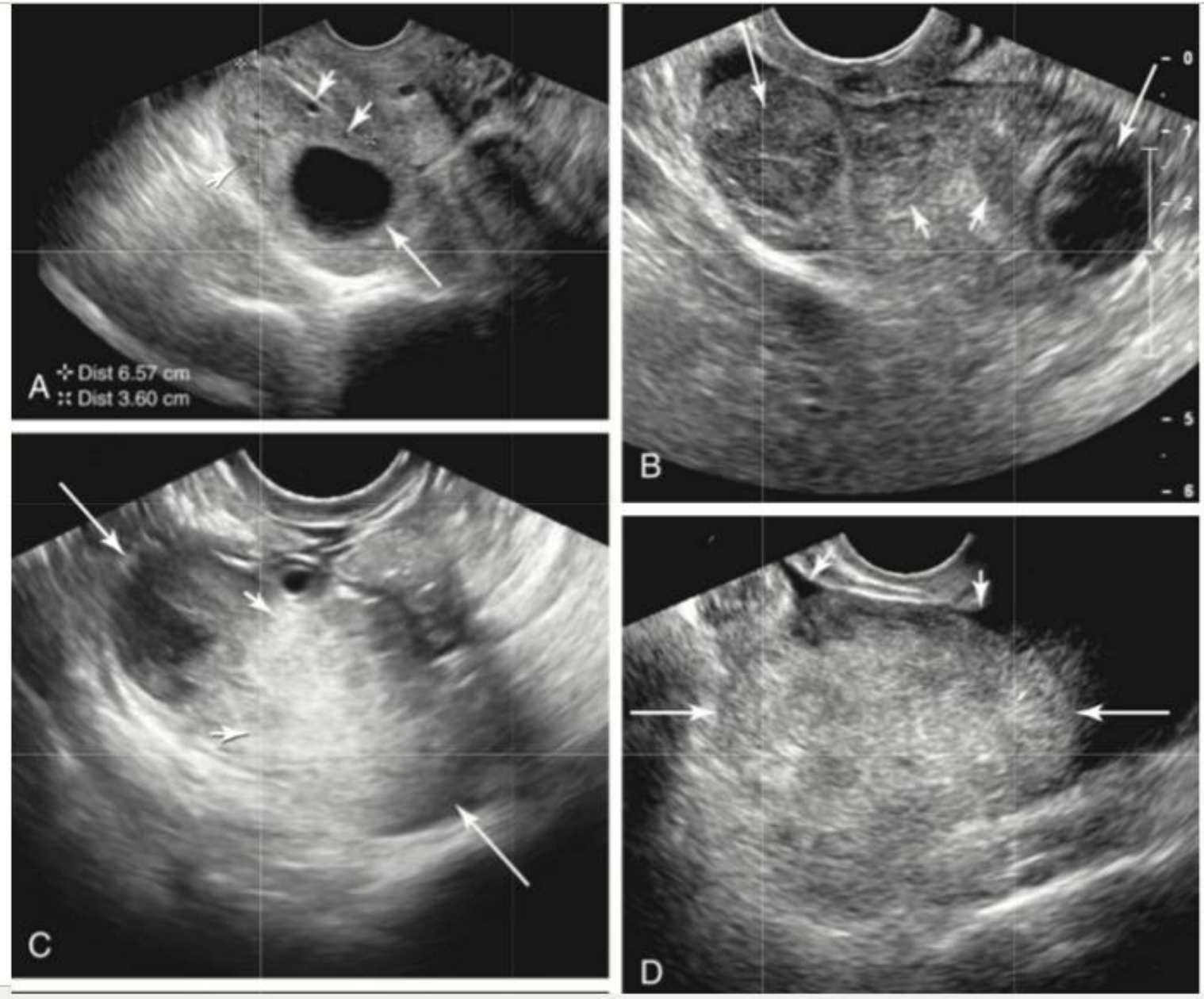
Small follicles displaced peripherally

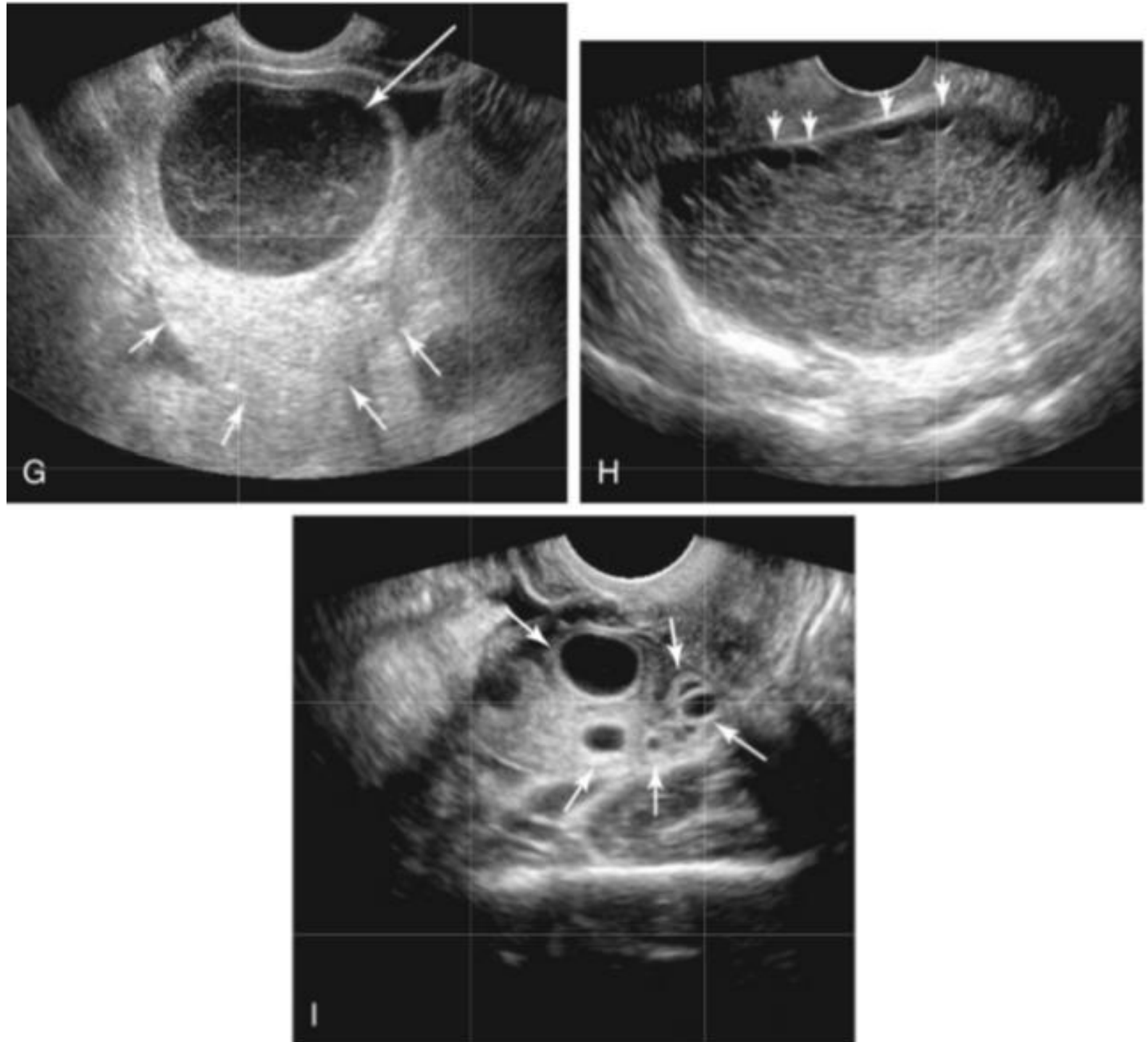
Peripheral echogenic ring around follicles *(follicular ring sign)*

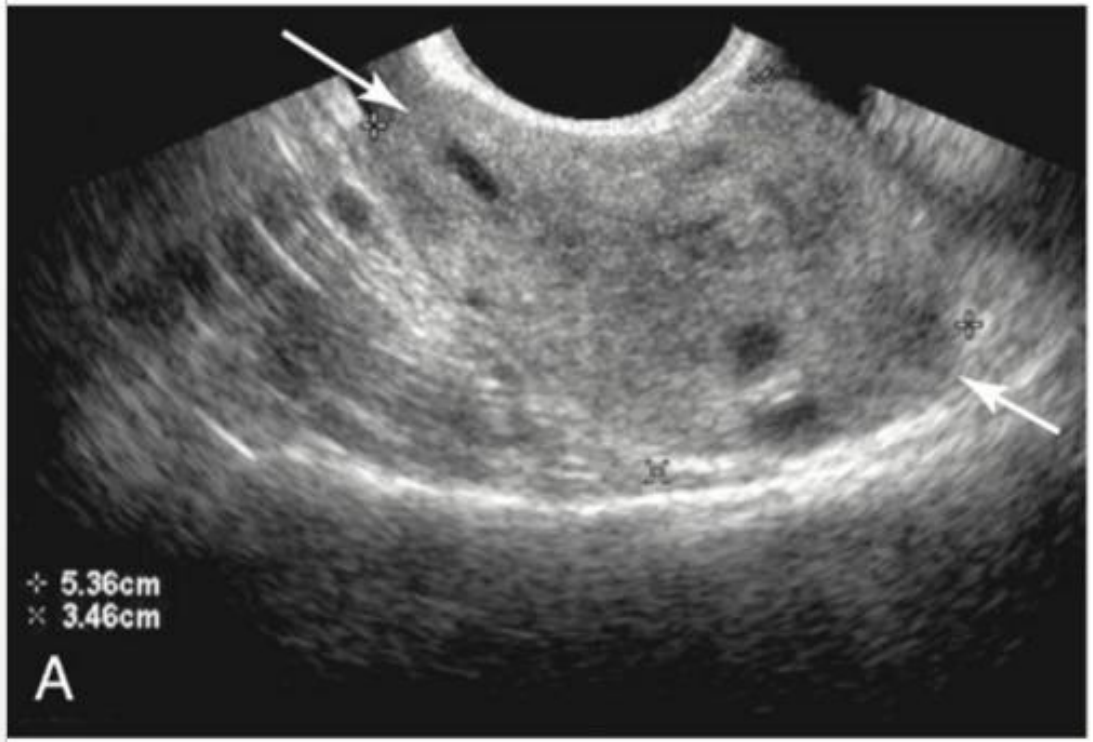
Twisted pedicle with concentric circular bands

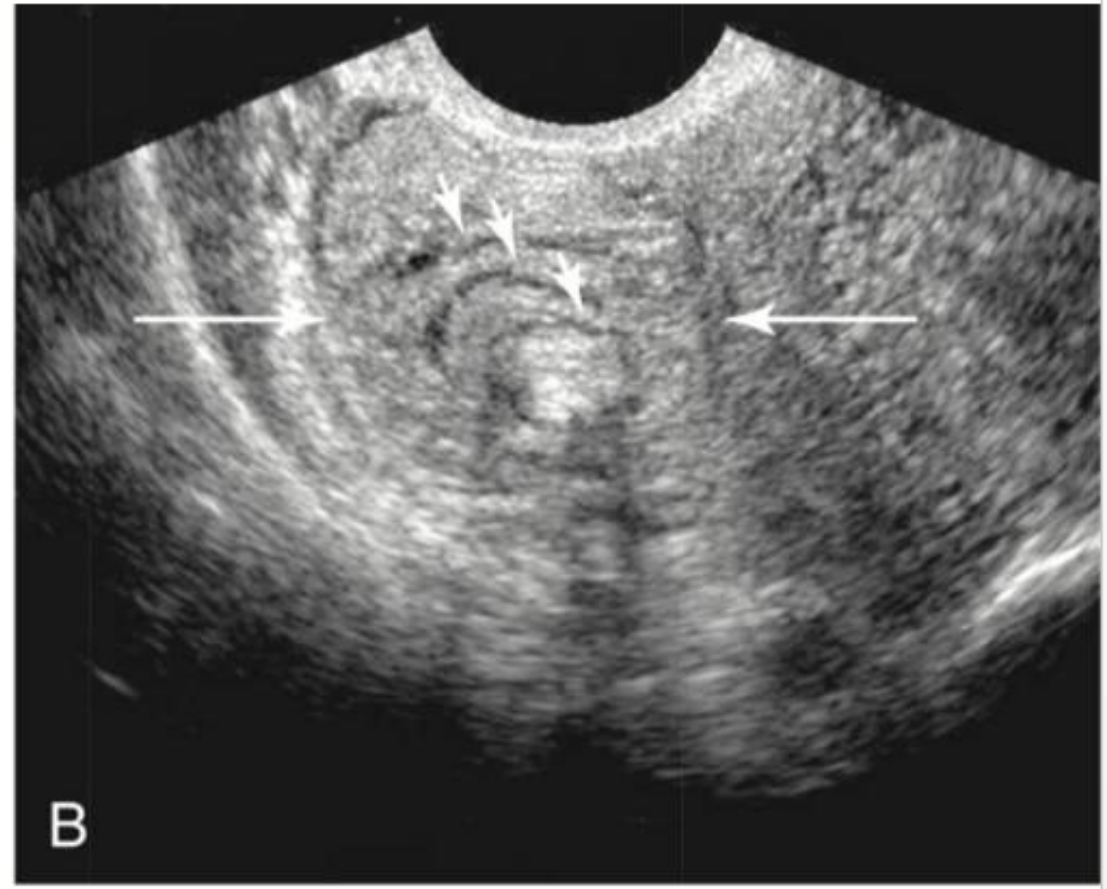
Whirlpool sign

Ovarian cyst


A
Dist 6.57 cm
Dist 3.60 cm
B
C
D


G
H
I


5.36cm
3.46cm
A


B

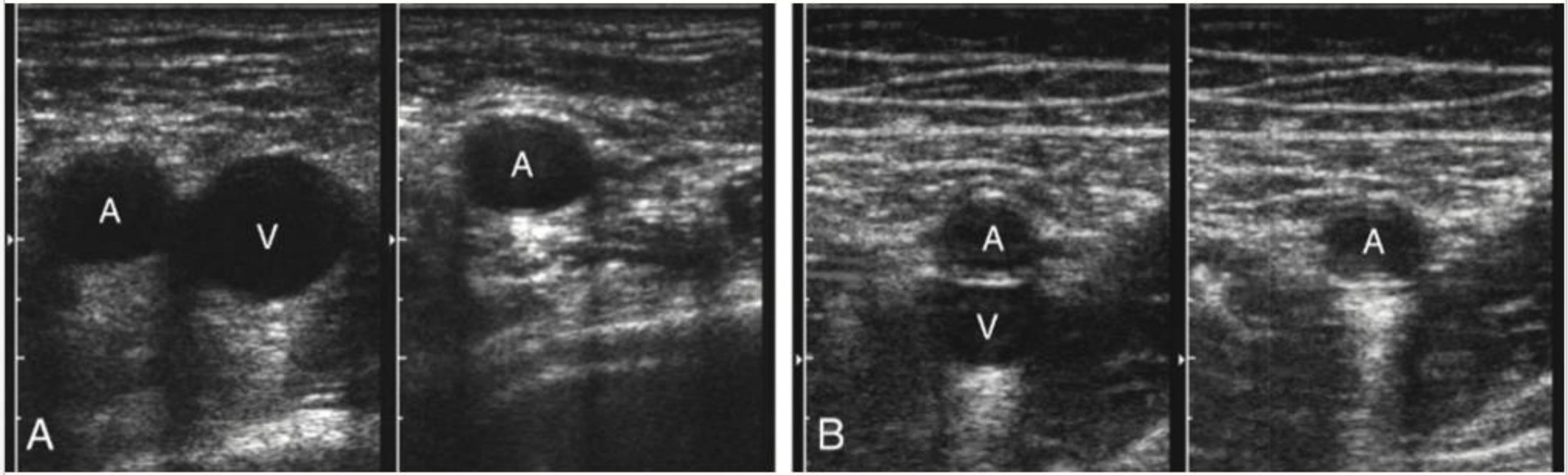

RT OV SAG
D=61.1 mm
D=33.3 mm
6cm
14fps
Fr56

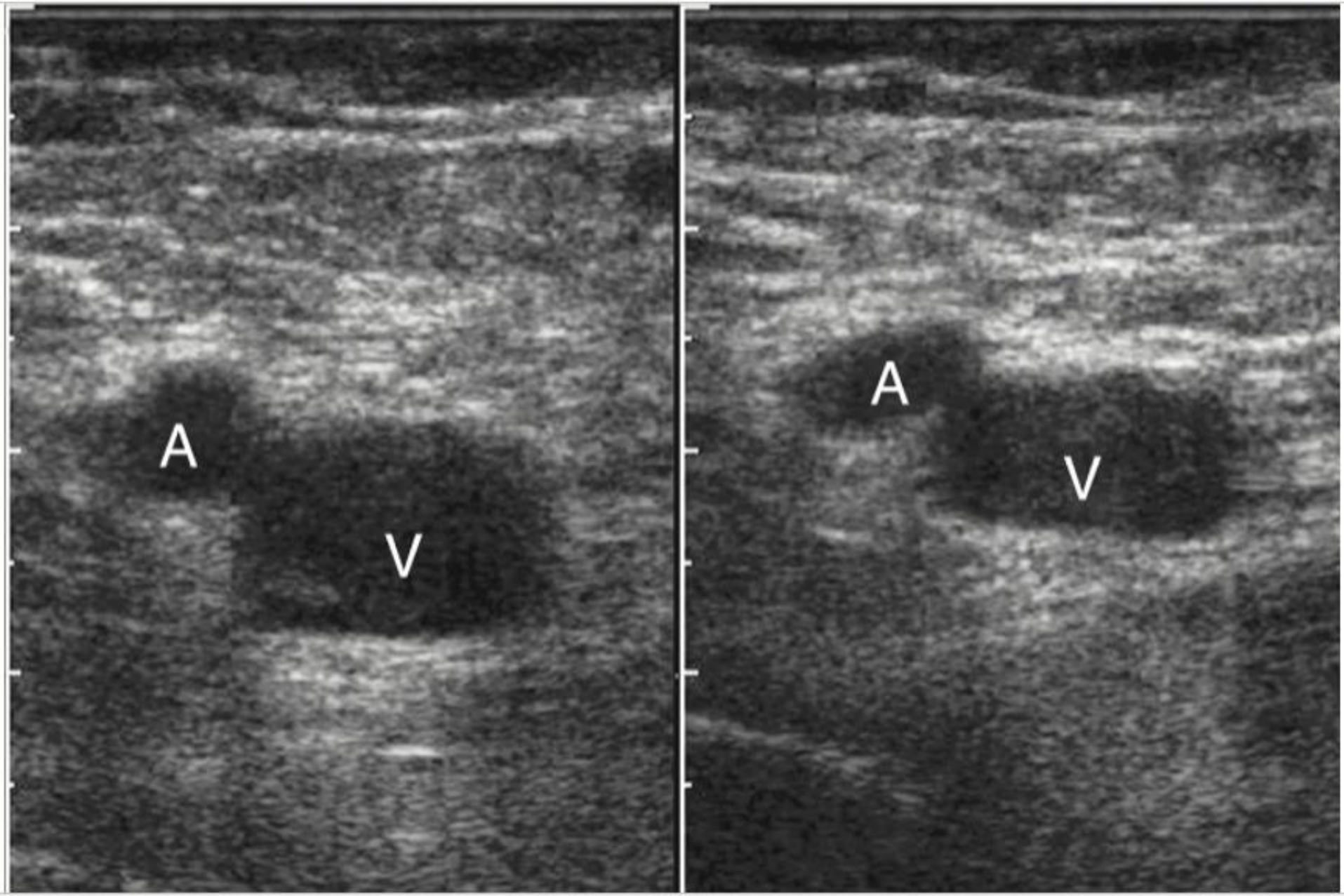
- Doppler demonstration of blood flow in an ovary does not exclude torsion; torsed ovaries frequently exhibit blood flow at Doppler evaluation.
- Patterns of blood flow reported in surgically proven torsed ovaries include arterial and venous flow, arterial but no venous flow, venous but no arterial flow, and no flow.
- flow is frequently not identified in the normal nontorsed ovary when it is suboptimally visualized, as may occur due to deep location or a pelvic mass such as a fibroid positioned between the transducer and the ovary.
- Given these limitations, it is important to interpret the Doppler findings in cases of suspected ovarian torsion in conjunction with ovarian size, morphologic appearance, and clinical presentation.

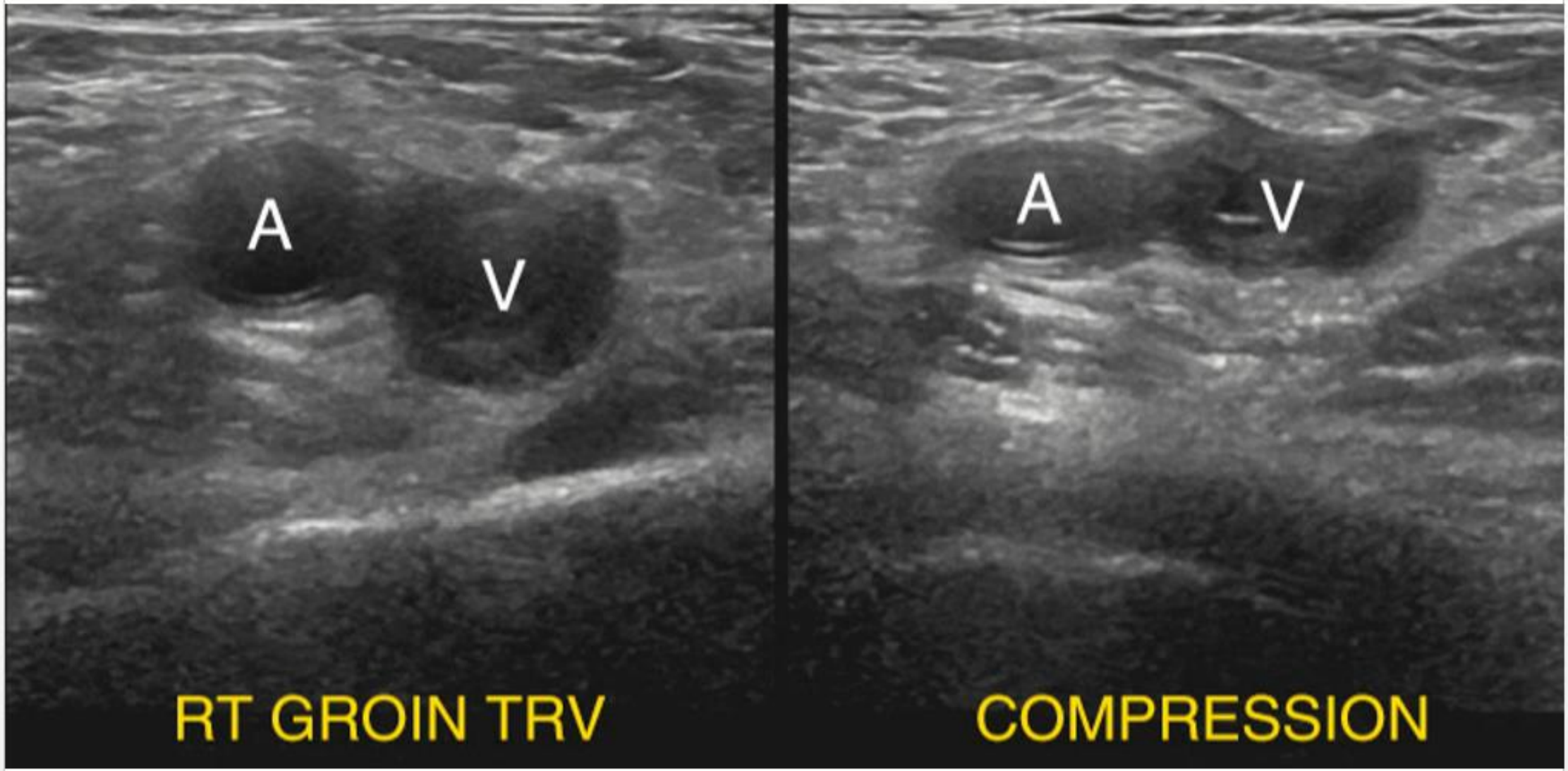
DVT AND PE

- Pulmonary embolism occurs in up to 50% of untreated cases and the mortality of pulmonary embolism is up to 25%.
- The clinical diagnosis of DVT is very difficult.
- Ultrasound is the procedure of choice in the evaluation of suspected lower extremity DVT.
- In the femoral-popliteal system of symptomatic patients, the sensitivity and specificity exceed 95% and 98%, respectively.

- Lower extremity venous examinations should include evaluation of the common femoral vein, femoral vein (previously referred to as the superficial femoral vein), origin of the profunda femoris vein, proximal greater saphenous vein, and popliteal vein.
- Normal deep veins are completely compressible.
- Lack of complete compressibility is the primary criterion for diagnosing DVT in the femoral-popliteal veins

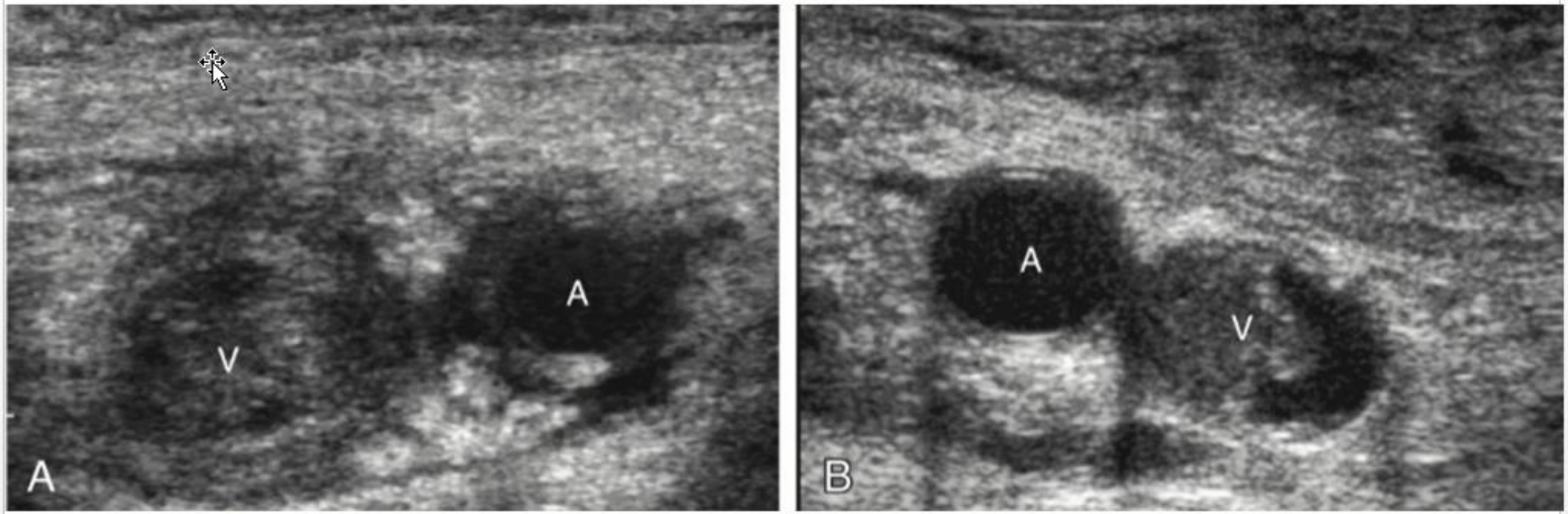

A
V
A
A
A
B
A


A
V
A
V


A
V
RT GROIN TRV
A
V
COMPRESSION

DVT

- In some cases thrombus can be seen on gray scale.
- However, the appearance of artifactual intraluminal echoes overlaps with the hypoechoic echoes from clot. Therefore analysis of echogenicity is not a primary focus of lower extremity venous examinations.


A
V
A
B
A
V

- In obese or very edematous patients, gray-scale identification of the femoral and popliteal veins may be very difficult.
- In these situations color Doppler may help to localize the vessels.
- Augmentation of proximal venous flow by compression of the calf or plantar flexion of the foot can accentuate the veins and further assist when color Doppler is required.

F.A.S.T

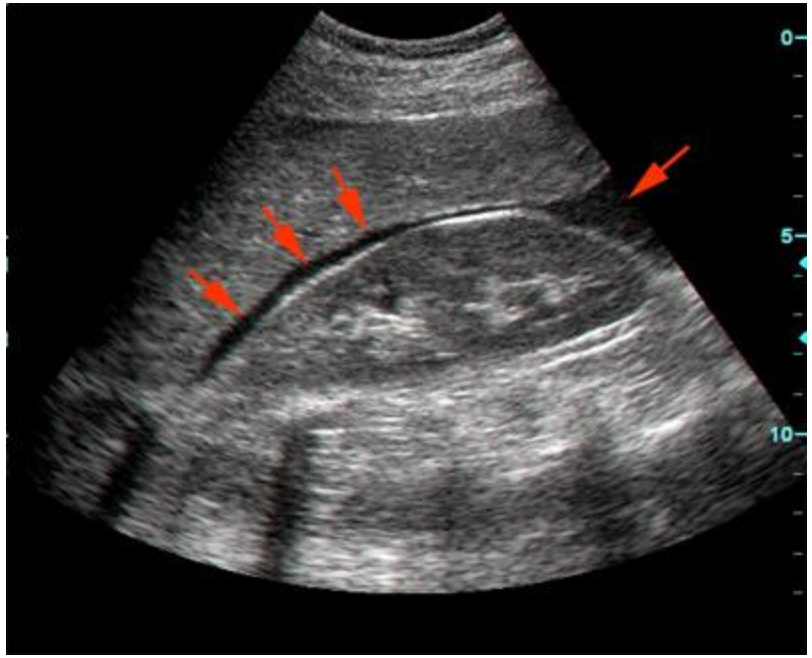
Focused Assessment with Sonography in Trauma

It's a bedside ultrasound exam done during trauma to evaluate for intra-abdominal injury.

SO WHAT IS A **POSITIVE** FAST?

The main principle of **FAST** is the presence of the **ANECHOIC Stripe.**

In any emergency case, it is the presence of **anechoic stripe** in <u>one</u> or <u>more</u> of the 4 known places.



WHAT'S ANECHOIC ON ULTRASOUND?

Fluid (not static)

Active Flow

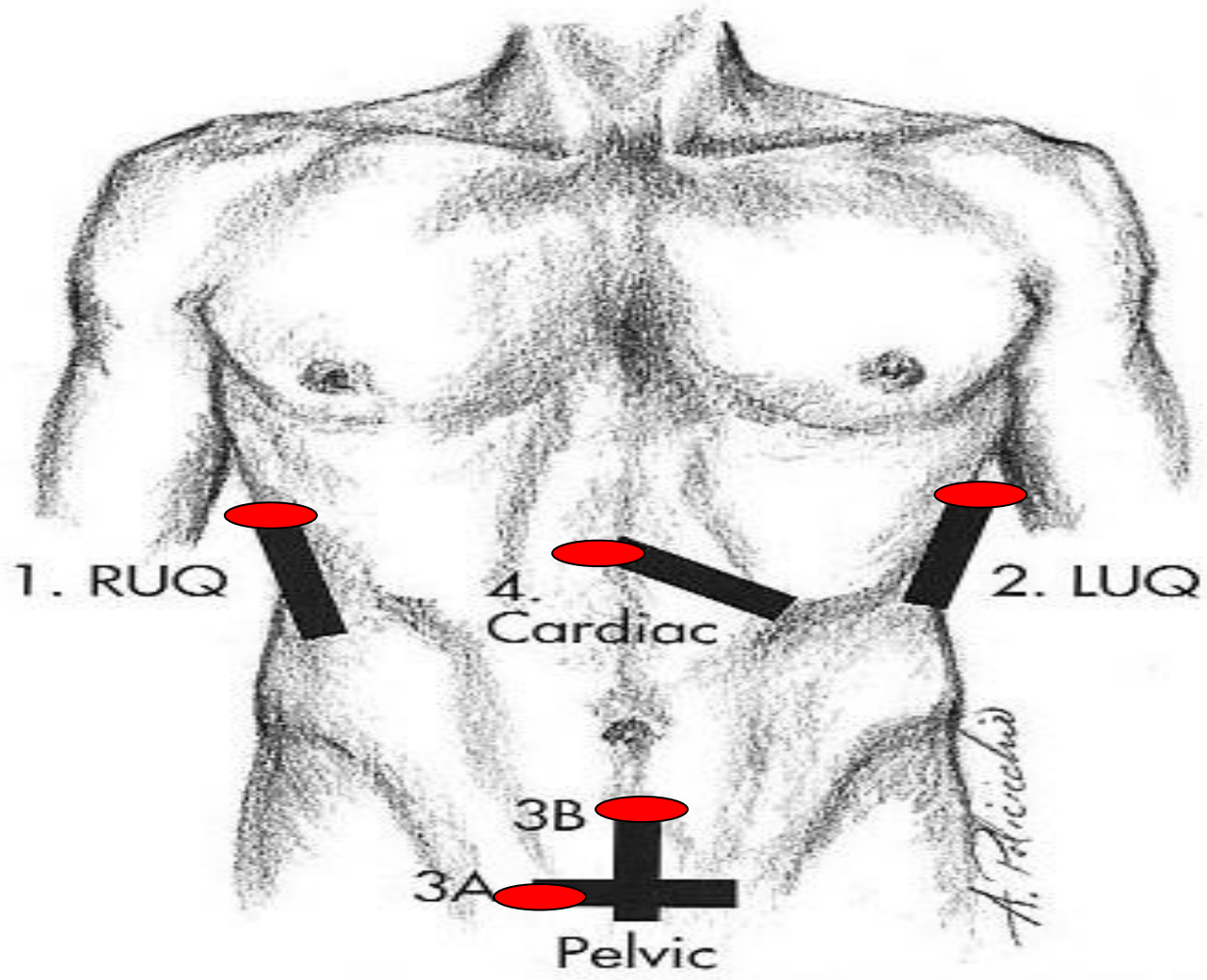
Old Blood

WHAT ARE THE KNOWN PLACES?

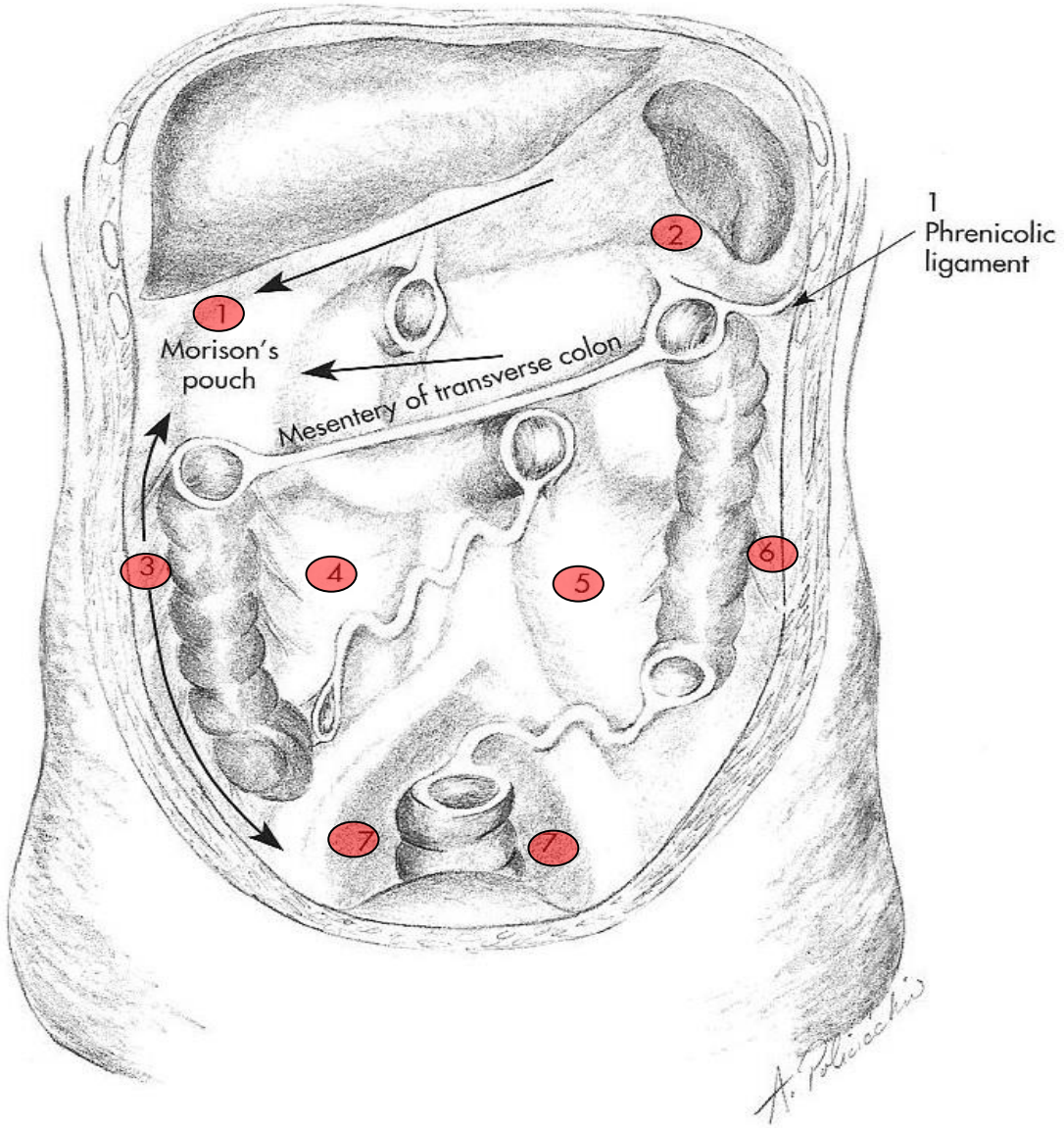
The **classical** four places to look for free fluid in FAST are:

- RUQ
- LUQ
- SubXiphiod
- Suprapubic

THE CLASSIC 4 PLACES



FAST: ANATOMY



7 dependent sites

1. Right Supramesocolic (Morison's pouch)
2. Left Supramesocolic (Splenorenal rescess)
3. Right Pericolic gutter
4. Right Inframesocolic
5. Left Inframesocolic
6. Left Pericolic gutter
7. Pelvic cul-de-sac

FAST: RUQ EXAM

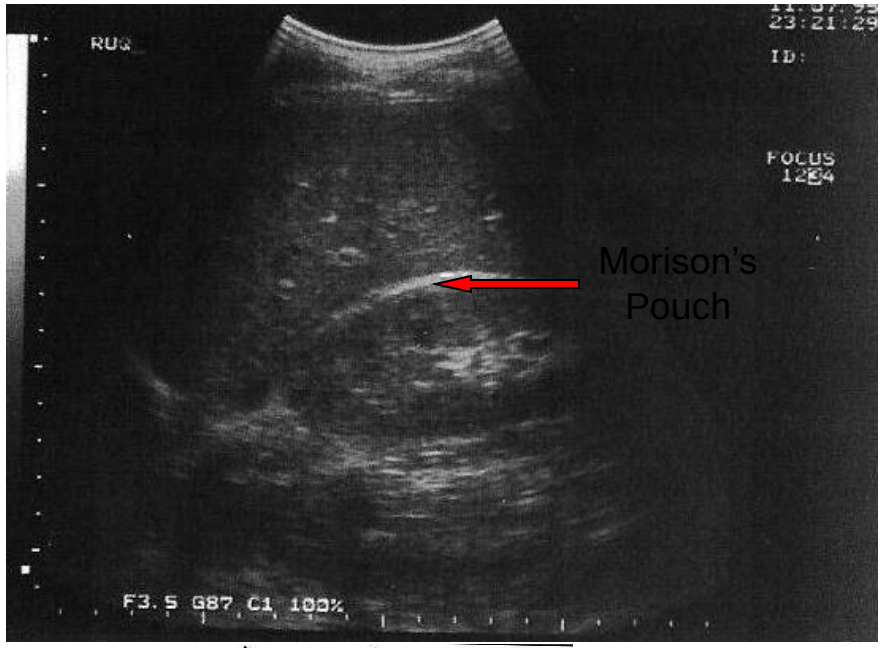
Evaluating

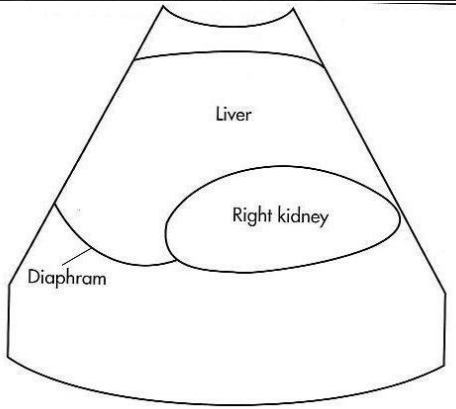
- Hepatorenal interface
- Possibility of fluid in Morison's pouch - Right Supramesocolic space

Technical Problems

- Body habitus
- Bowel gas
- Rib artifact

FAST: RUQ EXAM





Normal Anatomy

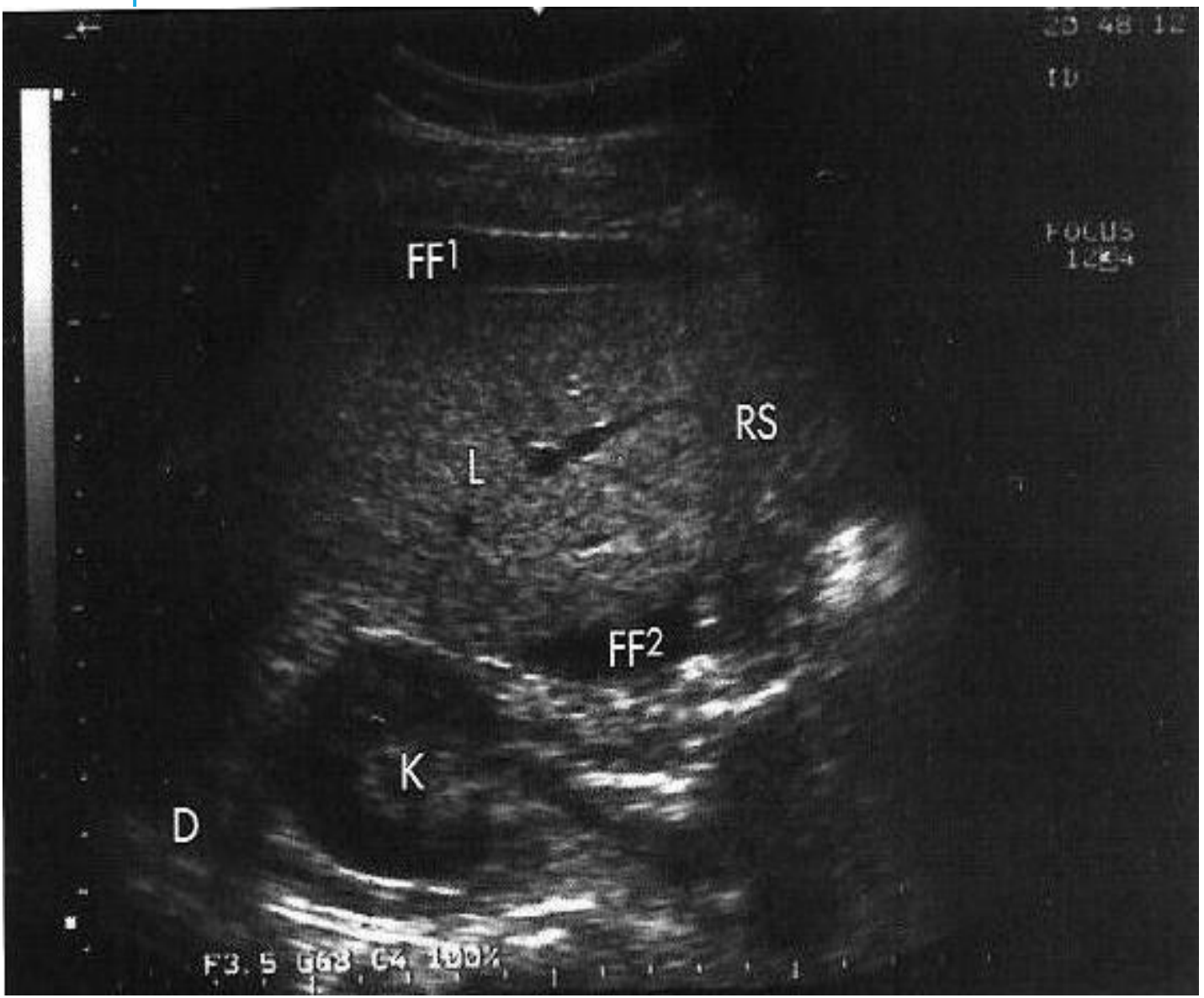
In the supine patient, the hepatorenal space is the most dependent area

Also is the least obstructed for fluid flow

Morison's Pouch

- Potential space between the liver and the right kidney in the hepatorenal recess

POSITIVE FAST: RUQ EXAM



Abnormal Anatomy

Pathologic Fluid - mild

L = liver

D = diaphragm

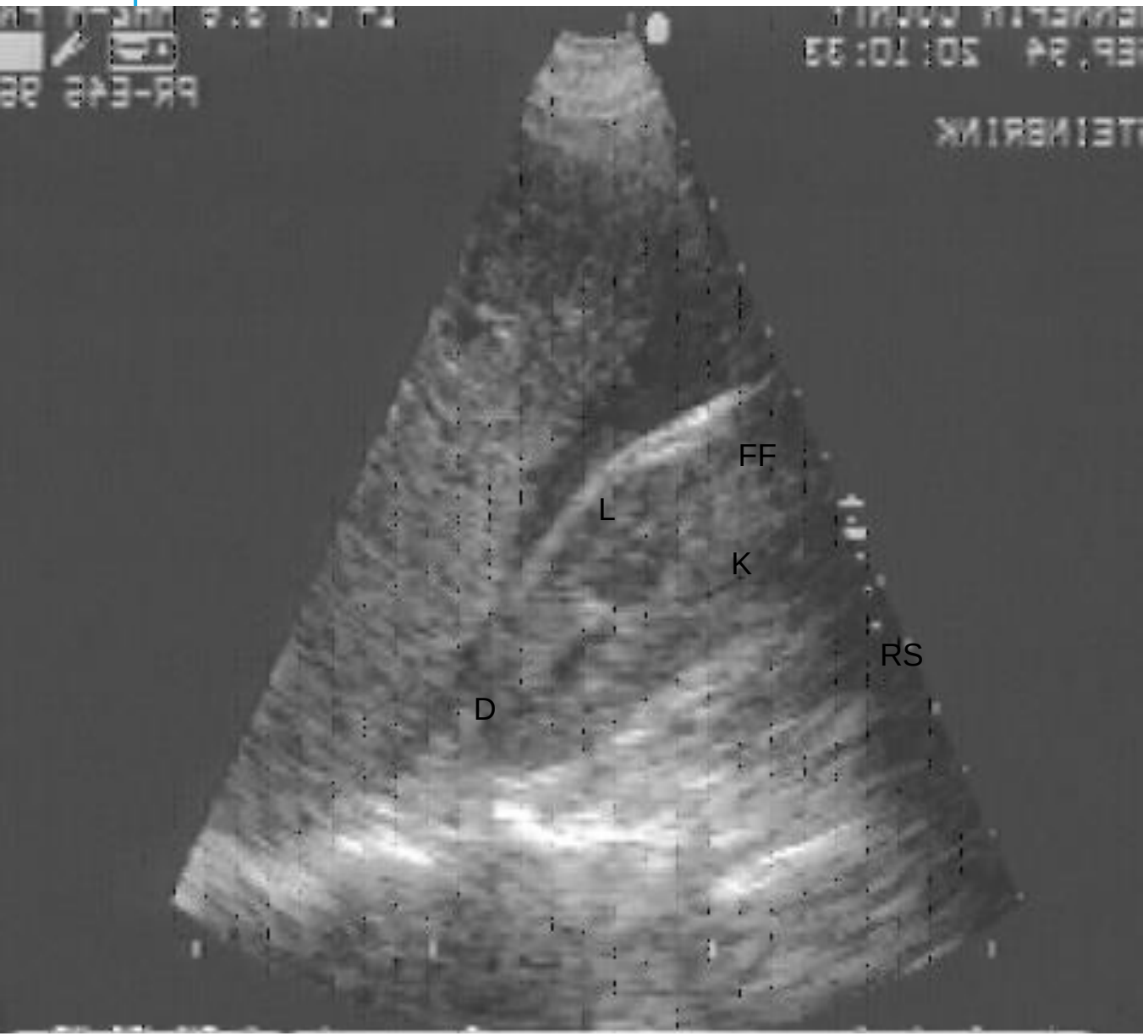
K = kidney

RS = rib shadow

FF1 = free fluid

FF2 = free fluid

POSITIVE FAST: RUQ EXAM



Abnormal Anatomy

Pathologic Fluid - moderate

L = liver

K = Kidney

FF = free fluid

RS = rib shadow

D = diaphragm

POSITIVE FAST: RUQ EXAM

Abnormal Anatomy

Pathologic Fluid - massive

L = liver

K = kidney

FF = free fluid

FAST: LUQ EXAM

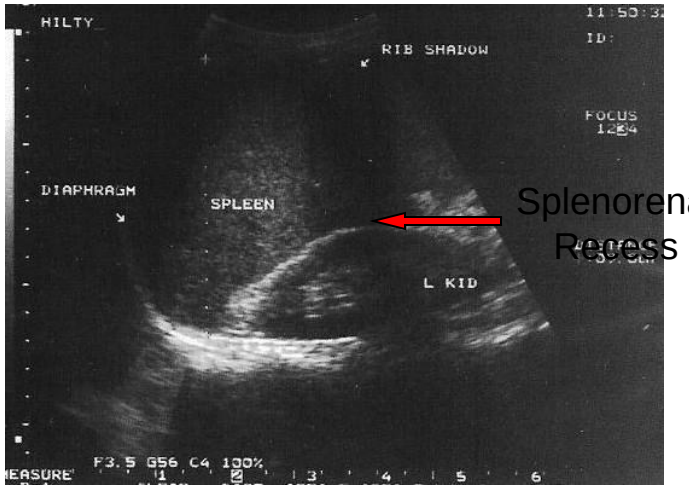
Evaluating

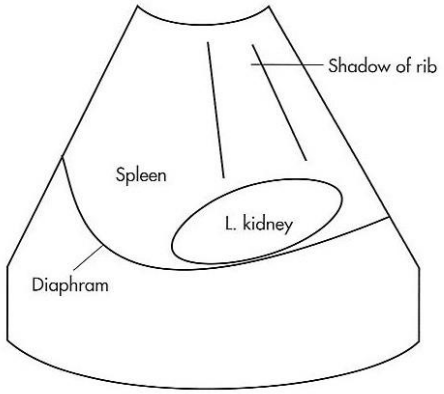
- Spleno-renal interface
- Possibility of fluid in splenorenal recess
- Inferior pole of left kidney
- Sub-phrenic space
- Pleural space ‘eFast’

Technical Problems

- Body habitus
- Bowel gas, splenic flexure gas
- Rib artifact

FAST: LUQ EXAM





Normal Anatomy

More difficult to evaluate than RUQ

Left kidney more superior than right

Do not have liver as acoustic window

Splenorenal Recess

- Potential space between kidney and spleen

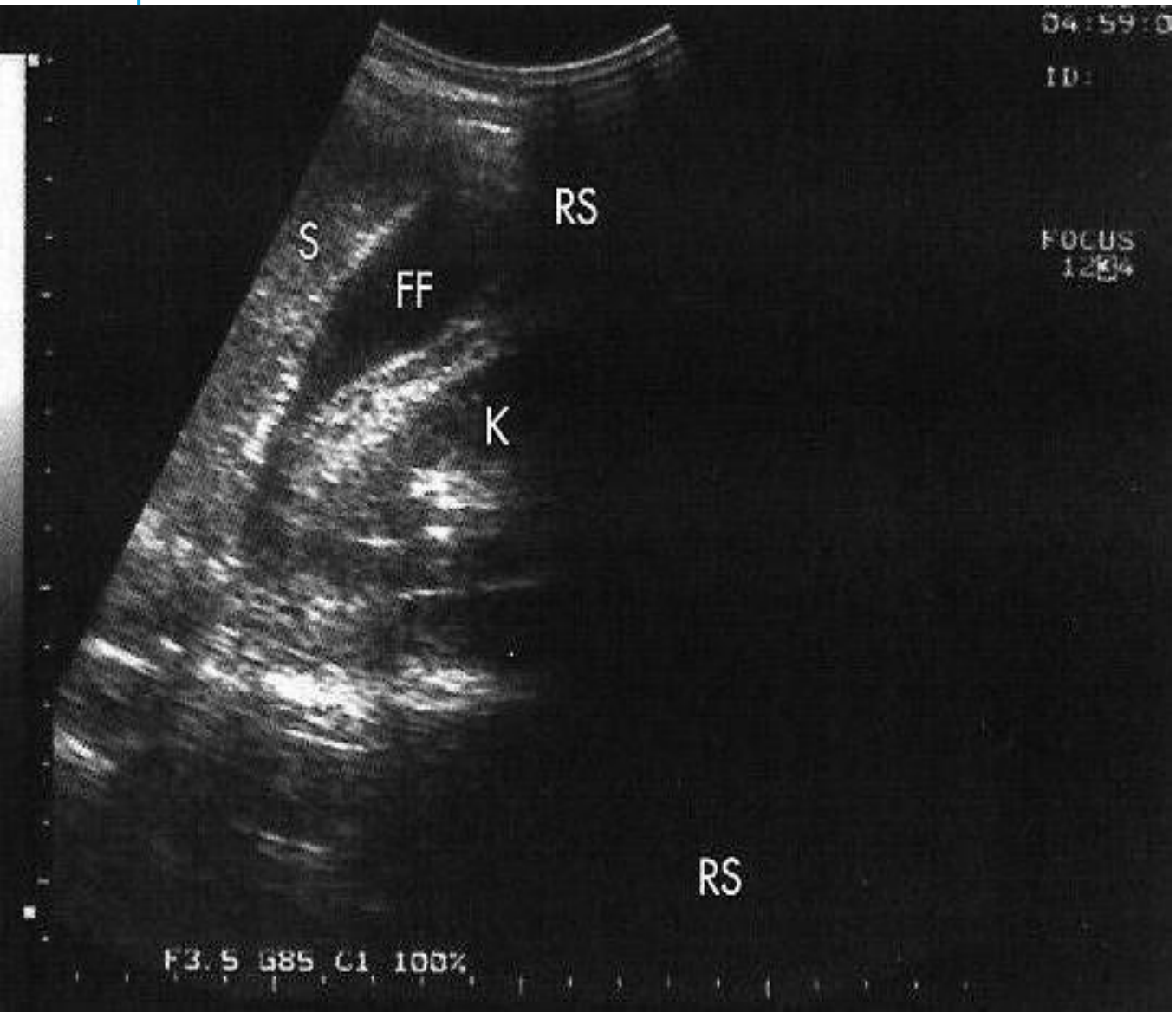
NEGATIVE FAST- NORMAL LUQ

In the **LUQ VIEW,** we look into 4 sites

1. Pleural space “in eFast”
2. Sub-phrenic Space
3. Spleno-renal recess
4. Area near between the **spleen** and the **inferior pole** of kidney, as it resembles the beginning of the left paracolic gutter.

NORMAL LUQ

POSITIVE FAST: LUQ EXAM



Pathologic Fluid

K = kidney

S = spleen

RS = rib shadow

FF = free fluid

FAST: SUBXIPHOID EXAM

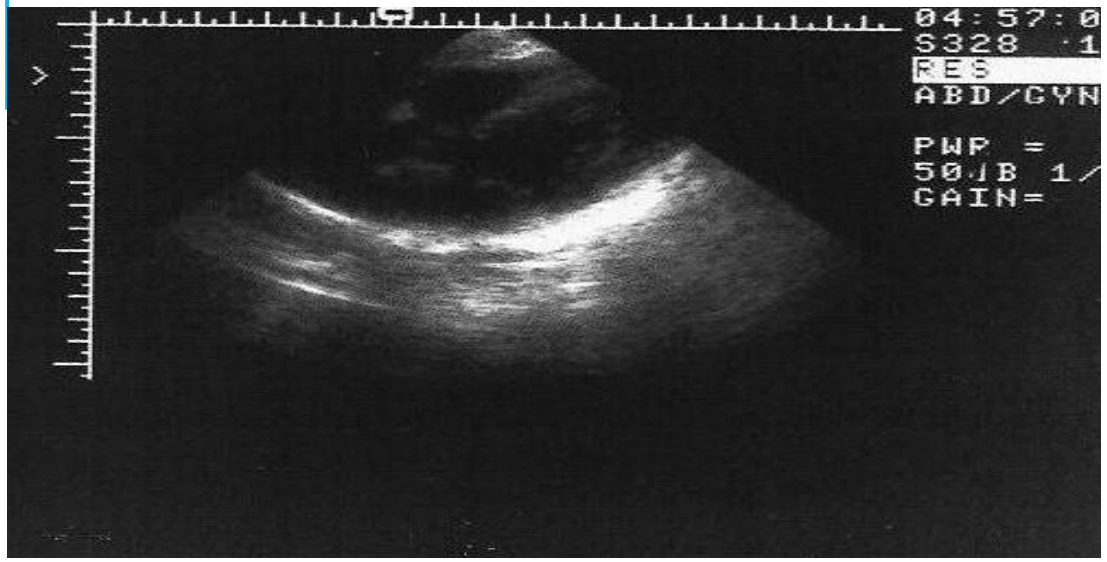
Evaluating

- Fluid in the pericardium
- Wall dysfunction
  - R heart strain
  - Septal "bowing"

Technical Problems

- Body habitus
- Inability to get probe under xiphoid

FAST: SUBXIPHOID EXAM



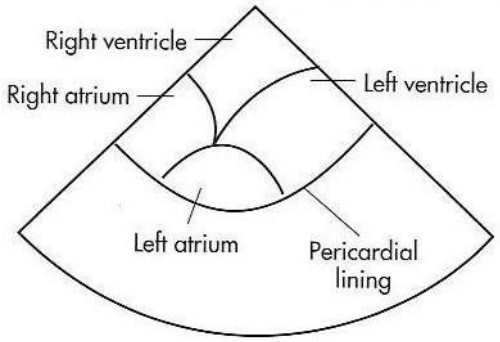
Normal Anatomy

Liver at very top of screen

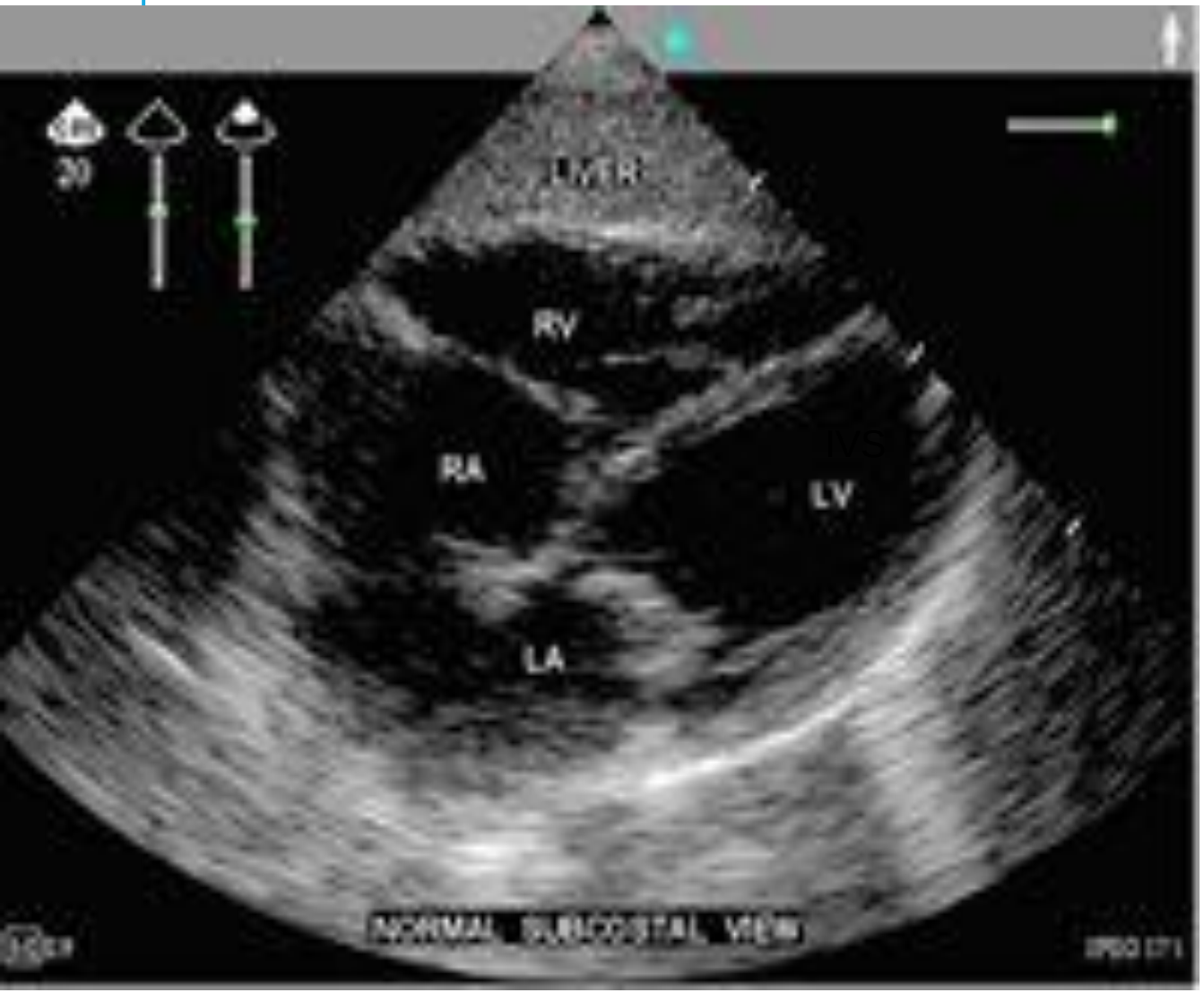
Right ventricle on top of screen

Right atrium and left ventricle line up below right ventricle

Left ventricle on bottom of screen



FAST: SUBXIPHOID EXAM



Review

Normal Subcostal view

RV = right ventricle

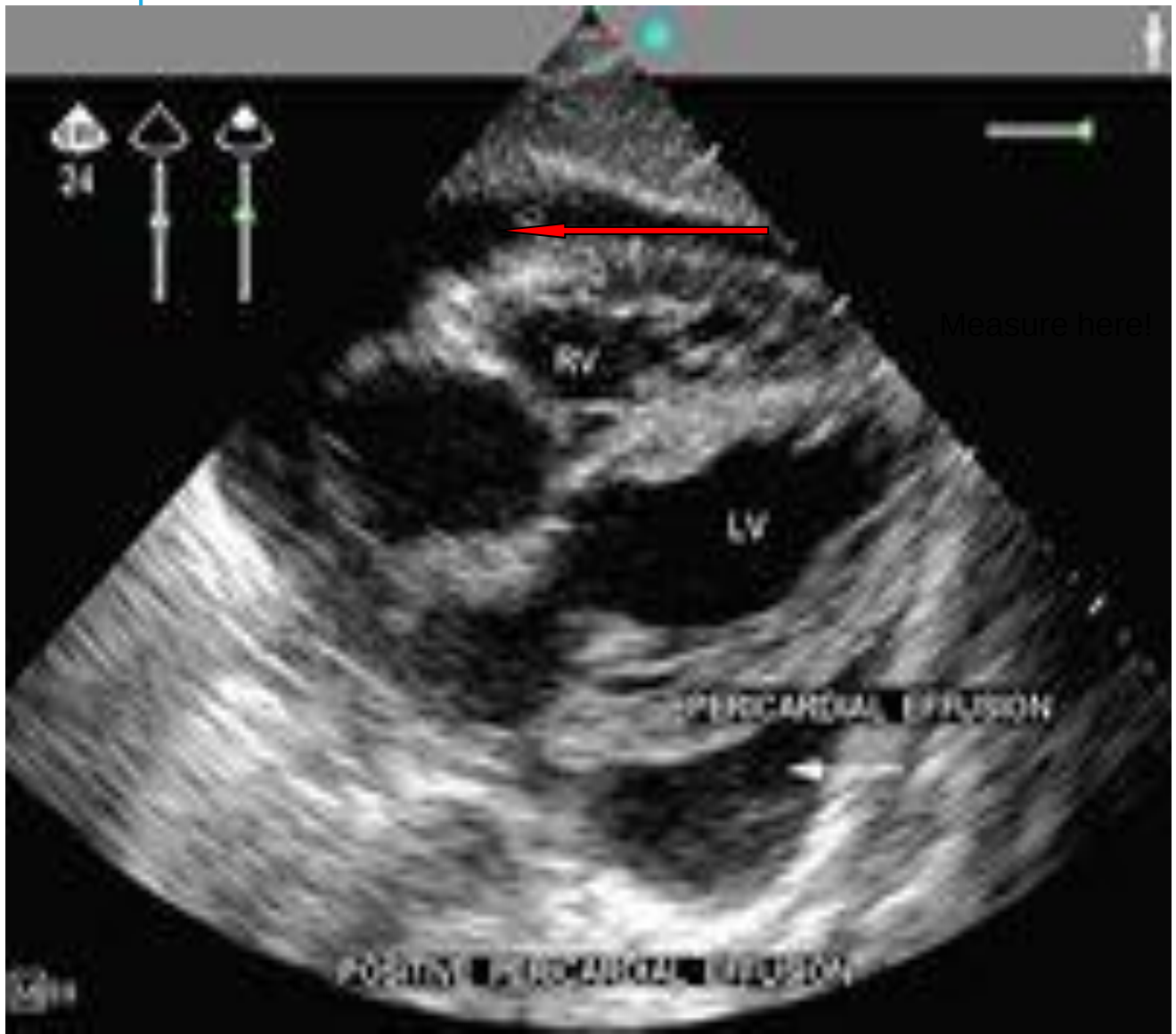
RA = right atrium

LV = left ventricle

LA = left atrium

IVS = interventricular septum

FAST: SUBXIPHOID EXAM



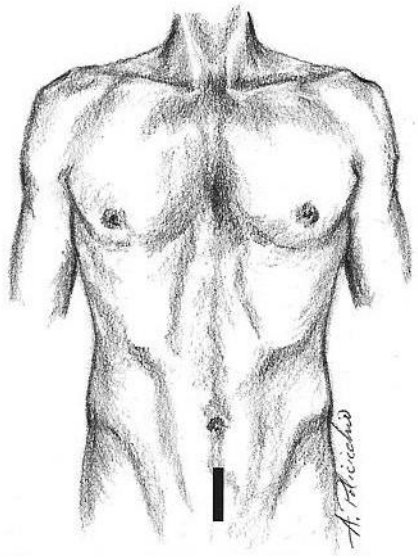
Subcostal view

Large pericardial effusion

Where to you measure amount of blood or fluid?

Answer: anteriorly between the heart and liver

FAST: PELVIS LA EXAM



Pelvis: Long Axis

Probe placed

- longitudinally
- 2 cm superior to the symphysis pubis
- Midline of the abdomen
- "aimed" caudally into the pelvis

Probe facing

- Toward patient's head

FAST: PELVIS LA EXAM

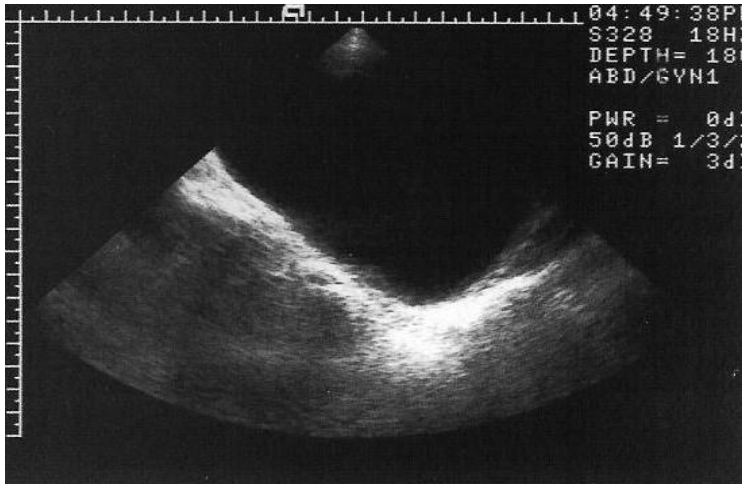
Evaluating

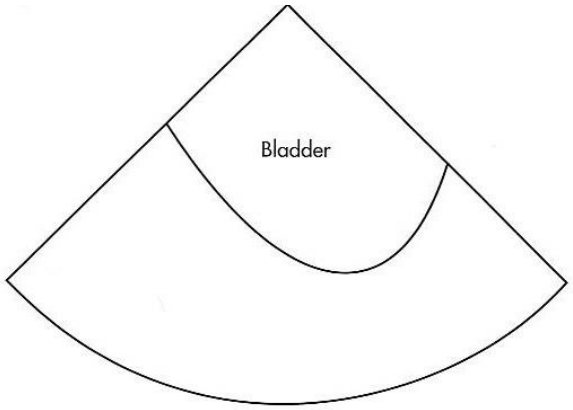
- Free fluid in the anterior pelvis
- Free fluid in the pelvic cul-de-sac (Pouch of Douglas)

Technical Problems

- Body habitus
- Empty bladder (no landmarks)
- Bladder trauma (no landmarks)

FAST: PELVIS LA EXAM





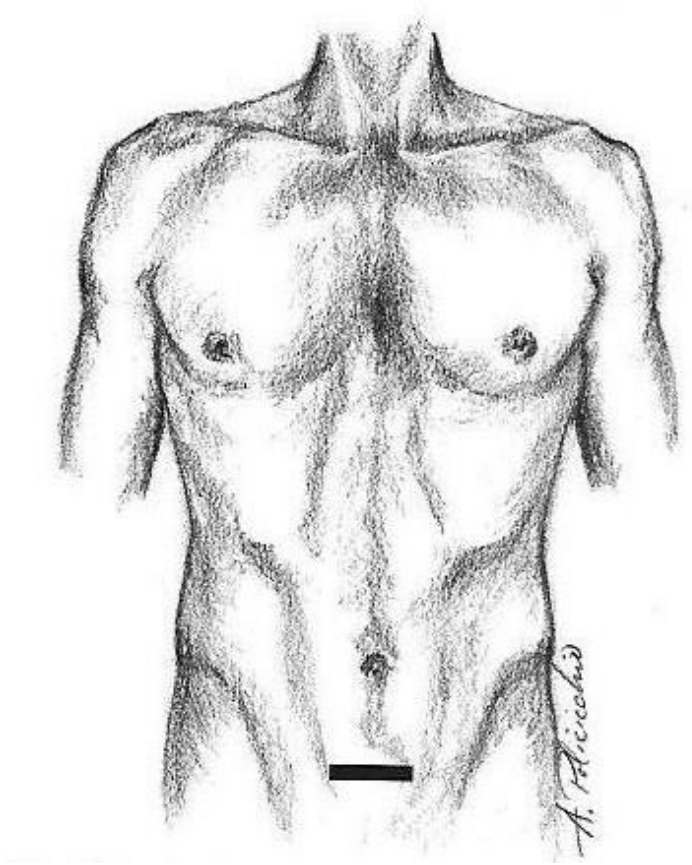
Pelvis: Long Axis

- Normal Anatomy

Evaluating

- Bladder
- Uterus in female: usually superior to bladder
- Prostate in male: usually posterior to bladder

FAST: TV PELVIS EXAM



Pelvis: Transverse

Probe placed

- 2 cm superior to the symphysis pubis
- Midline of the abdomen

Probe facing

- Toward patient's right
- Probe rotated 90 degrees counterclockwise from longitudinal

FAST: TV PELVIS EXAM

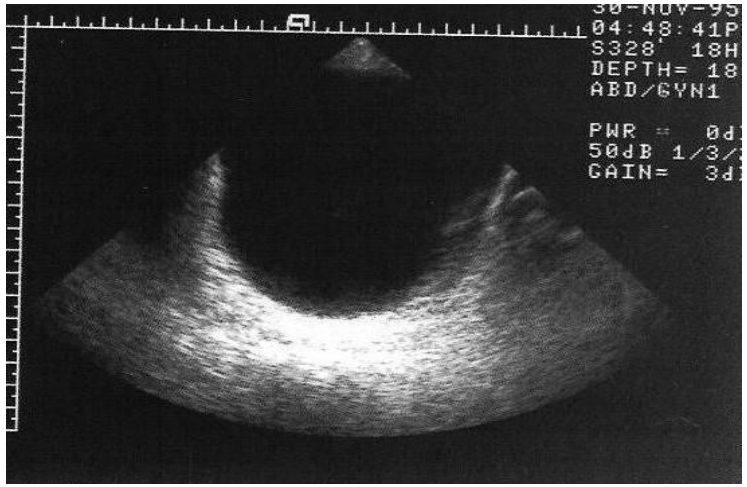
Evaluating

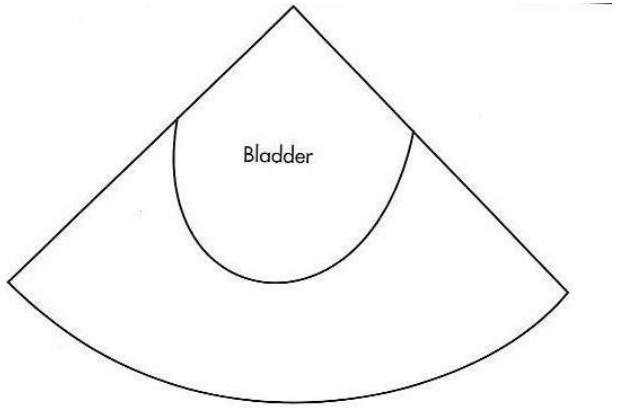
- Free fluid in the anterior pelvis
- Free fluid in the pelvic cul-de-sac (Pouch of Douglas)

Technical Problems

- Body habitus
- Empty bladder (no landmarks)
- Bladder trauma (no landmarks)

FAST: TV PELVIS EXAM





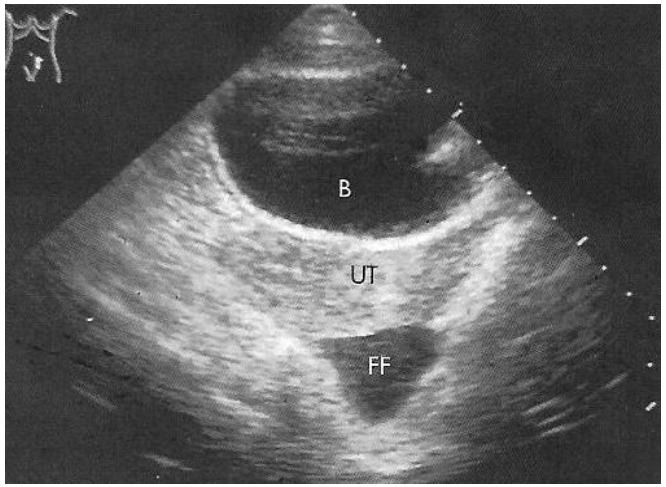
Pelvis: Transverse Axis

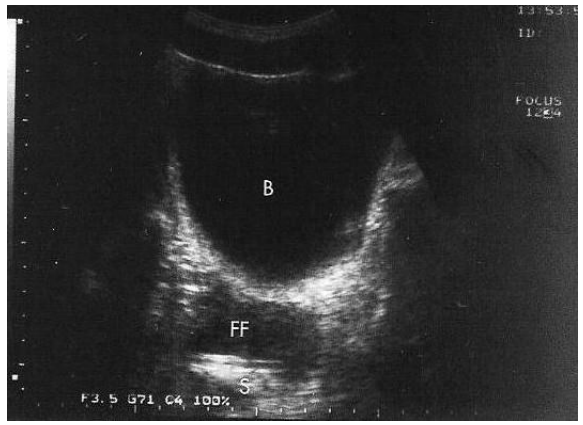
- Normal Anatomy

Evaluating

- Bladder
- Well cirucumscribed
- Contains fluid that appears anechoic

FAST: PELVIS EXAM - PATHOLOGY





Transverse scans with free fluid in pelvis

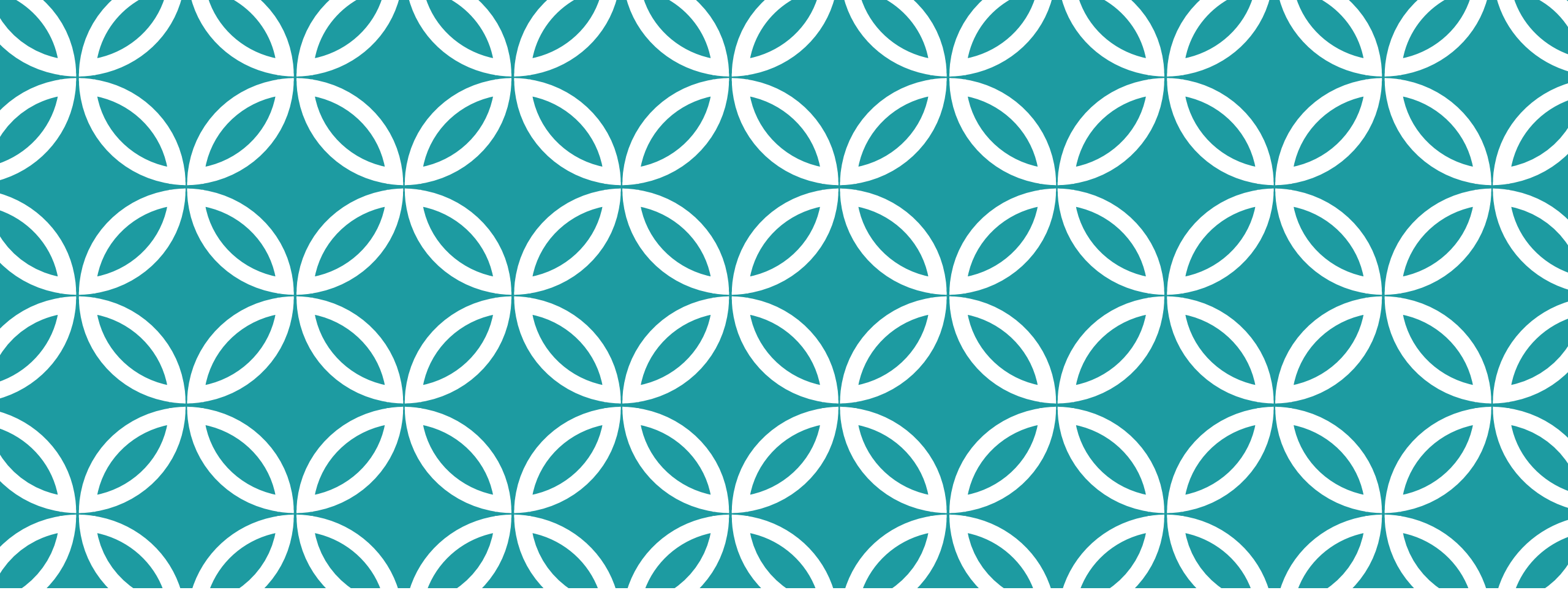
- Female (top): uterus posterior to bladder
- Male (bottom)

B = bladder

UT = uterus

FF = free fluid

S = spine



الحمد لله