**Developmental Anatomy**

**Testis and Kidney**

- In the 3-week-old embryo, the primordial germ cells in the wall of the yolk sac close to the attachment of the allantois migrate along the wall of the hindgut and the dorsal mesentery into the genital ridge.

- At 5-weeks, the two excretory organs, the pronephros and mesonephros systems regress, leaving only the mesonephric duct. The metanephros (adult kidney) forms from the metanephric diverticulum (ureteric bud) and metanephric mass of mesoderm. The ureteric bud develops as a dorsal bud of the mesonephric duct near its insertion into the cloaca.
Developmental Anatomy
Wolffian and Mullerian Duct

- Under the influence of SRY, cells in the primitive sex cords differentiate into Sertoli cells forming the testis cords during week 7. It is at puberty that these testis cords (in association with germ cells) undergo canalization into seminiferous tubules.
- At 7 weeks the indifferent embryo also has two parallel pairs of genital ducts: the Mesonephric (Wolffian) and the Paramesonephric (Mullerian) ducts.
- By week 8 the developing fetal testis produces at least two hormones:
  1. A glycoprotein (MIS) produced by the fetal Sertoli cells (in response to SRY) which suppresses unilateral development of the Paramesonephric (Mullerian) duct.
  2. Testosterone secretion by Leydig cells (6 to 12 weeks) stimulates the development of the mesonephric (Wolffian) duct into the male genital tract (testosterone).

Developmental Anatomy
Vestigial Remnants

- The Appendix of the Testis persists as a vestigial remnant of the Paramesonephric (Mullerian) duct.
- The Prostatic utricle is the male homologue of the female uterus and vagina, and is also derived from the Paramesonephric (Mullerian) duct.
- The Appendix of the Epididymis persists as a vestigial remnant of the cranial portion of the Mesonephric (Wolffian) duct.
- The Paradidymis occasionally persists as a vestigial remnant of the caudal portion of the Mesonephric (Wolffian) duct.
Developmental Anatomy

Testicular Descent

- In the 7 week old embryo the testes are positioned in the dorsal abdominal wall.
- At about 28 weeks the process vaginalis and testis begin to pass through the inguinal canal with fascial coverings from the abdominal wall.
- These fascial coverings become the vestments of the spermatic cord and testis.
- The process vaginalis closes and leaves a visceral (covering the testis) and parietal layer separated by a fluid filled space.

Developmental Anatomy

Scrotum

- Scrotum contains two compartments divided by a septum with multiple fascial layers beneath the skin and dartos fascia.
- The primary components of each compartment consists of a testis, epididymis and the spermatic cord.
- The spermatic cord contains the vas deferens together with the arterial and venous vessels (pampiniform plexus).
The testis is covered by a thick fibrous connective tissue layer (tunica albuginea) and two thinner connective tissue layers: a visceral and a parietal tunica. Together, the tunica vaginalis forms a cavity normally containing a small (physiologic) amount of fluid (1–2 ml).

A hydrocele is present when this cavity has greater than the physiologic amount of fluid.

Blood collecting in this cavity or areas outside the parietal vaginalis defines a hematocoele.

The tunica albuginea projects into the testis to form the mediastinum testis, which is the point where the testicular vessels and the 12 to 20 efferent ducts traverse the testicular capsule. One or more seminiferous tubules are contained in each of the 200-300 cone-shaped lobules formed from the connective tissue septa radiating to the inner surface of the tunica albuginea from the mediastinum testis.
Developmental Anatomy

testis vasculature

Three primary arteries supply the scrotal structures.

1. **Testicular artery (aka internal spermatic a.)** - arising from the aorta and supplies the testis
2. **Cremasteric artery (aka external spermatic a.)** - a branch of the inferior epigastric artery (which arises from the external iliac artery) and supplies the scrotal sac and coverings of the spermatic cord
3. **Deferential artery** - arising from the superior vesical artery (which arises from the internal iliac artery) and supplies the vas deferens and epididymis.

The veins draining the testis exit at the mediastinum.

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Scanning Terminology

Scrotal Orientation

- **Longitudinal View** (Sagittal)
  - Epididymis
    - Head (caput)
    - Body (corpus)
    - Tail (cauda)

- **Transverse View**
  - Medial and lateral
Clinical Interpretation

Echogenicity

- The liver is usually used as the benchmark for echogenicity. In Scrotal Ultrasound always compare the two testes
  - Hypoechoic = darker and black
  - Hyperechoic = bright and white
  - Isoechoic = similar to the reference
  - Anechoic = without echo
  - Homogeneous = uniform
  - Heterogeneous = mixed
- High water content makes tissue appear hypoechoic
- High fat content makes tissue appear hyperechoic

Normal Imaging

Adult testis

- Testis size: 4-5 cm long, 3 cm wide & 2.5 cm AP (20 to 30 cc volume)
- Ultrasound appearance of testicle
  - smooth homogeneous ovoid gland
  - septa & mediastinum testes may appear as linear echogenic areas
Normal Imaging

Adult Epididymis

- Epididymis courses behind posterior wall; head = 10-12 mm, body = 2-4 mm, tail = 2-5 mm
- Usually (not always) more echogenic than testis and coarser in appearance
- Post vasectomy may mimic epididymitis; less echogenic

Normal Imaging

testicular vasculature

Normal Imaging

mediastinum testis

At the mediastinum testis the tunica albuginea projects into the testis. It is also the point where the testicular vessels and the 12 to 20 efferent ducts traverse the testicular capsule. On ultrasound, the mediastinum testis is seen as a partial septum often seen on US as a highly reflective (hyperechoic) line at the posterior superior aspect of the testis.

Normal Imaging

mediastinum, rete testis

The rete testis is formed by the anastomosing network of seminiferous tubules traversing the mediastinum testis. Rete tubular ectasia is a disorder of the rete testis in which benign cysts are present.
Normal Imaging
appendix testis and epididymis

Probes used for testis scanning

Frequency: 6 mHz - 18 mHz
“Footprint”: 25 mm - 50 mm
Small “Footprint” Probe

Trapezoidal Imaging
Normal Imaging

Scanning Protocol

- Utilize high frequency 6.0 - 18 MHz transducer
- Support the scrotum: Legs, towel or drape
- Lay a second towel or disposable drape across the penis
- Longitudinal scan - medial to lateral
  - measure long axis @ mid testis
- Transverse scan - superior to inferior
  - measure AP & width @ mid testis
- Take comparison views of right & left testes
  - Split screen, same settings
- Color Doppler Imaging (CDI) to demonstrate flow to help with differential diagnosis (e.g., torsion, epididymitis)
- Coronal or Apical view sometimes better for CDI or to compare R/L

The following images should be obtained, labeled, attached to the written report:

- Transverse view of left testis
  - width and AP measurement at mid-testis
- Transverse view of right testis
  - width and AP measurement at mid-testis
- Transverse view (split screen) of both testes
  - compare echogenicity
- Longitudinal (sagittal) view of left testis
  - length and AP measurement at mid-testis
- Longitudinal (sagittal) view of right testis
  - length and AP measurement at mid-testis
- Longitudinal (sagittal) of caput and cauda epididymis
  - Compare size and echogenicity
- Color Doppler evaluation (Longitudinal (sagittal) and/or Transverse view) of both testes
  - Parenchymal blood flow evaluation
  - Measurement of varicocele size in mid-sagittal and/or mid-transverse view
Normal Imaging Documentation

- The report should include:
  - patient identification
  - date of examination
  - measurement parameters and anatomical findings of examination.
- The report is signed by the physician who performed the ultrasound examination
- Indication for performing the examination is clear and provided on the report.

Images should include:
- patient identification
- date and time of each image
- Clear image with orientation and measurements
- Labeling of anatomy and any abnormalities
- Images should be attached to the report

Normal Imaging Scanning Protocol - Transducer

- High frequency (7 - 18 MHz)
- Linear array probe with footprint able to measure longitudinal length of testis
- Curved array probe can be used for large testis and to compare both testes
- Color and spectral Doppler capabilities
Normal Imaging
patient positioning

Normal Imaging
patient positioning
Normal Imaging

patient positioning

Normal Imaging
longitudinal view (video)

Scan medial to lateral
Normal Imaging
transverse view (video)

Scan superior to inferior

Normal Imaging
measurements (video)

At the mid point of testis obtain:
- Length (Sup - Inf)
- AP (Ant - Post)
- Width (Med - Lat)
Normal Imaging
comparative view - convex transducer

- Provides a global perspective
- Allows for comparison of structure and echogenicity
- Allows for measurement of larger structures

Normal Imaging
comparative views
Normal Imaging

epididymis

Normal Imaging
caput epididymis (video)
Normal Imaging
cauda epididymis

Normal Imaging
color flow (video)

Varicocele
Indications for Scrotal Ultrasound

- Assessment of scrotal mass or enlargement
  - Painful enlargement
    - Epididymitis/Orchitis
    - Testicular abscess
    - Torsion
  - Non-painful enlargement
    - Testicular Tumor
    - Hydrocele
    - Varicocele
    - Spermatocle/Epididymal cyst
    - Scrotal hernia
    - Cyst
- Trauma
  - Testicular rupture
  - Hematocele
- Empty/abnormal scrotal sac
  - Undescended testis
  - Thickened scrotal skin
- Fertility and related issues
  - Varicocele
  - Atrophic testis
  - Microlithiasis
  - Impaired semen quality
  - Azoospermia
  - Antisperm antibody
- Post surgical follow up
  - Varicocele
  - Testis biopsy

* Specific AUA routine indications (not for routine screening)
** AUA Doppler indications
Indications
painful enlargement - epididymitis/orchitis

- May be acute or chronic
- Epididymis may be hypoechoic & enlarged
- Acute presentation
  - unilateral painful swelling
  - dysuria
  - fever
  - high WBC count
- Causes include
  - trauma
  - Infection (patients > 40 years old)
  - Post procedure (e.g., vasectomy)

Indications
painful enlargement - epididymitis/orchitis

- Ultrasound presentation
  - enlarged
  - heterogeneous
  - hypoechoic
  - flow w/ Doppler/CDI
- Chronic Epididymitis
  - scrotal enlargement & hard/ firm epididymis on palpation
  - inhomogeneous w/ calcifications often present
  - thickening of epididymis
  - associated hydrocele
  - testis may become inhomogenous
Indications

painful enlargement - epididymitis/orchitis sequela

**Indications**

- Torsion of the spermatic cord is a Urologic emergency
- Irreversible testicular damage is presumed after 4 hours of torsion. However, only 50% of men detorted less than 4 hours after symptoms began had normal semen quality (Bartsch G, et al J Urol 1980;124:375-378)
- *Torsion is a clinical diagnosis proven at surgery.*
- Ultrasound does not diagnose torsion...only the Urologist (or Pathologist) can.
- Ultrasound should only be used to document findings. Many conditions (e.g., torsion-detorsion, intermittent torsion, persistent capsular flow, color flow artifacts) can result in apparent flow when none exists.
Indications

painful enlargement - torsion

Spermatic Cord
- Arterial Supply
  - Deferential (flows to the tail of epididymis)
  - Cremasteric (external spermatic)
  - Testicular (branches into capsular arteries that supply the deep testis)


Indications

painful enlargement - torsion

- Testicle usually hypertrophic and hypoechoic
- Always compare with contralateral side
- Use multiple views – longitudinal, transverse, and coronal
- Use apical views to try to align parallel to flow

Indications

“Whirlpool sign” - torsion

Vijayaraghavan, SB. J Ultrasound Med 25:563-574 • 0278-429

Indications

painful enlargement - torsion

Color Doppler Imaging

Normal testis duplex Doppler

Right torsion at 24 hours with capsular blood flow

Left torsion without testicular blood flow blood flow
Indications

**Intermittent torsion - torsion de-torsion**

- Right testis after manual detorsion
- Normal contralateral left testis

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Indications

**Non-painful enlargement - hydrocele**

- Abnormal accumulation of fluid between the layers of tunica vaginalis (greater than 1-2 ml)
- Painless scrotal swelling
- Causes include
  - infection
  - trauma
  - neoplasm
  - torsion
  - idiopathic
Indications
non-painful enlargement - hydrocele

- Anechoic fluid collection greater than 2 mm surrounding the testis
- May be associated with debris
- Septations may suggest infection or metastasis

Indications
non-painful enlargement - spermatocele/epididymal cyst

- Smooth, well circumscribed surface
- Anechoic
- Acoustic enhancement (through transmission)
Indications
non-painful enlargement - spermatocoele/epididymal cyst

- Benign cyst of the epididymis
- Contains sperm
- Most common in the epididymal head
- Usually an anechoic cyst w/ septations
- Treatment may cause epididymal obstruction
Indications
non-painful enlargement - scrotal hernia

- Mesenteric fat and/or bowel loops from an inguinal hernia can extend to the scrotum and be visualized with ultrasound.

Indications
non-painful enlargement - testis tumor

**Benign Neoplasms**
- Granuloma
- Lipoma
- Adenomatoid
- Cyst

**Malignant Neoplasms**
- Seminoma –most common
- Teratoma
- Embryonal cell carcinoma
- Choriocarcinoma
- Mixed germ cell tumor
- Lymphoma
- Metastases
**Indications**

*non-painful enlargement - testicular cyst*

- smooth, well circumscribed surface
- anechoic (at times, may contain septations)
- acoustic enhancement (through transmission)

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**Indications**

*non-painful enlargement - testis tumor - Seminoma*

- Most common solid tumor in males age 18-35 years of age
  - Seminoma comprise 50% of all testicular tumors
- Differential diagnosis difficult without biopsy
- Presents:
  - well defined mass within the testis
  - hypoechoic or isoechoic
  - Increased flow within the tumor
Indications

non-painful enlargement - testis tumor - Seminoma

“Scar” from burned out testicular tumor

Hypoechoic testicular mass
Indications
non-painful enlargement - testis tumor

Right testicular tumor with heterogeneous echogenicty

Right testicular tumor with increased blood flow surrounding the tumor

Bilateral testicular tumors with increased blood flow

Indications
non-painful enlargement - testis tumor

Epidermoid Cyst:
• alternating hypoechogetic-hyperechogetic concentric rings (onion skin or bull's-eye appearance)
• no flow inside, increased flow surrounding
Indications

non-painful enlargement - vascular anomalies

- Most commonly seen is an intratesticular varicocele. However, vascular malformations can be confused with tumor
- Case report:
  - 24 yo with h/o undescended testis presented with a palpable mass in his left testis
  - US with 1.5 cm heterogeneous, hypoechoic mass
  - CF Doppler demonstrates both low and high flow around and within mass
  - Pathology: normal testicular tissue with thick walled vessels

http://brighamrad.harvard.edu/Cases/twix tacos/372/full.html

Indications

trauma - testicular rupture

Testicular rupture
Testicular rupture with disruption of tunica albuginea
Indications

trauma - hematocele

Indications

empty/abnormal scrotal sac

- Anorchism – complete absence of both
- Monorchism – absence of one testis
- Cryptorchidism – undescended testis
- Incomplete descent
- Retractile Testis
- Testicular Ectopia
**Indications**

*empty/abnormal scrotal sac*

- A cryptorchid or undescended testis
  - Most commonly found below the inguinal ring in the groin area
  - Has never been palpated in the scrotum
  - Even after the undescended has been surgically brought down into the scrotum it is usually smaller than the normal testis
  - The cryptorchid testis often has impaired spermatogenesis and an increased risk of testicular cancer

**Overall efficacy of imaging modalities (with comparison to laparoscopy)**

<table>
<thead>
<tr>
<th></th>
<th>Ultrasound</th>
<th>CT</th>
<th>MRI</th>
<th>Laparoscopy</th>
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</thead>
<tbody>
<tr>
<td>specificity</td>
<td>62.5%</td>
<td>72.0%</td>
<td>94.0%</td>
<td>100%</td>
</tr>
<tr>
<td>sensitivity</td>
<td>11.0%</td>
<td>16.6%</td>
<td>30.0%</td>
<td>100%</td>
</tr>
<tr>
<td>accuracy</td>
<td>30.0%</td>
<td>49.0%</td>
<td>79.0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Approximately 75% are in the inguinal canal (pre-scrotal 20%, abdominal 5%)*

(AS Hashem et al, Egyptian Urol Assoc)
Indications
empty/abnormal scrotal sac - thickened scrotal wall
Indications

fertility related issues - varicocele

- Prevalence
  - 15% of fertile males
  - 30% to 40% primary subfertility
  - 80% to 90% secondary subfertility
- Usually located on post & lateral aspect of testis w/ spermatic cord & epididymis
- Frequently associated w/ impaired semen quality, less commonly with pain
- Color Doppler Imaging helpful to identify and document
- Bilateral incidence as high as 80% (Y Gat et al, Fert Steril, 81:424,2004)
**Indications**

**fertility related issues - atrophic testis**

- **32 yo male with fructose positive azoospermia - Leydig Cell Hyperplasia**
  - Testosterone 337 ng/dl, LH 8.8 u/l, FSH 17.4 u/l

- **31 yo male w/ fructose positive azoospermia - Leydig Cell Tumor**
  - Testosterone 461 ng/dl, LH 5.6 U/L, FSH 17.8 U/L
Indications
Fertility related issues - microlithiasis

Twinkle Artifact

The twinkling artifact is a Doppler color artifact. It is a rapidly changing mixture of colors seen deep to a strong reflector such as a calculus with a rough surface. Twinkle artifact may also be used to differentiate echogenic foci (vascular, solid masses) from calcifications in the testis.

Twinkling occurs when the ultrasound machine receives an echo that is different in frequency from the pulse leaving the transducer. This could occur because of the wide bandwidth of the initial pulse. The strong reflectors, on the other hand, ring at a narrower band of frequency. This “ringing” cause the continuing echoes deep to the reflector.
Indications
Fertility related issues - microlithiasis

- Rare – less than 1% of men w/o tumors
- Usually symmetrical; asymmetry 20%
- Initially considered benign process
- > 5 echogenic foci recommend close F/U
  - instruct patient in self-examination
  - US every 6 months….duration of f/u?
- Increased incidence and/or coexistence w/ primary testicular neoplasm reported*
  - 40% coexistence w/ germ cell tumor

*Testicular Microlithiasis with Invading Neoplasm, JDMS, January/February 2002, Volume 18 Number 1, Stuber et al