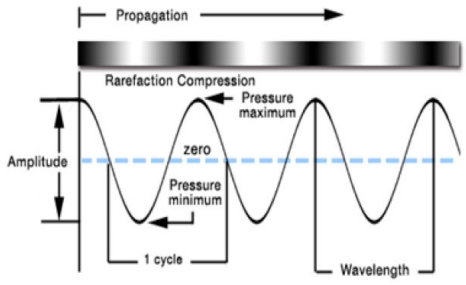
PI Session: 2021.11.19_D and T_Radiology: Imaging of Reproductive 1 system_ Preparatory_Marcus John Julius, M.D.

Objectives: At the end of this session, students will be able to:

1. Explain the relationship between ultrasound wavelength, frequency, and velocity (as well as how the principle of sound wave reflection aids in the creation of ultrasound images).
2. Differentiate the four main categories of breast abnormalities evident on mammography.
3. Contrast the sonographic features of breast cyst, fibroadenoma, and malignancy.
4. Understand the role of nuclear medicine imaging in the staging of breast cancer.
5. Apply the use of sonography in the workup of scrotal pain.
6. Utilize scrotal sonography to differentiate intra-testicular from extra-testicular mass lesions.

Ultrasonography

-**PHYSICS**



Ultrasound waves

-Mechanical disturbance traveling through a medium

-*Wavelength*: distance between successive waves

-*Frequency*: number of oscillations per second (in hertz, Hz)

-Ultrasound frequency is higher than audible sound

-Audible sound frequencies: 15Hz-20,000Hz

-Ultrasound frequencies: greater than 20,000Hz

-*Velocity* of sound (in medium) = Frequency x wavelength

-Average velocity of sound in soft tissues: 1540 m/s

-Velocity of sound in air: 330 m/s

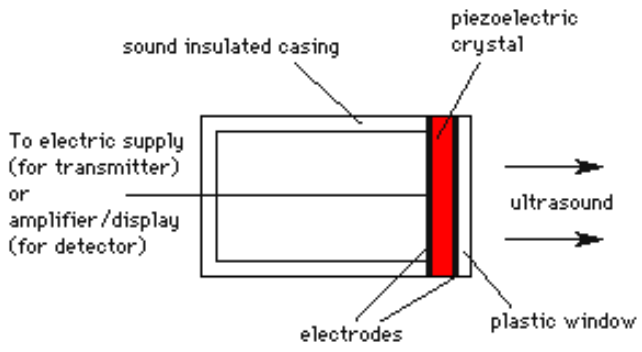
-Velocity of sound in bone: 3,300 m/s

-Velocity of sound in metal: >4,000m/s

Production of ultrasound

-*Transducer*: device that converts one form of energy to another form of energy

-*Ultrasound transducer* (**see below**) is comprised of high-quality crystals, a backing material, electrode wires, and a focusing lens



-Converts electrical energy into ultrasound waves (and vice versa) via the 'piezoelectric (i.e. 'pressure electricity') effect

-High frequency voltage oscillations cause a high-quality crystal to change shape, which alters the pressure in front of the transducer (producing ultrasound waves)

-Electricity…to…pressure (as a '*transmitter*')

-Returning echoes (i.e. reflected sound) subject the crystal to changes in its shape. These pressure changes are then converted to electrical signals (and ultimately an image)

-Pressure…to…electricity (as a '*receiver*')

-Transducer resonant frequency is determined by crystal thickness and acoustic velocity of crystal elements

-*Crystal thickness is usually manufactured to ½ wavelength*

-Based on crystal thickness (and, therefore, wavelength) as well as acoustic velocity of crystal, frequency can be calculated

-Higher frequency transducers are thinner

-Lower frequency transducers are thicker

ULTRASOUND INTERACTION WITH MATTER

-*Reflection*

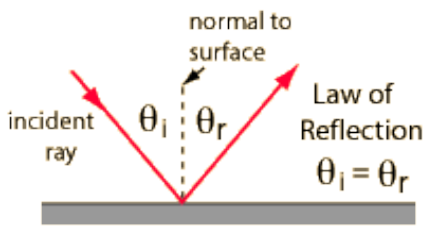
-Sound *reflected* at a tissue interface forms an echo, which is used to create an image

-Degree of reflection is based on both *angle of incidence* and *acoustic impedance* of tissues

-Angle of incidence equals angle of reflection

-As angle of incidence increases, reflected sound waves are less and less likely to reach the transducer

-At angles of incidence greater than 3 degrees from perpendicular to an interface, no appreciable reflected echoes are detected



-*Acoustic impedance* = density of medium x velocity of sound in medium

Material	Speed of sound ($m\ s^{-1}$)	Density ($kg\ m^{-3}$) x 10^{-3}	Acoustic Imp Z ($kg\ m^{-2}\ s^{-1}$) x 10^{-6}
Air	330	1.2	0.0004
Water	1480	1000	1.48
Steel	5000	7800	39.0
Blood	1575	1057	1.62
Fat	1459	952	1.38
Muscle	1580	1080	1.70
Bone	4080	1912	7.8

-Air has the lowest acoustic impedance
-Soft tissues have intermediate acoustic impedance
-Bone and metal have the highest acoustic impedances
-*The greater the degree of acoustic impedance difference at a tissue-tissue boundary, the greater the degree of wave reflection*

-*The overall amount of reflected and transmitted waves must equal 1*

Reflection

Interface	Reflection co-efficient (%)
Soft Tissue - Air	99
Soft Tissue - Bone	66
Fat - Muscle	1.08
Muscle - Liver	1.5

-The greater the degree of reflection, the lesser the degree of transmission
    -This leaves less useful sound waves to image deeper tissues
        -*'Posterior acoustic shadowing'*
-The lesser the degree of reflection, the greater the degree of transmission
    -This leaves more useful sound waves to image deeper tissues
        -*'Posterior acoustic enhancement'*
-This explains the need to use gel material to 'couple' the probe to the patient's skin (eliminating intervening air)
-This explains the difficulty in visualizing through/deep to both aerated lung and bone
-**Note**: Additional ultrasound interactions with matter (i.e. scatter, absorption, and refraction) have been described in 'Radiology: Thorax' lecture in CPR.

BREAST IMAGING

-Mammography

-Example of a standardized mammography report:

-'**The breasts are almost *entirely fatty*. There are no mass lesions, suspicious calcifications, architectural distortion, or skin thickening'.**

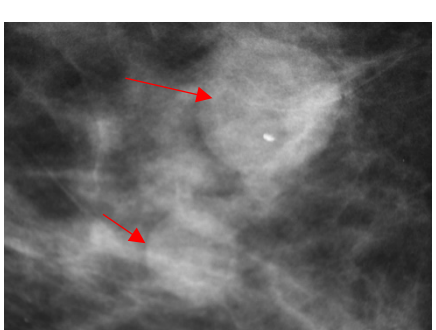
-BI-RADS: Breast Imaging Reporting and Data System categories

- Category 0: needs additional imaging evaluation (or comparison with prior mammograms)
- Category 1: negative
- Category 2: benign finding
- Category 3: probably benign finding (3-6 month follow-up)
- Category 4: suspicious abnormality (Biopsy should be considered)
- Category 5: highly suggestive of malignancy (appropriate action should be taken)
- Category 6: known biopsy-proven malignancy (appropriate action should be taken)

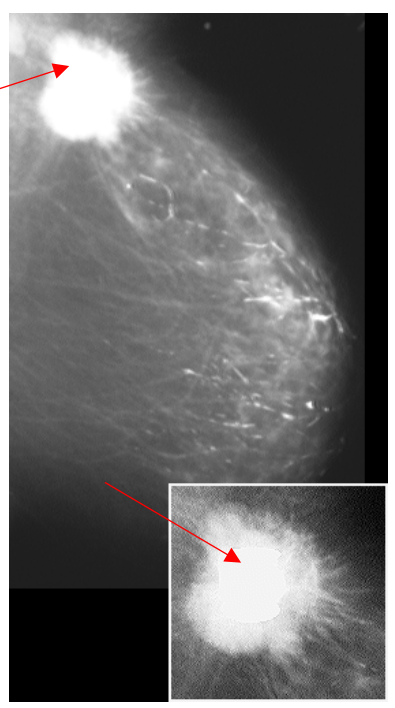
-Categories of breast abnormalities on mammography

-**Mass**: breast lesion visualized on both mammographic views (CC, craniocaudal and MLO, mediolateral oblique)

-*Size*.
-*Shape:* (round, oval, lobular, irregular)
-*Margin:* (circumscribed, macrolobulated, microlobulated, obscured, indistinct, spiculated)
-*Density* relative to breast tissue (not fat): (hyperdense, isodense, hypodense, fatty density)



Benign-appearing breast masses (arrows)



Malignant-appearing spiculated mass (arrows)

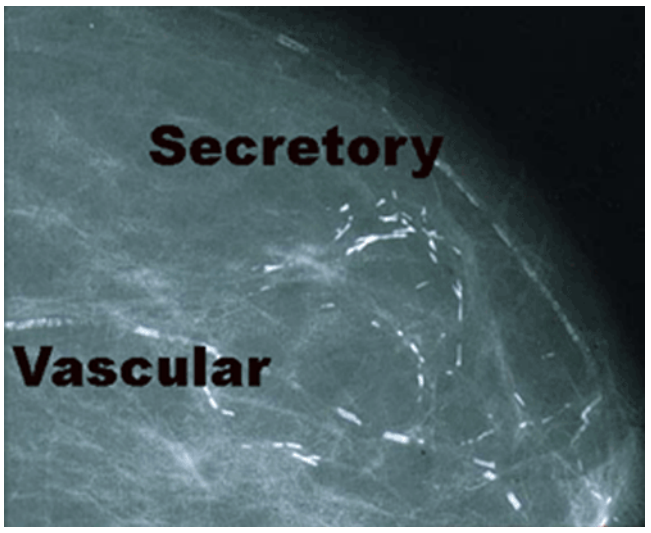
-**<u>Calcifications</u>**: range from benign (vascular and secretory) to highly suspicious

-'<u>suspicious features</u>:

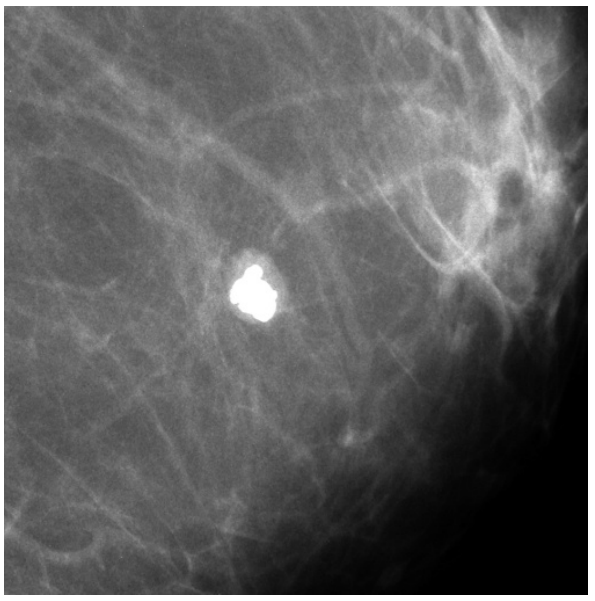
-*pleomorphic* (many shapes) and *heterogeneous microcalcifications* (each submillimeter)

-*clustered* (greater than 5 in number in 1-2cc of tissue)

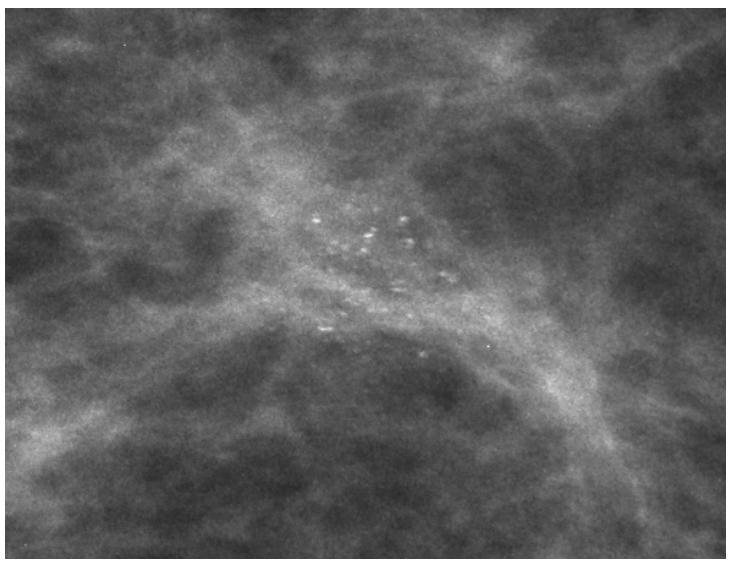
-fine, linear, irregularly-branching (casting, intraductal, associated with DCIS))



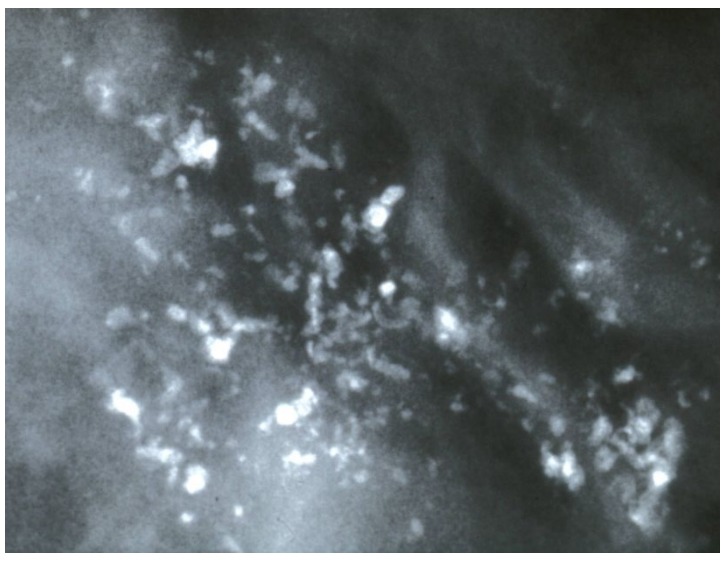
Left image: *Vascular calcifications parallel vessel walls. Secretory calcifications are large and rod-like*



Right image: *'Popcorn-like' calcification of involuting fibroadenoma*



Left image: *Granular and clustered microcalcifications*



Right image: *Heterogeneous, pleomorphic calcifications*

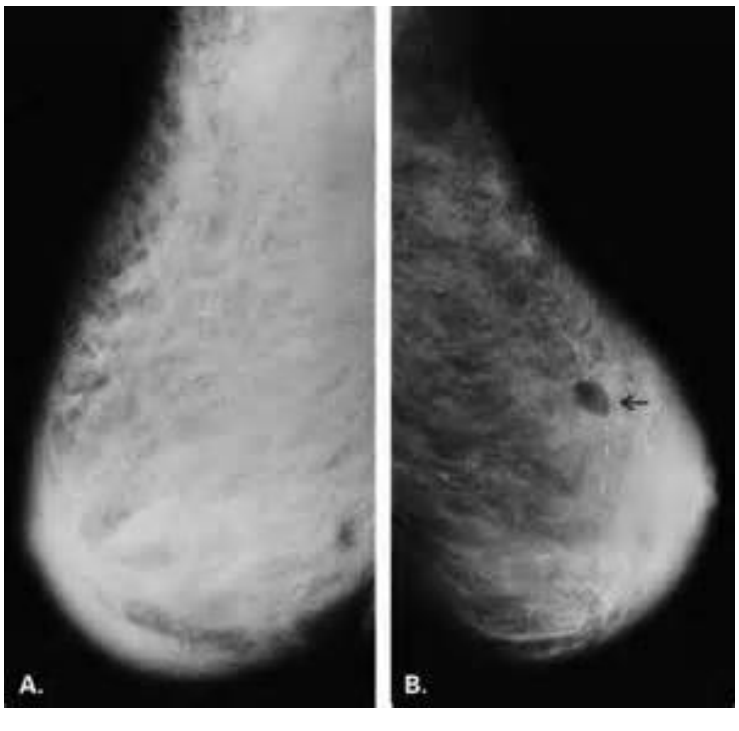
-**<u>Architectural distortion</u>**

-Loss of orderly arrangement of breast parenchyma (as it flows' from posterior periphery to the nipple)

-**<u>Skin thickening</u>**

-increased density of mammogram

-edema may be due to inflammation (i.e. mastitis), trauma, or neoplasia (i.e. dermal extension of malignancy)



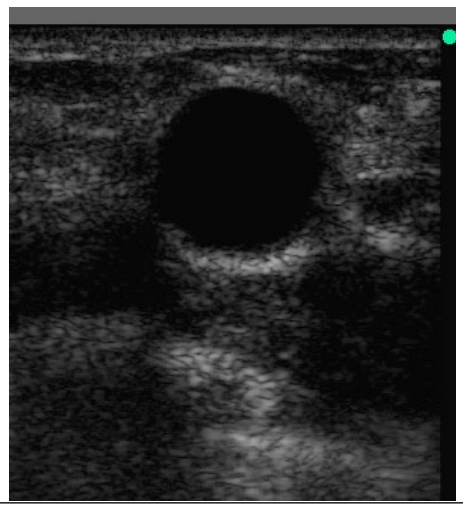
A. Diffuse skin thickening. B. Arrow demonstrates mass of fatty density (www.msdlatinamerica.com)

-Breast sonography

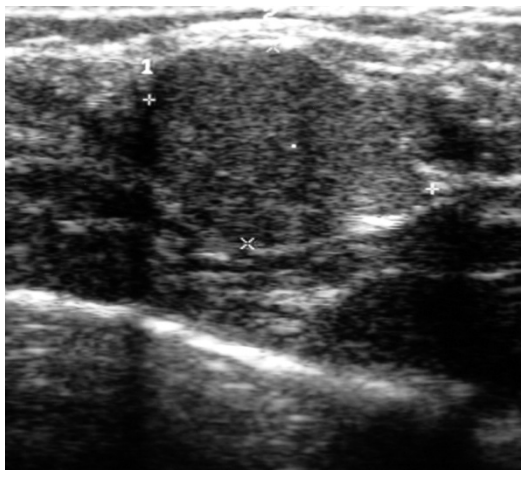
-characterize mammographically-visualized masses as 'cystic' or solid'

-initial assessment of palpable abnormalities in woman younger than 28 years-old

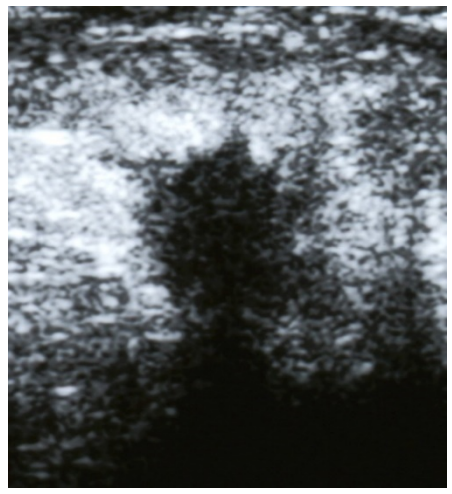
-guidance for biopsy



Breast cyst:
-anechoic
-thin, imperceptible wall
-posterior acoustic enhancement
-lack of vascular flow (not shown)



Fibroadenoma: smooth margins; solid mass of intermediate echoes; homogeneity



Breast cancer: irregular margins; hypoechogenicity; posterior acoustic shadowing

-Nuclear medicine

-Functional and structural assessment

-*Sentinel node localization*: intra-operative localization of primary draining axillary lymph node (discussed in 'Breast Overview')

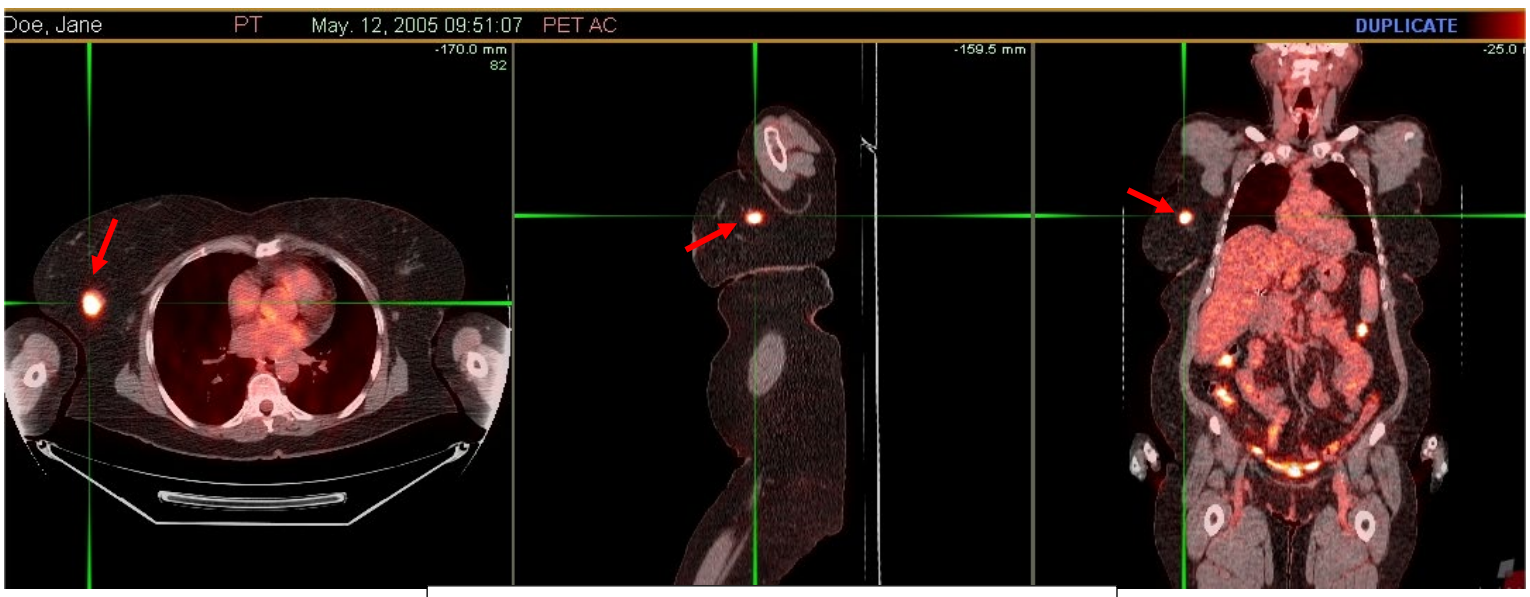
-Positron emission tomography (PET):

-Imaging after intravenous administration of 2-deoxy-2-[18F] fluoro-D-glucose, FDG

-Dependent on increased glucose metabolism in tumor

-Fused with CT imaging (to allow for more optimal structural assessment)

-Aids in staging of breast cancer (i.e. TNM: tumor, lymph node status, and potential metastases)



PET-CT of right breast cancer (red arrows)
Axial (left), sagittal (middle), and coronal (right)

-Magnetic resonance imaging (MRI)

-screening breast imaging modality for high-risk patients (discussed in 'Breast Overview')

-diagnostic breast imaging modality (for problem-solving)

-potential guidance for biopsy (of lesions only demonstrable on MRI)

Scrotal sonography

Utilized as modality of choice for the initial assessment of scrotal pain and scrotal mass

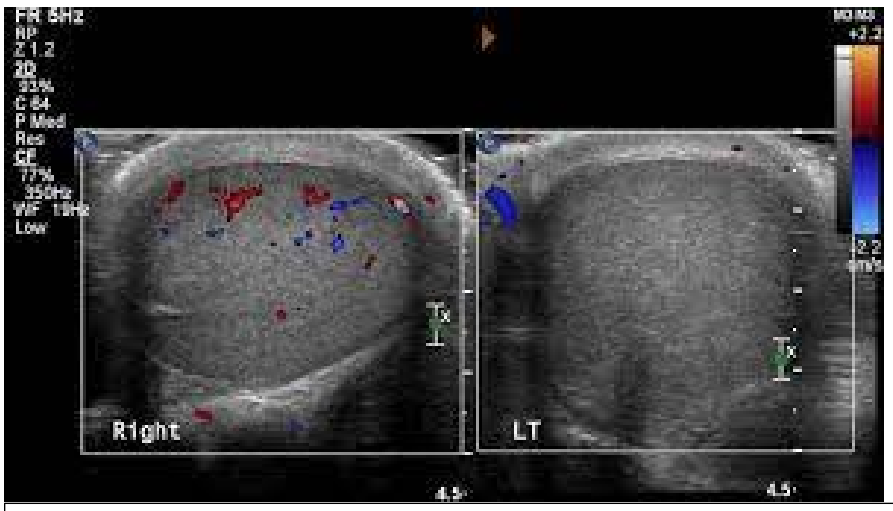
-D/D of scrotal pain

-testicular torsion

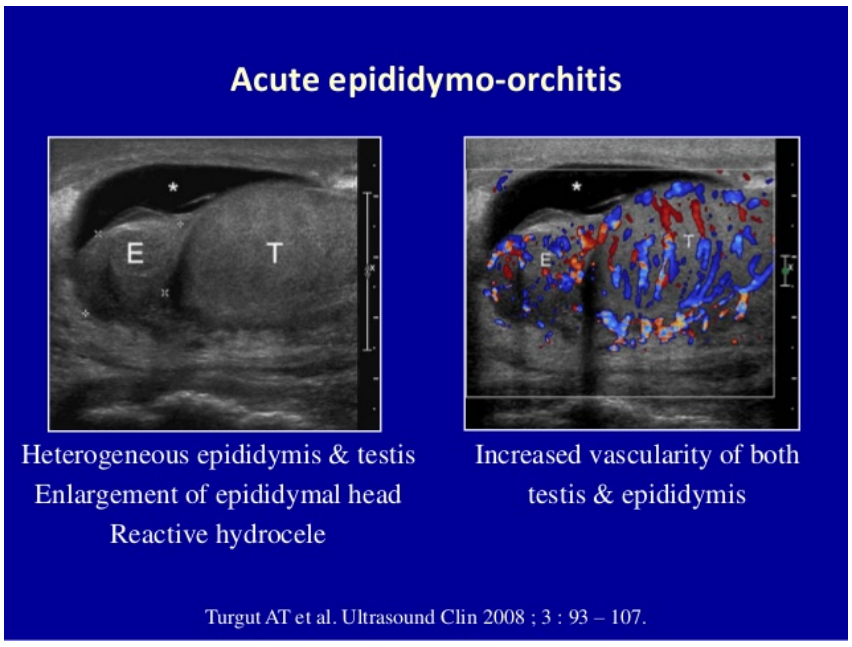
-epididymitis and/or orchitis

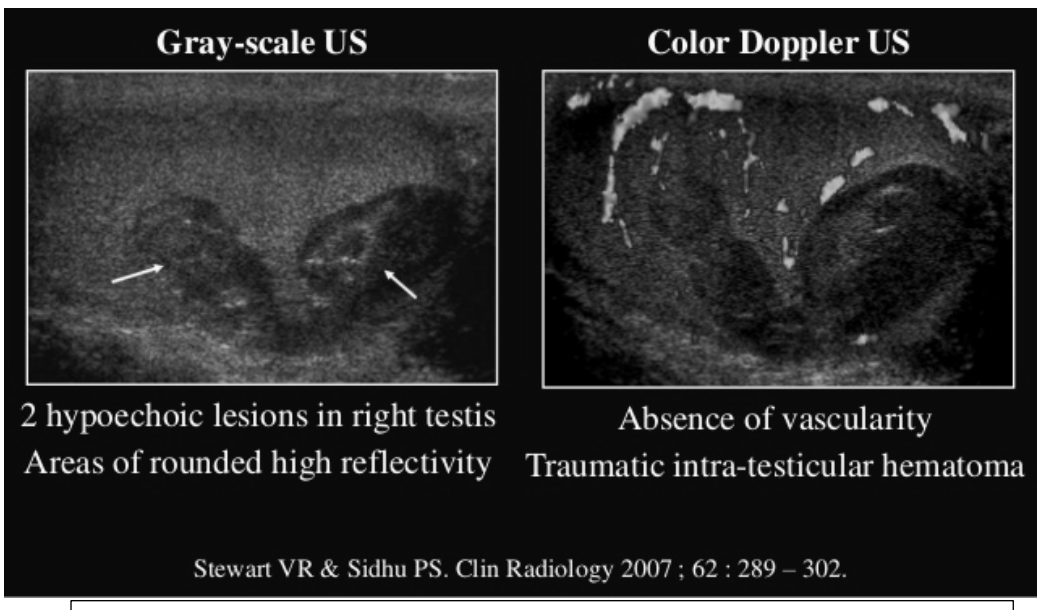
-testicular rupture

-(testicular neoplasia)



Testicular torsion: Absent vascular flow to left testicle (right image) (SAEM)





Intra-testicular hematoma: Presenting as scrotal pain (and mass)

Testicular neoplasia: Seminoma

-D/D of scrotal mass (intra-testicular)

-Neoplasia: Most worrisome!

-Orchitis

-Hematoma

-Torsion

-D/D of scrotal mass (extra-testicular)

-Hydrocele

-Varicocele: potential cause of infertility

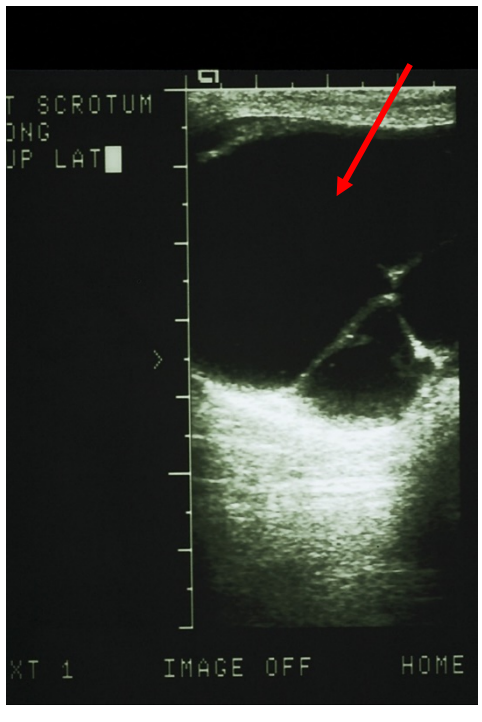
-Hernia

-Spermatocele

-Hematocele

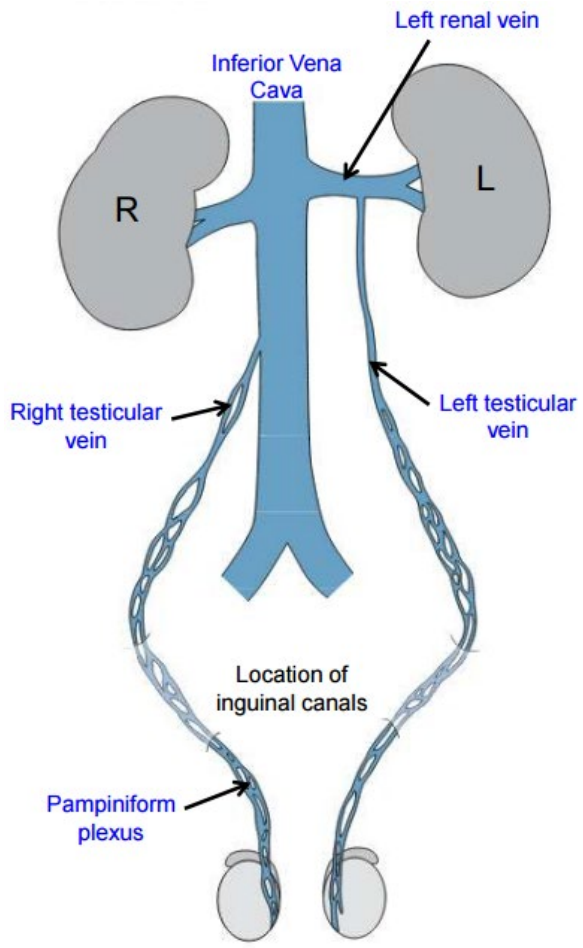
-Epididymitis

-Epididymal cyst



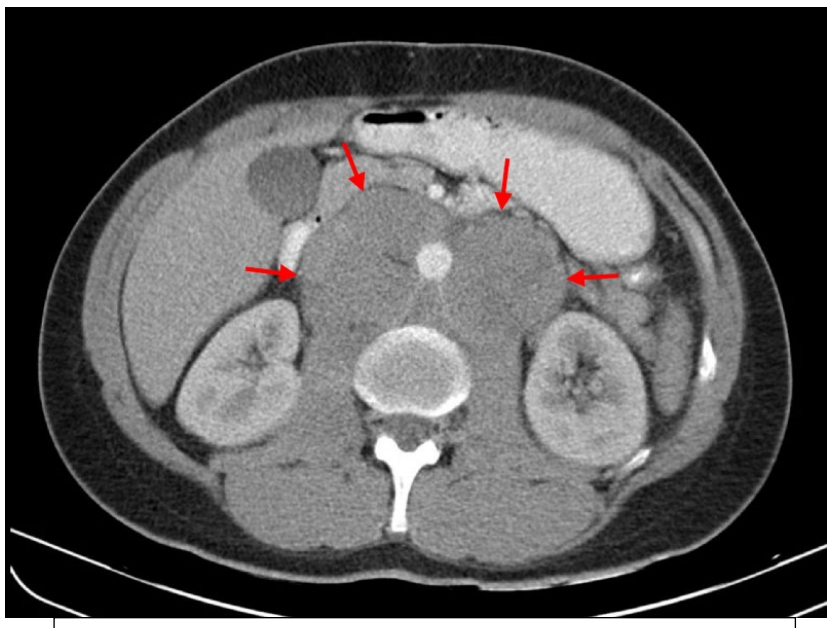
Extratesticular, intrascrotal hydrocele (red arrow)

Left-sided varicocele (accentuated by Valsalva maneuver) (Ultrasound Imaging)



Based on anatomy of gonadal vein drainage:
Solitary, compressible left-sided varicoceles are less worrisome than solitary (potentially non-compressible) right-sided varicoceles

Note: CT (and potentially PET-CT) are utilized in the staging of testicular neoplasia. Retroperitoneum is a potential site of lymphadenopathy in patients with gonadal tumors (i.e. testicular and ovarian)



Retroperitoneal lymphadenopathy (red arrows) in a patient with known testicular neoplasia (histology-

References:

-Clinical Radiology: The Essentials. Daffner et al. 4th ed. (Chapter 6).

-Primer of Diagnostic Imaging. Weissleder et al. 4th ed. (Chapters 4 and 9).

-Genitourinary Radiology: The Requisites. Zagoria et al.

-Note: Medical images are from anonymized patient data and online archives (as detailed)

OPTIONAL: Want to know more?

https://www.med-ed.virginia.edu/courses/rad/

www.auntminnie.com

www.acr.org

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