

# Emergency Ultrasound Review

Sandy Werner, MD, RDMS, FACEP  
Case Western Reserve University  
MetroHealth Medical Center



## Objectives

- Review indications for emergency ultrasound
- Review essential ultrasound physics
- Review normal anatomy and key pathological findings for each of the main EM US exams and review procedural applications

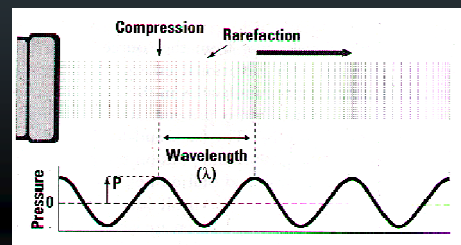


## Emergency Ultrasound

- Indications for EM Bedside Ultrasound
  - Emergent –
    - Trauma, Cardiac Arrest/Hypotension, AAA, Ectopic Pregnancy
  - Urgent –
    - Gallbladder, Renal, DVT
  - Procedural –
    - Vascular Access, Abscess Identification, Fluid aspiration



## Sound Waves



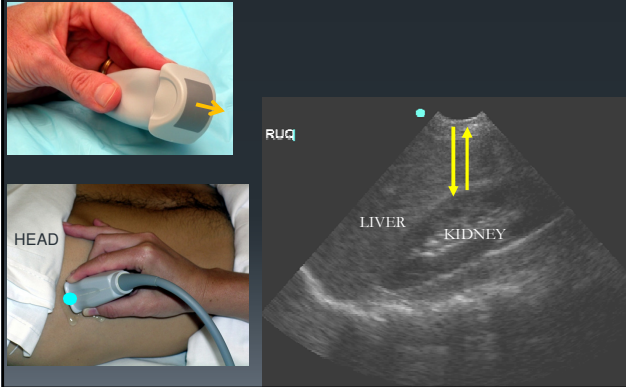
Frequency = Waves per second = Hertz (Diagnostic US 2-22 MHz)

Long wavelength = Low Frequency = **Good penetration**/Poor resolution

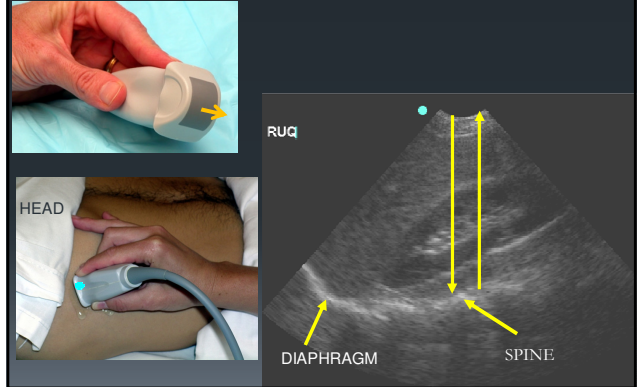
Short wavelength = High Frequency = **Good resolution**/Poor penetration



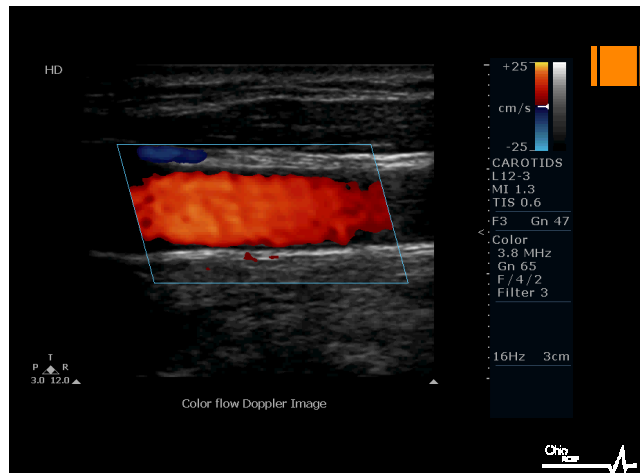
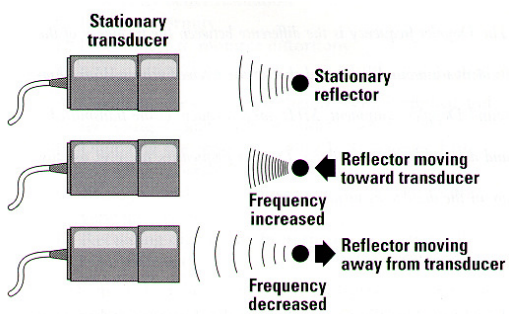
## Ultrasound Physics – The Essentials



## Ultrasound Physics – The Essentials



## Doppler Physics



### Curvilinear Transducer

2-5 MHz

Liver  
Kidney

Chin  
acep

### Phased Array Transducer

Flat Surface

2-5 MHz – Standard cardiac transducer – also used for abdominal scanning

Chin  
acep

7-10+ MHz

### Linear Transducer

Superficial Scanning

Chin  
acep

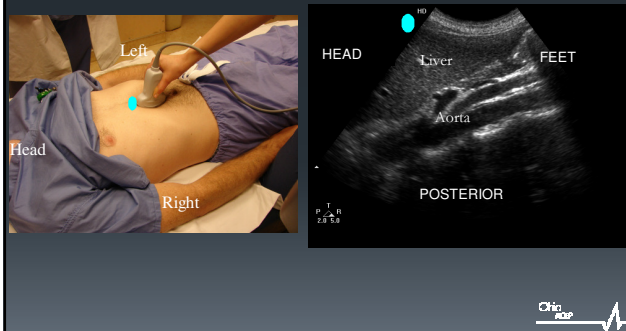
### Terminology

RUQ  
LIVER  
KIDNEY  
RENAL CAPSULE  
FF

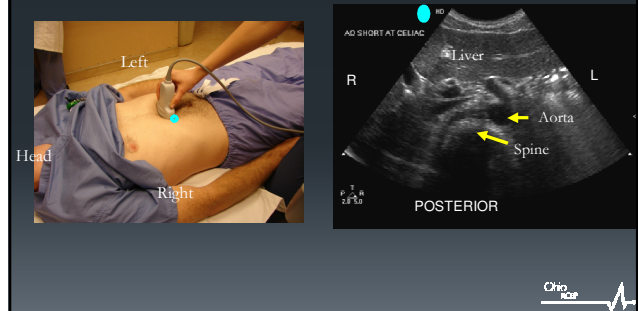
- Anechoic
- Hypoechoic
- Hyperechoic
- Isoechoic

Chin  
acep

## Orientation – Sagittal or Long Axis



## Orientation – Transverse or Short Axis



# FAST

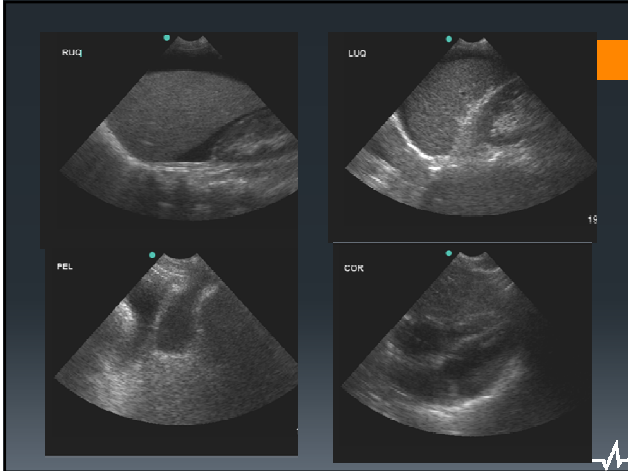
Focused Assessment  
with Sonography in  
Trauma



## FAST

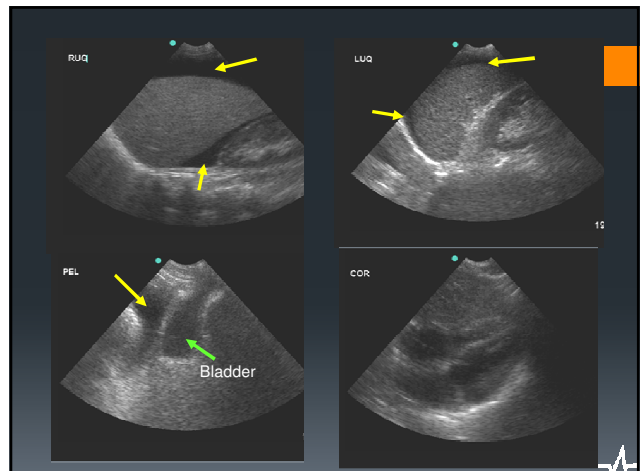
- Primary Goal: Rapid identification of hemoperitoneum and hemopericardium
- Extended exam (E-FAST)
  - solid organ injury
  - HTX/ PTX
- Will **NOT** identify all pathology



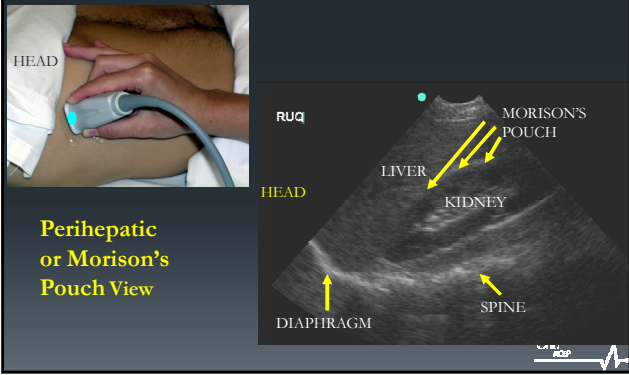


- A. The patient has hemoperitoneum and should go directly to the OR
- B. There is free fluid in all three abdominal views
- C. The FAST is inadequate
- D. Free fluid is demonstrated only in the Morison's pouch and pelvic windows

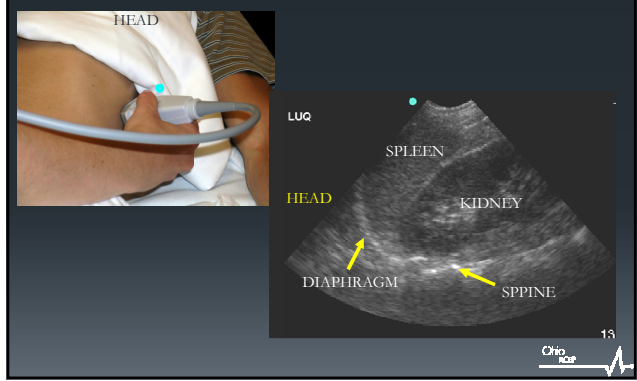
- A. The patient has hemoperitoneum and should go directly to the OR
- **B. There is free fluid in all three abdominal views**
- C. The FAST is inadequate
- D. Free fluid is demonstrated only in the Morison's pouch and pelvic windows



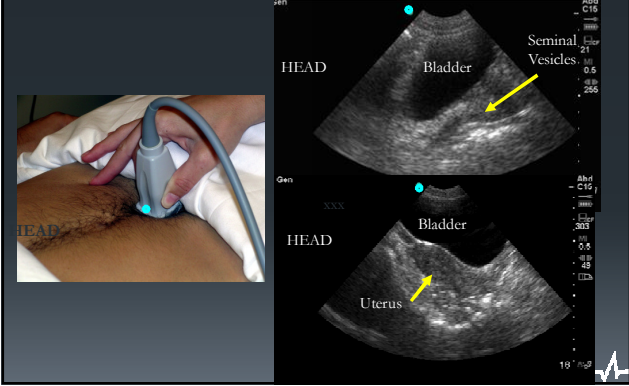
### Four FAST Windows - RUQ



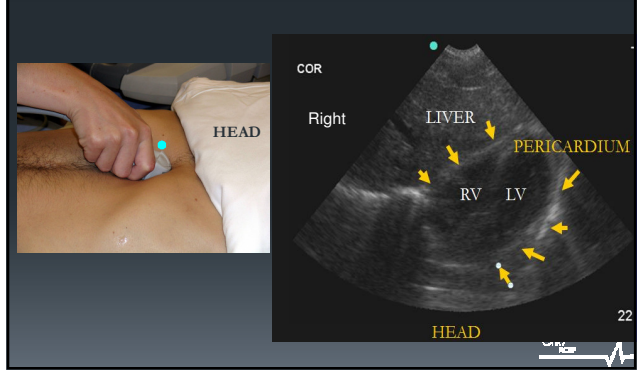
### Four FAST Windows - LUQ



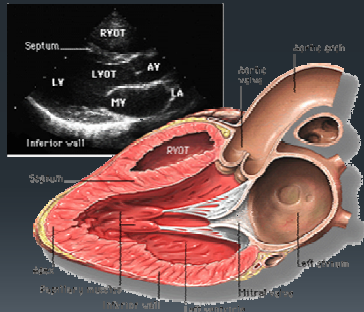
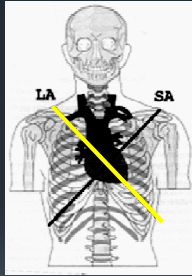
### Four FAST Windows - PELVIC



### Four FAST Windows - Subx Card



## Parasternal Long Axis

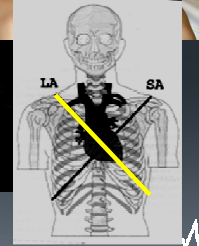
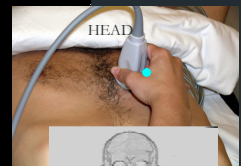
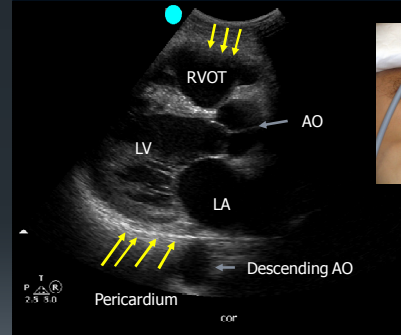


Cardiac orientation image courtesy O. John Ma, James R. Mancoske, *Basic Emergency Ultrasound*, McGraw-Hill Companies, Inc. 2003. Used with permission.

Cardiac illustration courtesy Patrick J. Lynch, C. Carl Jaffe, Yale University, 2006. Used with permission.



## Parasternal Long Axis



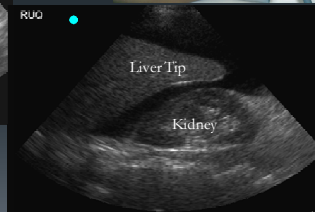
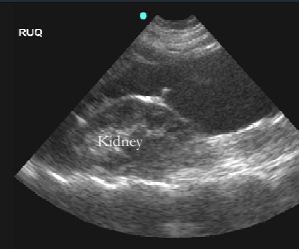
Cardiac orientation image courtesy O. John Ma, James R. Mancoske, *Basic Emergency Ultrasound*, McGraw-Hill Companies, Inc. 2003. Used with permission.



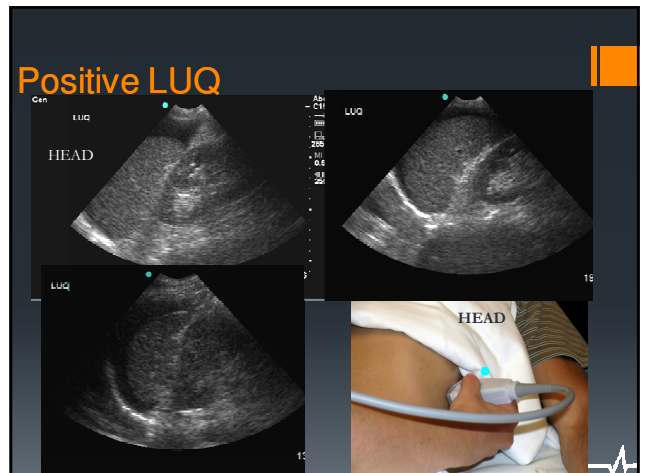
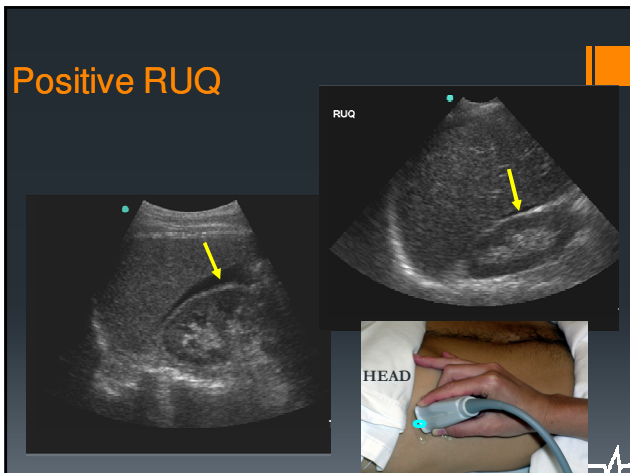
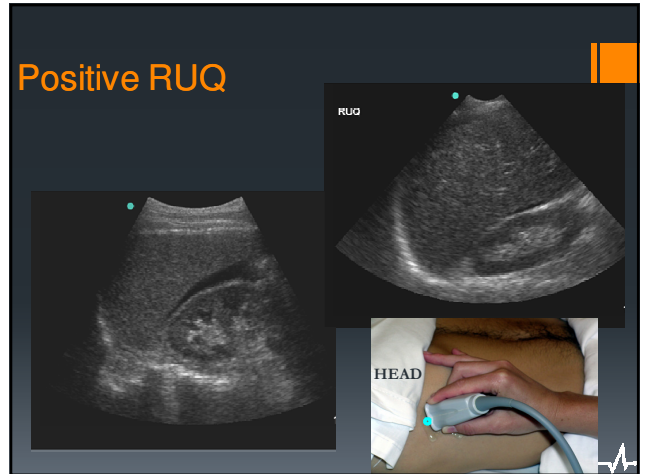
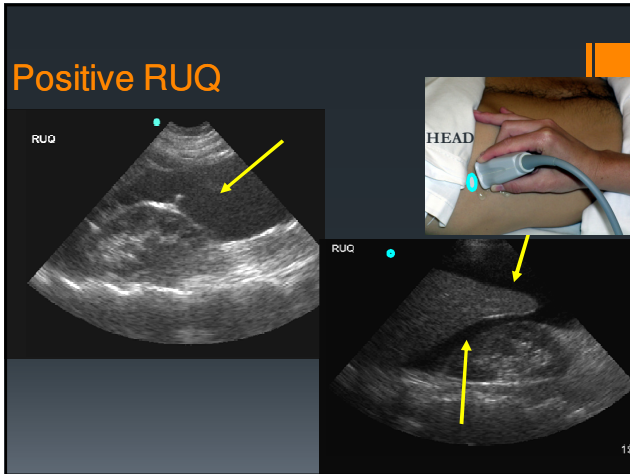
## The Positive FAST



## Positive RUQ

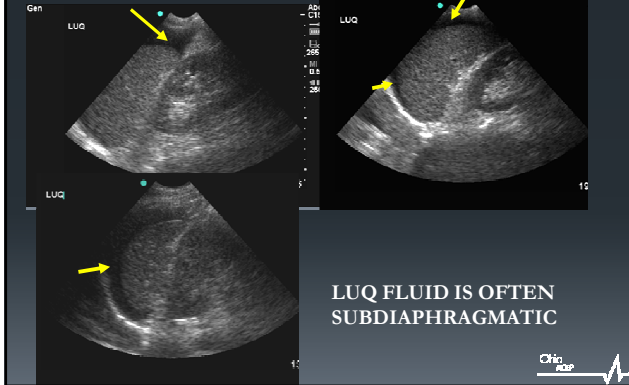


18

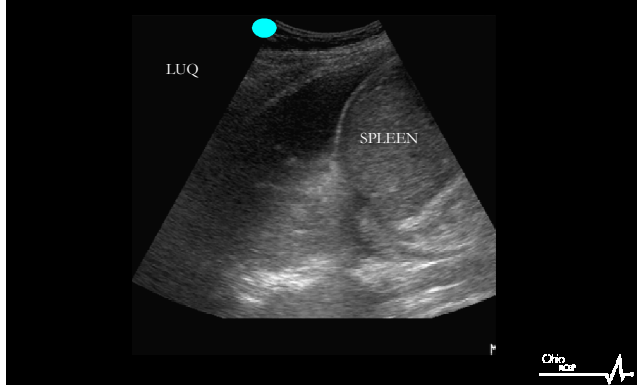




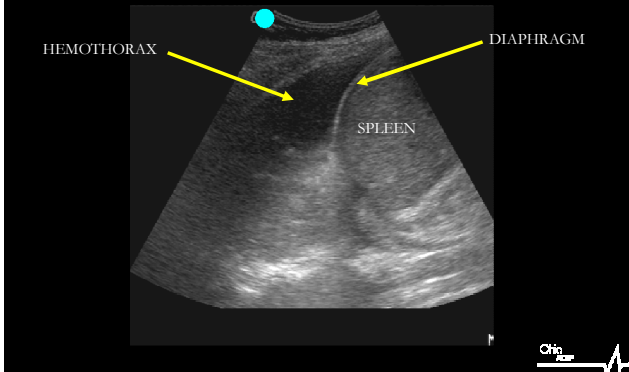
## Positive LUQ



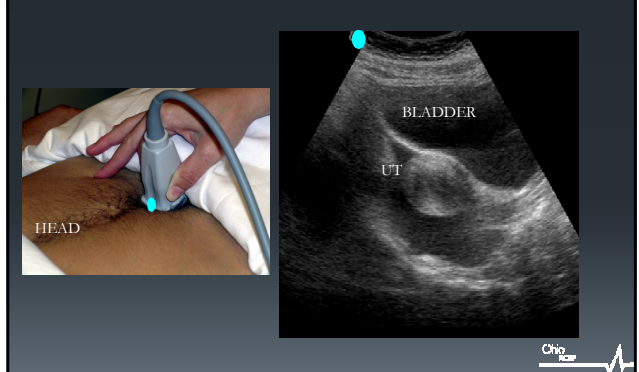
## Where is the fluid??



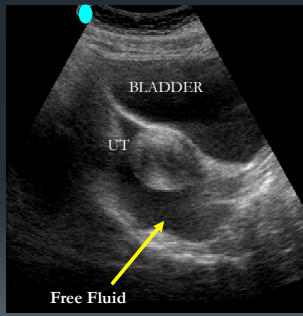
## Hemothorax



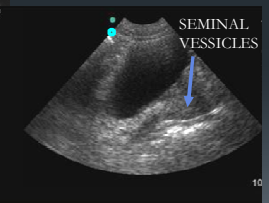
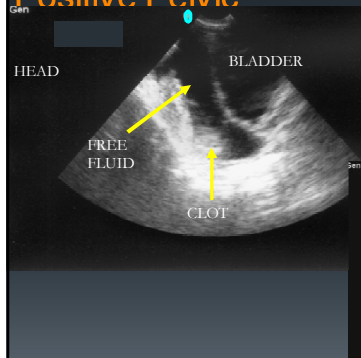
## Positive Pelvic



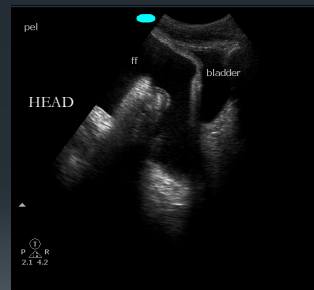
## Positive Pelvic



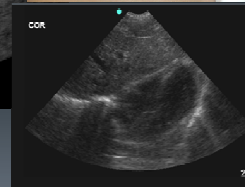
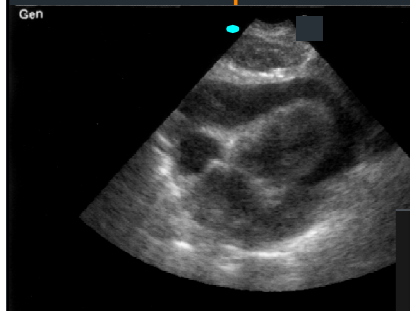
## Positive Pelvic

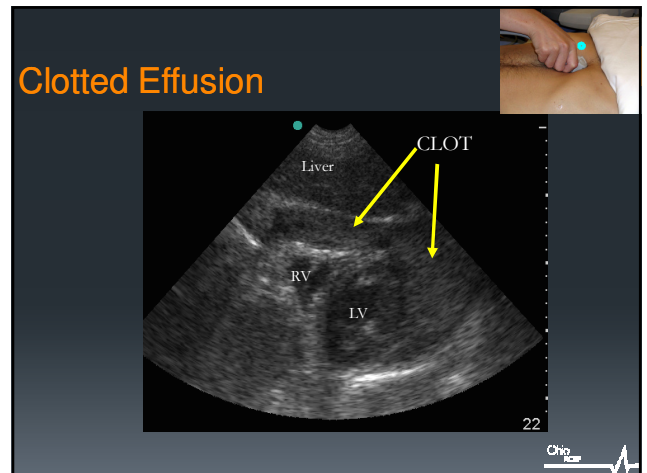
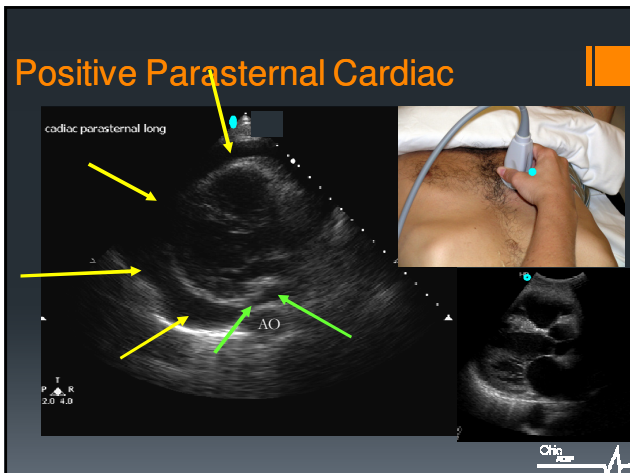
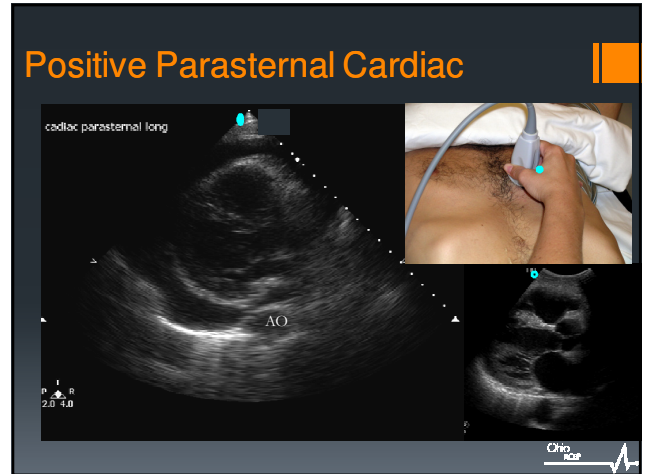
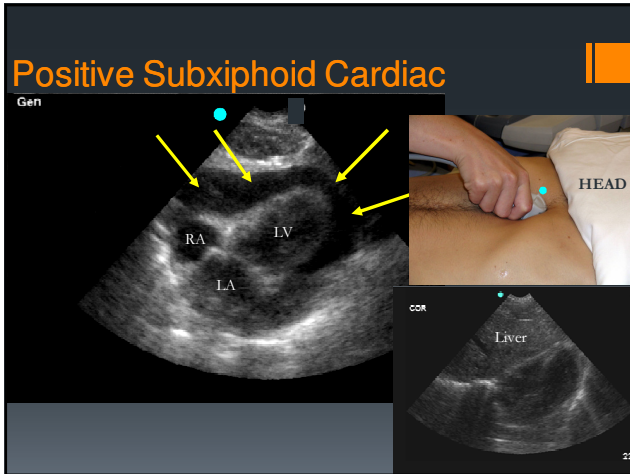


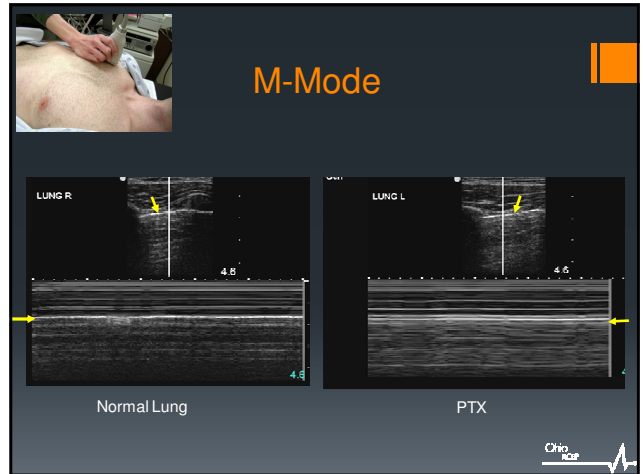
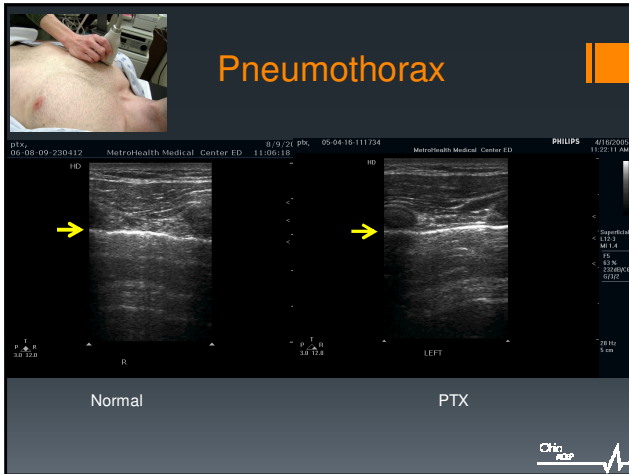
## Positive Pelvic



## Positive Subxiphoid Cardiac







## FAST Limitations

- Body Habitus
- Empty Bladder
- SQ Air
- Time
- Fluid ≠ Blood
- Negative vs indeterminate

## FAST vs Other Imaging

- FAST – Rapid, bedside, no preparation, no contrast
  - High sensitivity/specificity for free fluid
  - NOT sensitive for other pathology
- CT – GOLD STANDARD for trauma imaging
  - Contrast, radiation, patient out of ED
- DPL – Highly sensitive – unnecessary laparotomies
  - 5% complication rate
  - NOT recommended as first line

## Clinical Decision Making

- Level One Trauma Centers
  - Blunt trauma
    - Unstable patients
    - Unreliable exam
    - Unexpected hypotension and equivocal exam
  - Penetrating Trauma
    - Unclear need for emergent surgery not clear
    - Locate bleeding source
    - Identify compartments involved



## Clinical Decision Making

- Non-Level One Trauma Centers
  - Identify immediate need for intervention
  - Identify patients who require immediate OR / transfer



## Cardiac US

- Cardiac Arrest
  - Activity?
- PEA?
  - Hypodynamic = hypovolemia
  - Tamponade
  - Dilated RV = PE



## Cardiac Views

- Subxiphoid
  - Transverse and sagittal
- Parasternal Long and Short
  - Large body habitus, abdominal trauma
  - Global wall motion, valves
- Apical – at PMI
  - Masses, LV aneurysms, paracardiocentesis



## Effusions

- Normal pericardium < 50 mL fluid
- Usually anechoic
  - BUT clots echogenic
- Small < 100 mL - posterior
- Large > 300 mL – anterior and posterior
- Pericardial sac can accommodate > 1 Liter fluid
- Tamponade – RV, RA collapse in diastole



### PARASTERNAL VIEWS

Cardiac orientation image courtesy O. John Mc James R. Maceo, *Basic Emergency Ultrasound*, McGraw-Hill Companies, Inc. 2003. Used with permission.

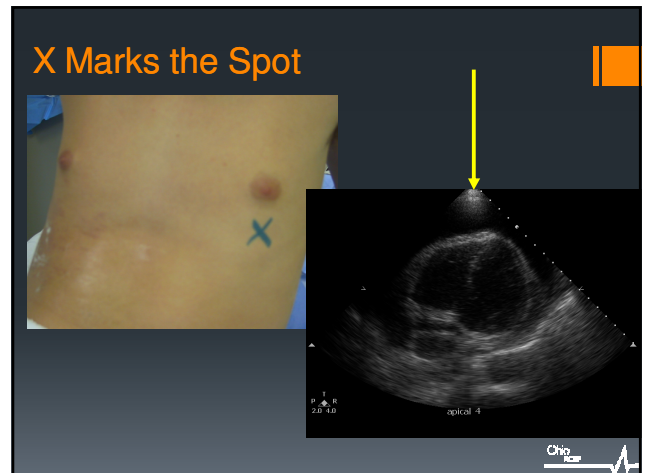
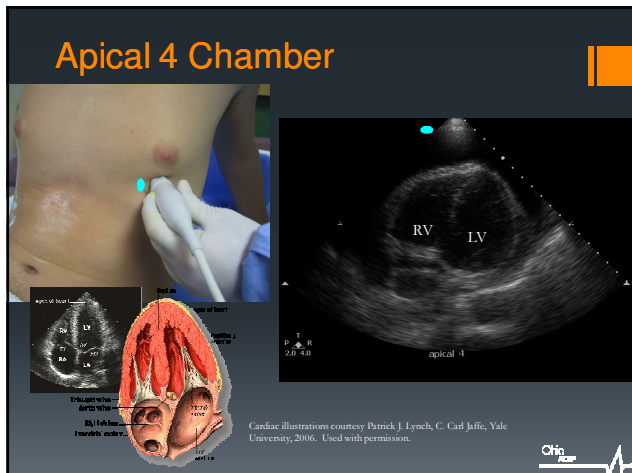
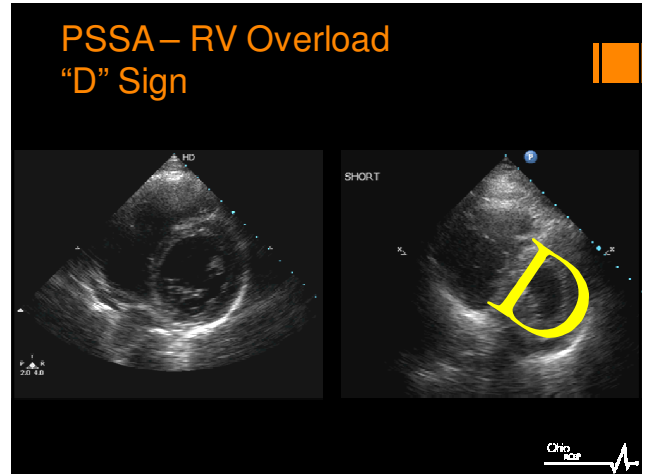
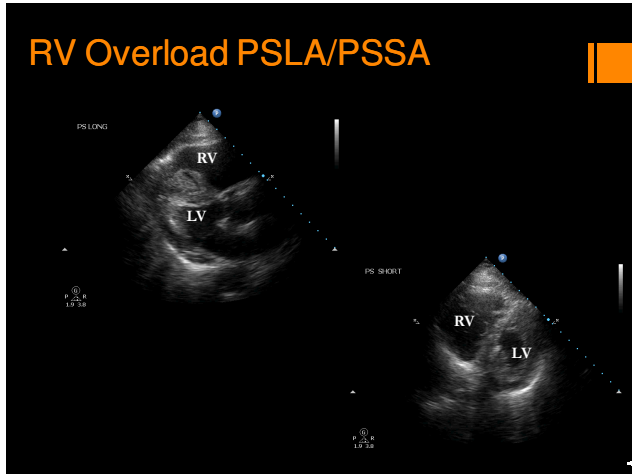
### Parasternal Short Axis

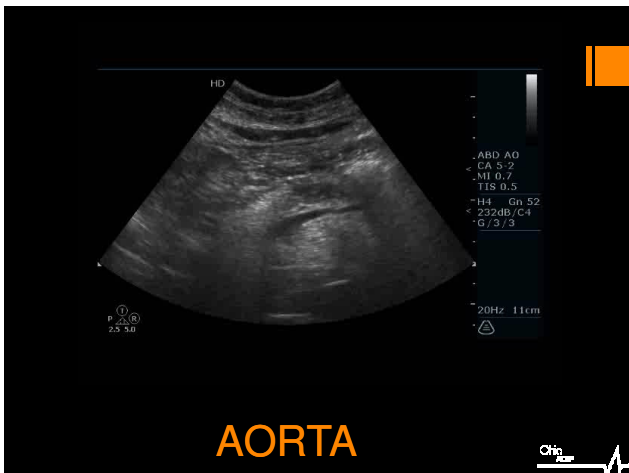
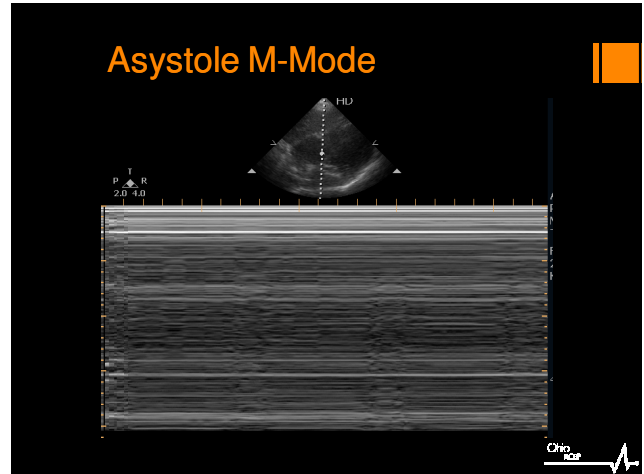
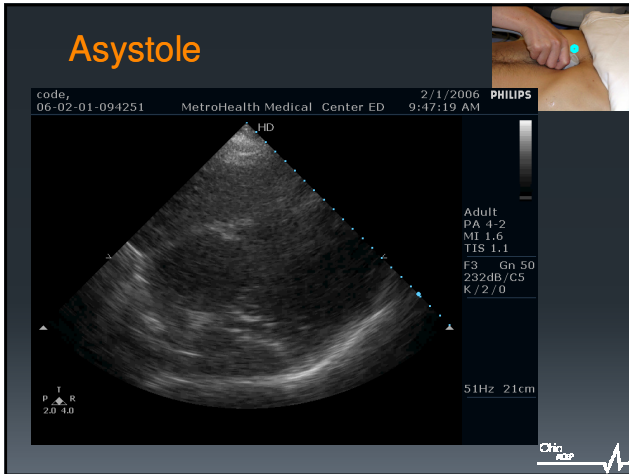
PSLA LEFT VENTRICLE

PSLA - AORTA

Cardiac illustrations courtesy Patrick J. Lynch, C. Carl Jaffe, Yale University, 2006. Used with permission.

### PSLA Effusion/Tamponade





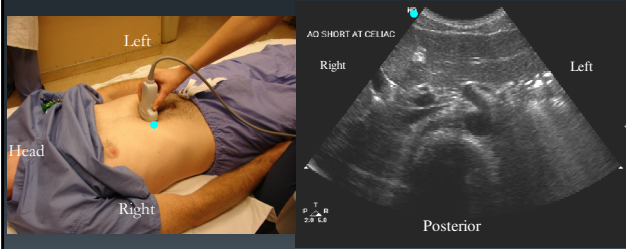
## AORTA

- Goal: Diagnose AAA
  - Decrease time to OR and mortality
- Indications: Elderly patient with
  - Back pain
  - Abdominal pain
  - Flank pain
  - Hypotension
- US vs CT

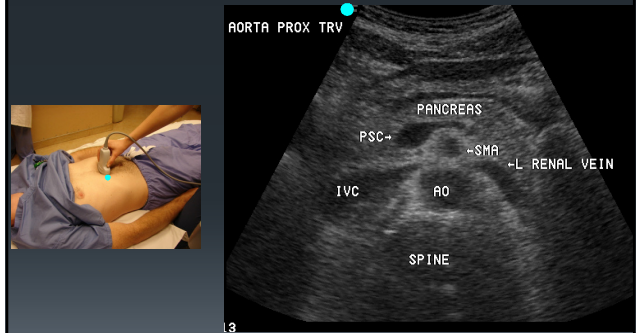
Chin  
acep



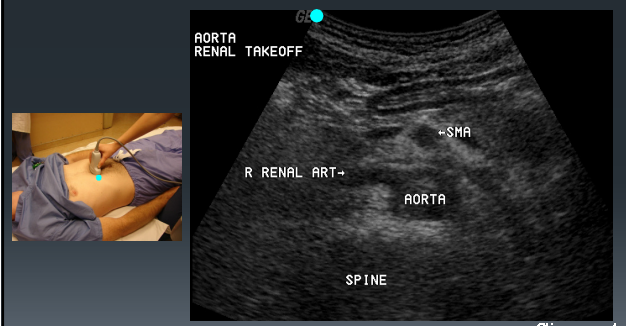
## Transverse Aorta at Celiac Axis



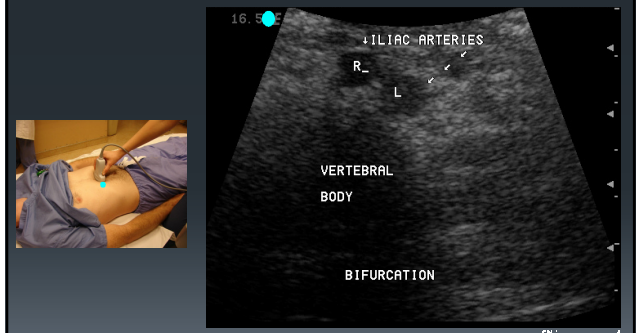
## Transverse Aorta at SMA



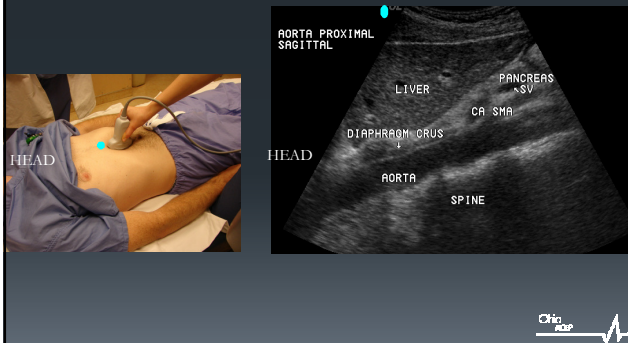
## Renal Artery Takeoff



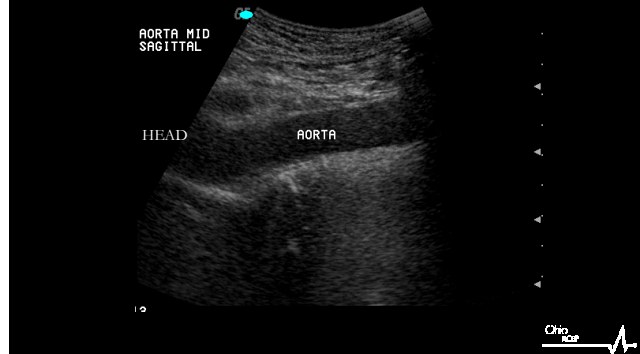
## Bifurcation



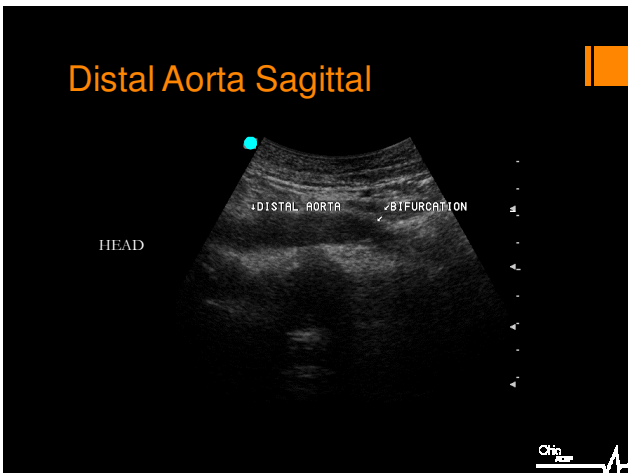
## Proximal Aorta Sagittal



## Mid Aorta Sagittal



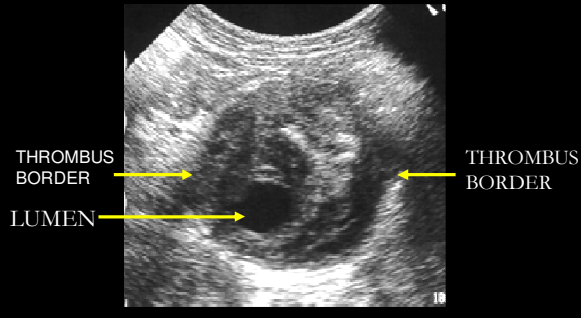
## Distal Aorta Sagittal



## Aneurysms

- Diameter > 3 cm
  - Increased risk of rupture when > 5 cm
  - US NOT sensitive for rupture
- Most are infrarenal, fusiform
- Mural thrombus
- Dissections vs AAA

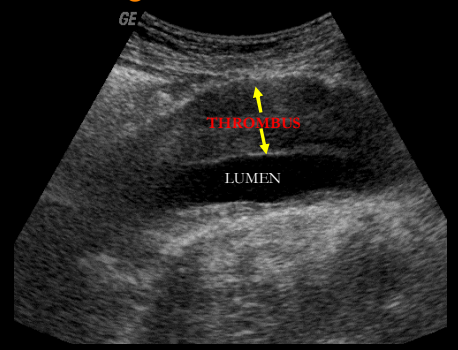
### AAA: Transverse



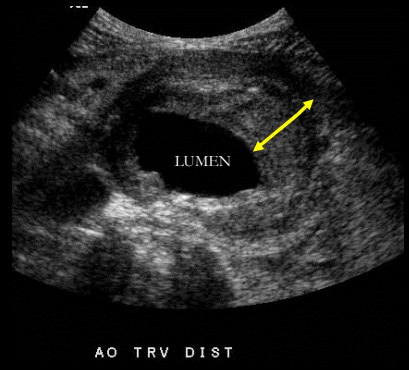
### AAA: Sagittal

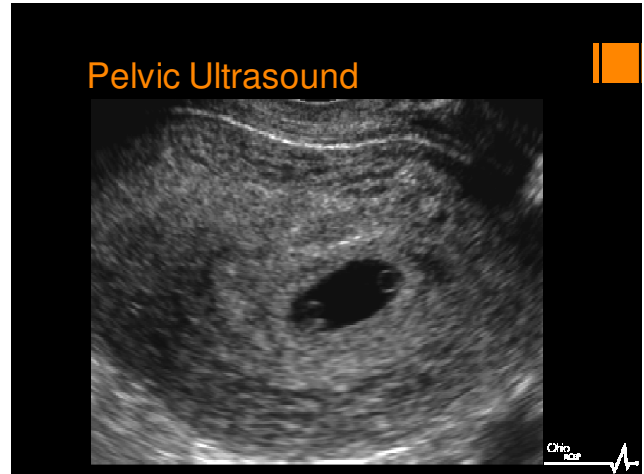
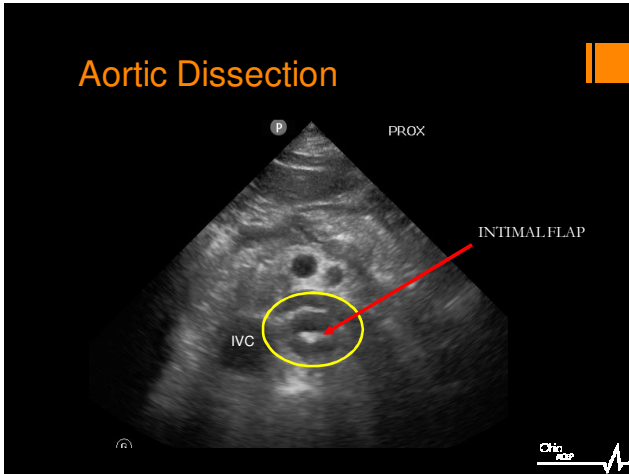


### AAA: Sagittal



### AAA with Thrombus





## First Trimester Ultrasound

- Primary Goal
  - Rule in an IUP
- Additional goals
  - Findings consistent with an ectopic
  - Abnormal early pregnancies
  - Adnexal pathology

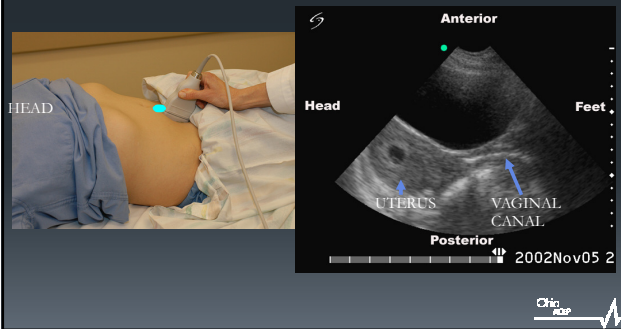
Chin  
ACEP

## First Trimester Ultrasound

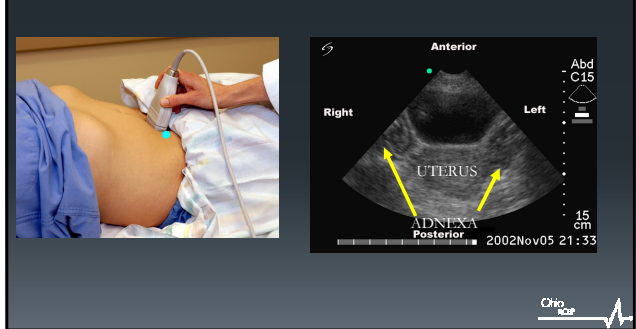
- Routine use of ED OB US
  - Early detection of ectopic pregnancies
    - Up to 1/2 of ectopics missed on initial ED presentation
  - Decreases ED LOS
- Transabdominal and Transvaginal
  - Complementary techniques

Chin  
ACEP

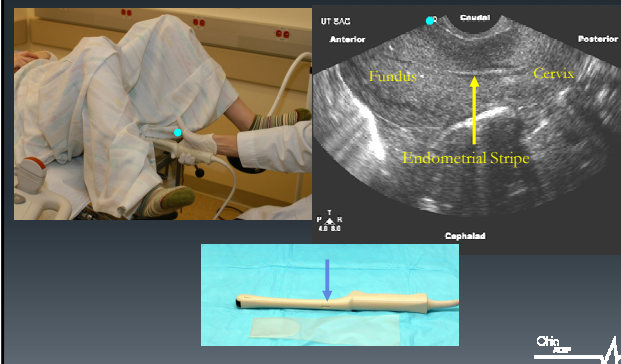
## Transabdominal – Sagittal



## Transabdominal - Transverse



## Transvaginal – Sagittal



## Transvaginal Sagittal

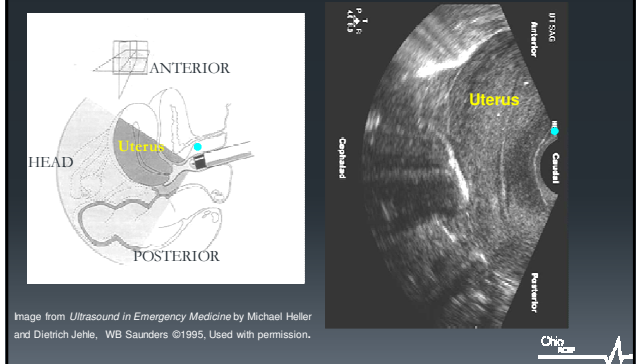
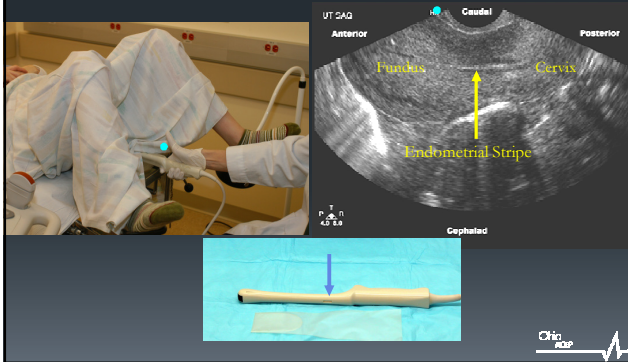
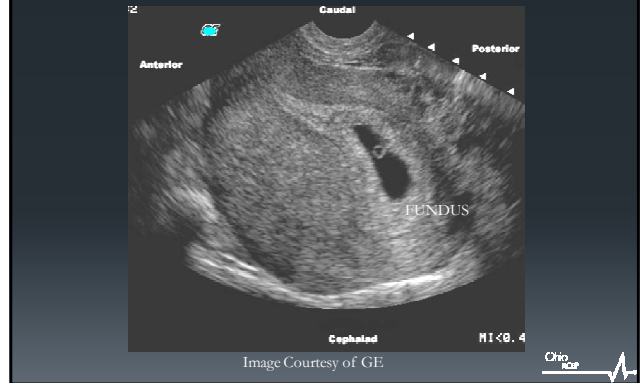


Image from *Ultrasound in Emergency Medicine* by Michael Heller and Dietrich Jethle, WB Saunders ©1995, Used with permission.

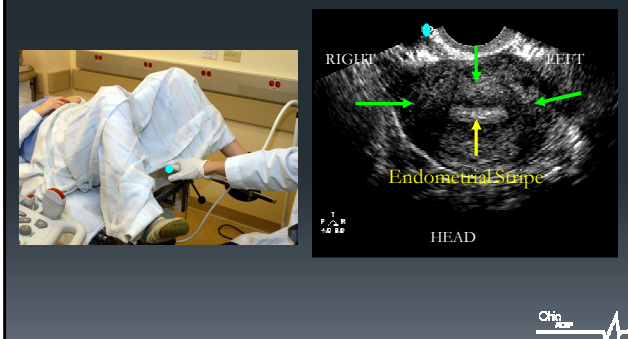
## Transvaginal – Sagittal



## Retroverted Uterus



## Sonographic Anatomy Transvaginal – Coronal



## Ovaries with follicles

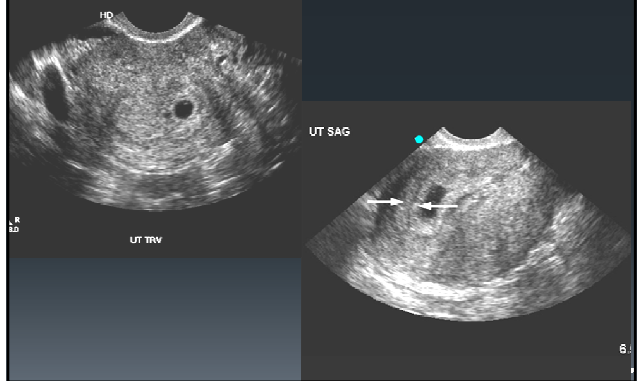


## Findings of Early Pregnancy

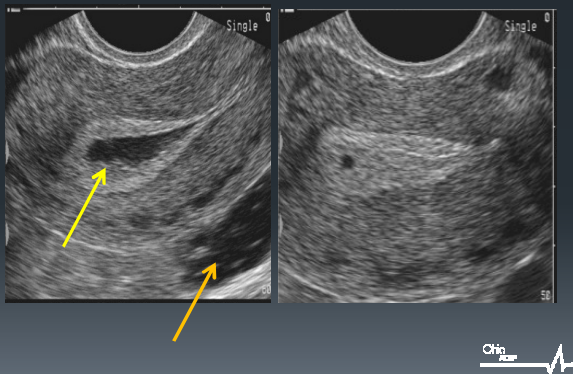
- Gestational sac
  - Beware the pseudogestational sac of an ectopic
- Yolk sac
- Fetal pole



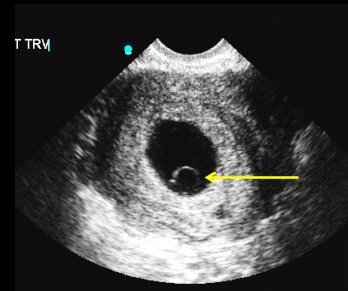
## Gestational Sac



## Pseudogestational Sac vs Early Decidual Sac



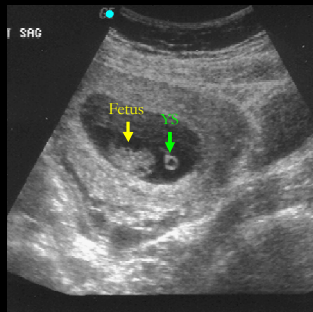
## Yolk Sac



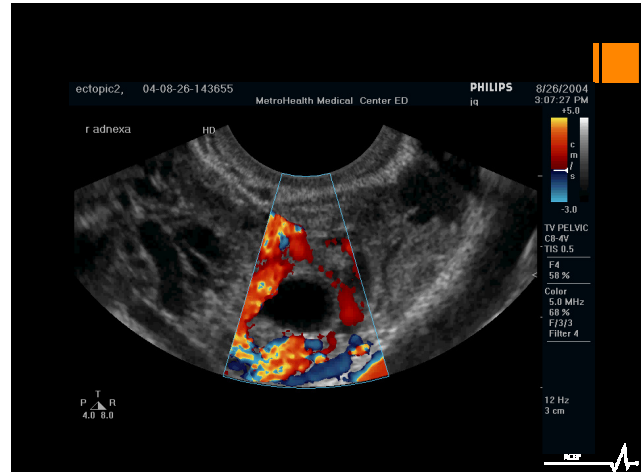
Visualization of a yolk sac within an intrauterine gestational sac confirms an IUP



## Embryo



- Cardiac activity should be seen when fetal pole is > 5-6 mm



## Ectopic Pregnancy

- B-hCG and US
  - Correlates approximately with fetal age
  - Rises abnormally in ectopics
  - Decision to scan NOT based on quantitative B-hCG



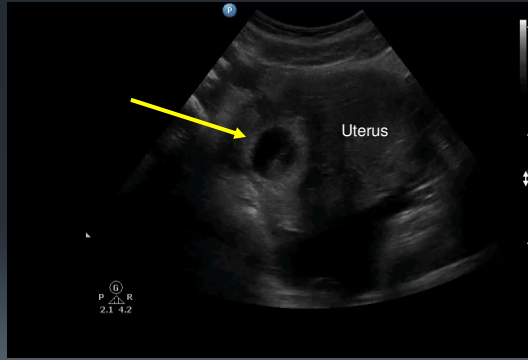
## Ectopic Pregnancy

- Use of ED Ultrasound
  - Live EXTRA-Uterine embryo seen in 15 – 20% of ectopics
  - YS or Fetal Pole within uterine gestational sac = IUP
    - Heterotopic risks 1:4,000, 1:100 with infertility treatment





## Ectopic Pregnancy – US Findings

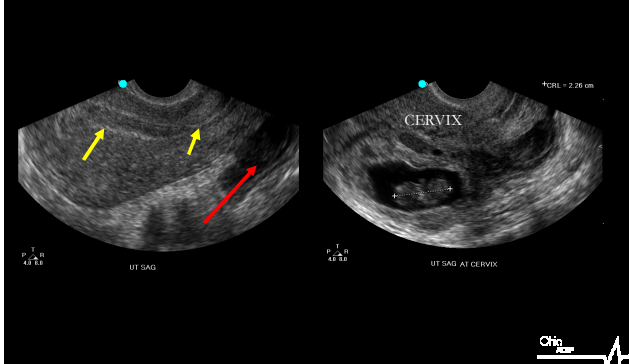


## Non-specific Findings

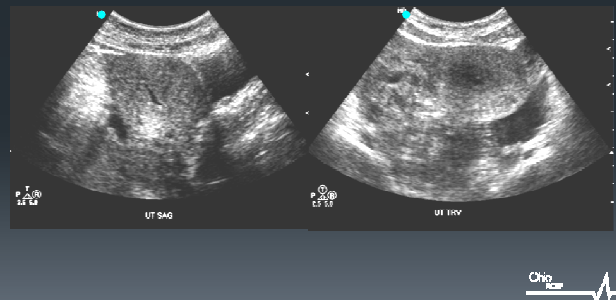
Finding	Likelihood (%)
Any Free Fluid	52
Complex Mass	75
Moderate/Large FF	86
Tubal Ring	95
Mass and FF	97
Hepatorenal FF	100

Chiro  
RCP

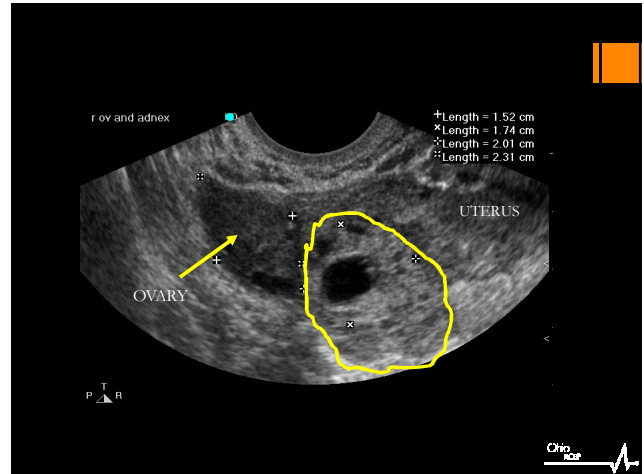
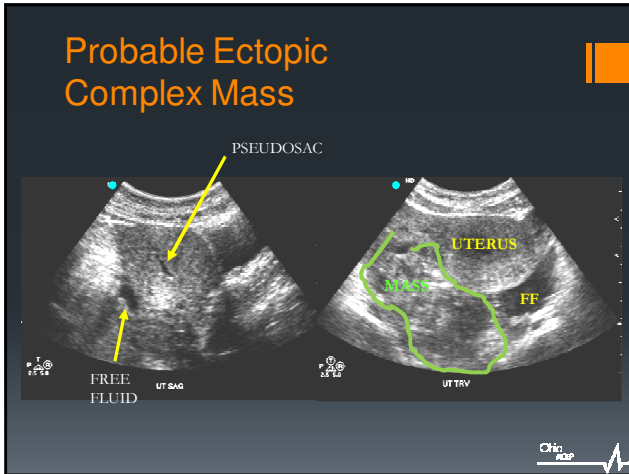
## Definite Ectopic



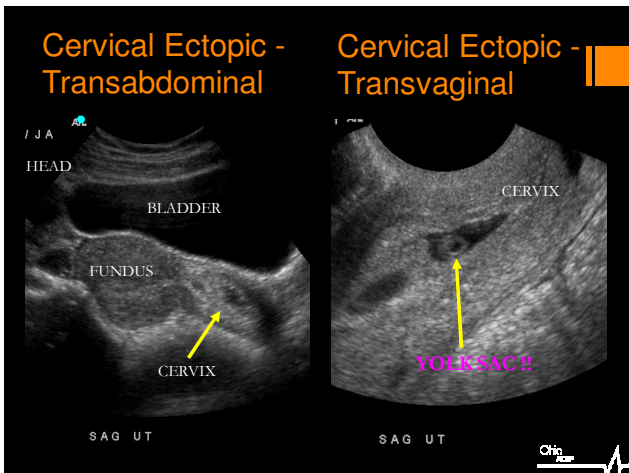
## Probable Ectopic Complex Mass



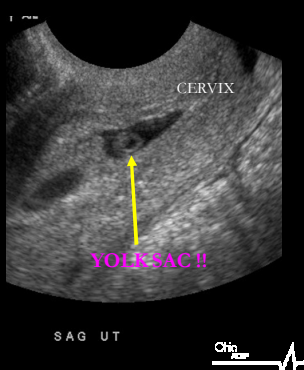
## Probable Ectopic Complex Mass



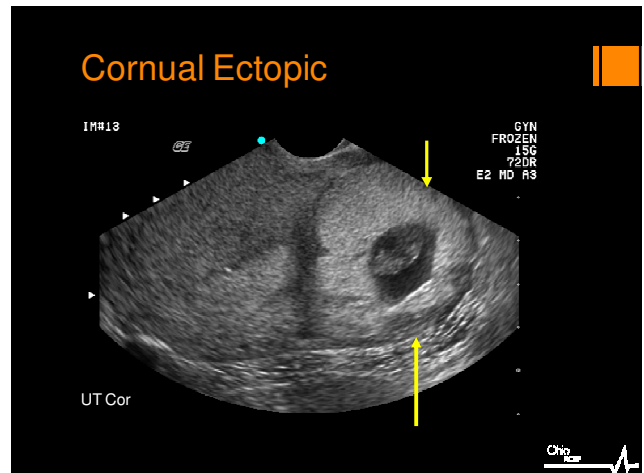
## Cervical Ectopic - Transabdominal



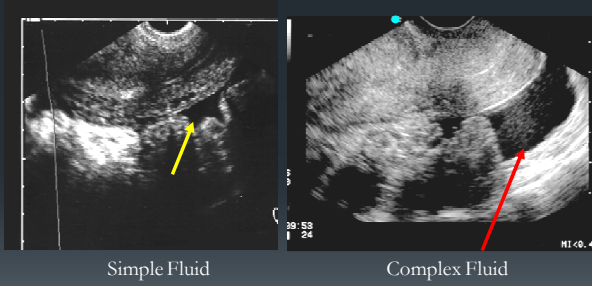
## Cervical Ectopic - Transvaginal



## Cornual Ectopic



## Cul-de-sac Fluid

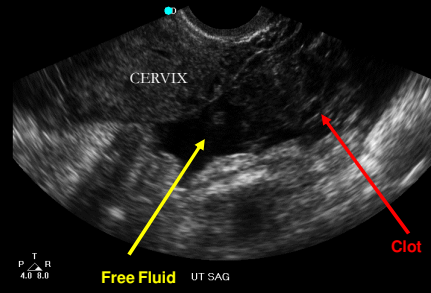


Simple Fluid

Complex Fluid



## Complex Cul-de-sac Fluid



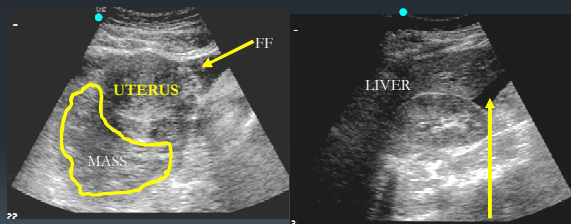
Free Fluid

Clot

UT SAG



## Ectopic Pregnancy: Hemoperitoneum



TRANSABDOMINAL  
TRANSVERSE UTERUS

RUQFAST VIEW

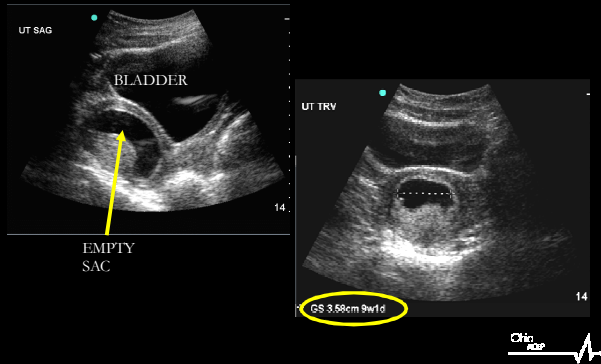


## Indeterminate ultrasound

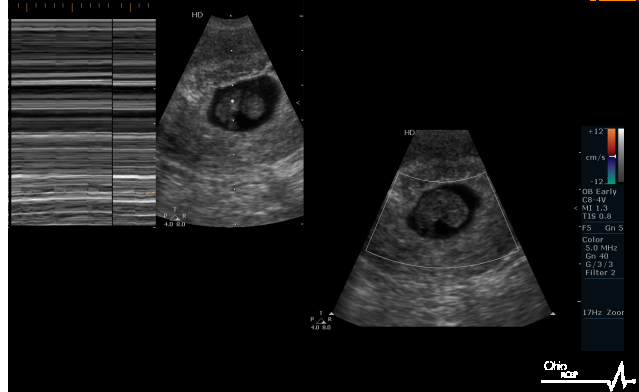
- Pregnancy of Unknown Location
- Positive pregnancy test with
  - no definite IUP
  - no definite failed pregnancy
  - no definite ectopic
- Use in conjunction with B-hCG
  - PUL with B-hCG over ~2000 is likely an ectopic
- Requires repeat B-hCG and close follow up



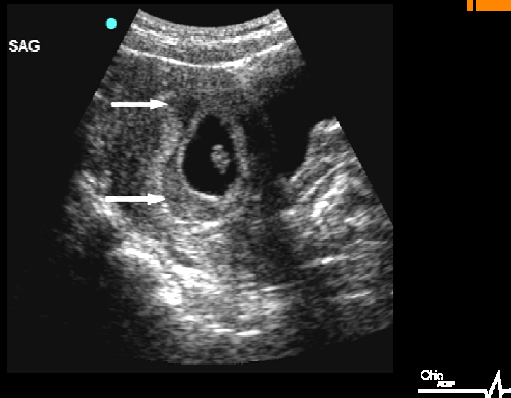
## Fetal Demise/Pregnancy Failure



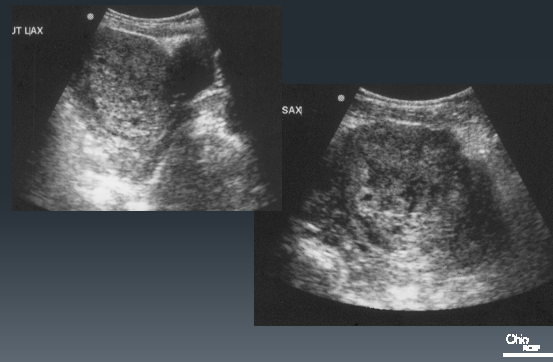
## Fetal Demise/Pregnancy Failure



## Subchorionic Hematoma



## Molar Pregnancy



## Adnexal and Tubal Pathology

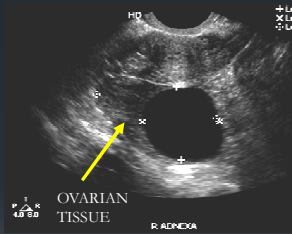
- Ovarian cysts
  - Simple or complex
  - Corpus luteal
- PID/TOA
  - PID – clinical dx
  - TOA - Complex tubal mass
- Torsion
  - Ovaries > 5 cm at risk
  - Diagnostic accuracy by US is poor



## Normal Ovary



## Simple Cyst



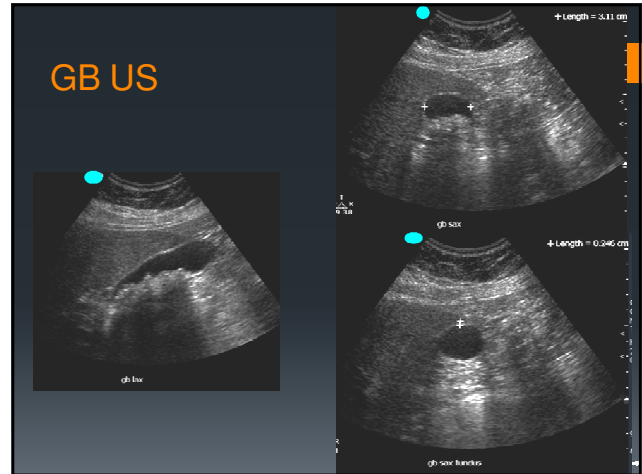
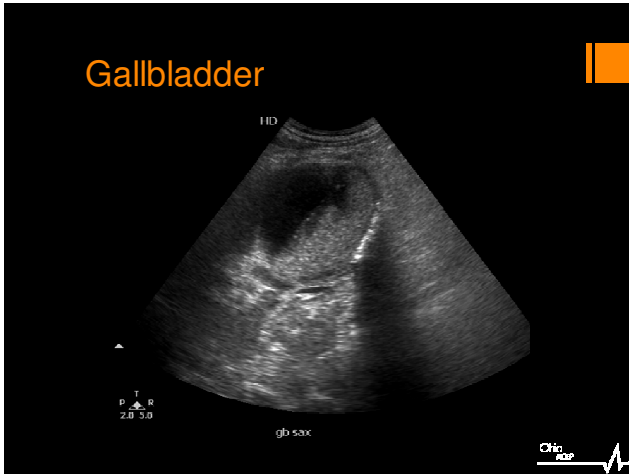
## Complex Cyst



## Pelvic US

- IUP can be ruled in but ectopic cannot be ruled out
- Decision to scan NOT based on quant B-hCG
- Pregnancy of unknown location requires early follow up
- Complex free fluid is hemoperitoneum
- Torsion is not easily diagnosed with ultrasound
  - ovaries greater than 5 cm are at greater risk



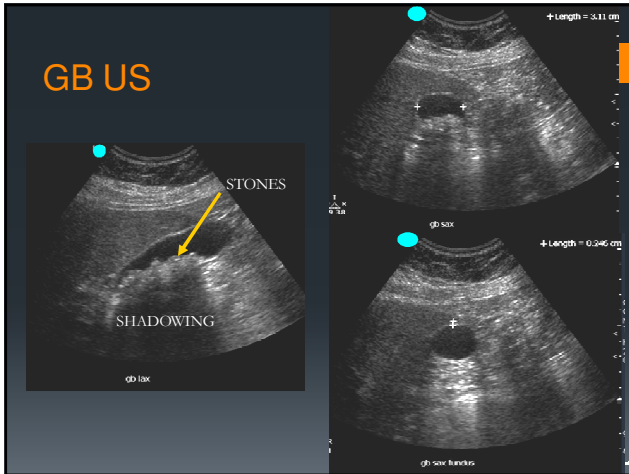


- A. The patient has gastritis
- B. The patient has cholelithiasis but you can't say with any certainty if that is the cause of his symptoms
- C. The most likely diagnosis is early cholecystitis
- D. The gallbladder is normal

Chin

- A. The patient has gastritis
- B. The patient has cholelithiasis but you can't say with any certainty if that is the cause of his symptoms
- **C. The most likely diagnosis is early cholecystitis**
- D. The gallbladder is normal

Chin



## Gallbladder Scanning

- Goals
  - Identify Cholelithiasis
  - Identify findings consistent with cholecystitis
- Indications
  - Right upper quadrant pain
  - Epigastric pain
  - Persistent vomiting

Chiro  
RCP

## Gallbladder Ultrasound

- Comparison to other imaging techniques
  - US initial imaging of choice
  - CT **NOT** sensitive for cholelithiasis
  - HIDA scan most sensitive for GB emptying time and retained stones

Chiro  
RCP

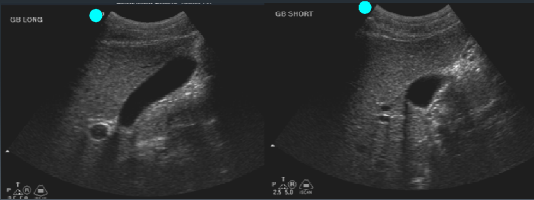
## Sonographic Anatomy

Four images showing sonographic anatomy. Top left: A photograph of a patient's back with an ultrasound probe on the right side, labeled 'HEAD'. Top right: A photograph of a patient's back with an ultrasound probe on the right side, labeled 'SHORT'. Bottom left: A longitudinal ultrasound image of the gallbladder with labels for 'HEAD', 'MAIN LIVER FISSURE', 'GB', 'R. PORTAL VEIN', and 'R. KIDNEY'. Bottom right: A short-axis ultrasound image of the gallbladder labeled 'RIGHT'.

Chiro  
RCP

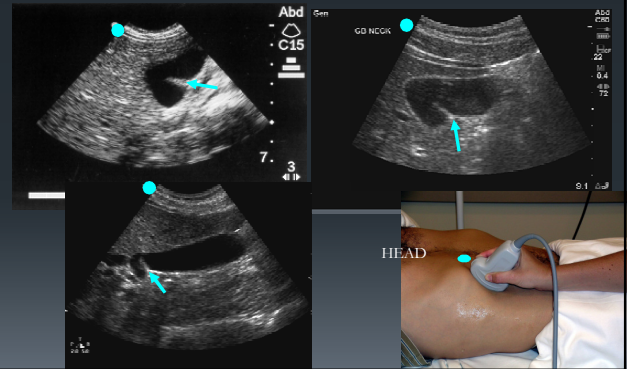
## Sonographic Findings: Normal

- Anechoic
- Wall thickness less than 4 mm
- Less than 10-12 cm longitudinal
- Less than 4 cm transverse diameter

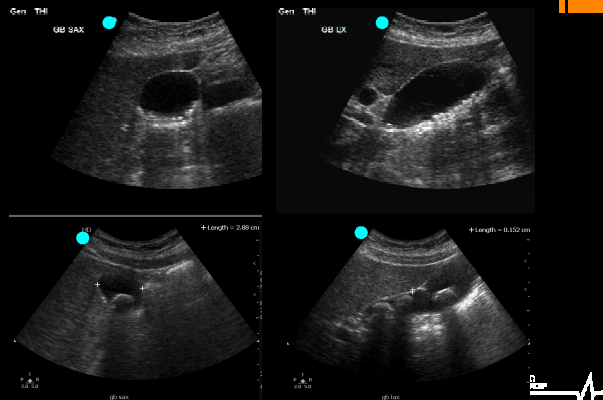


Chin  
ACUP

## Don't forget the Neck!



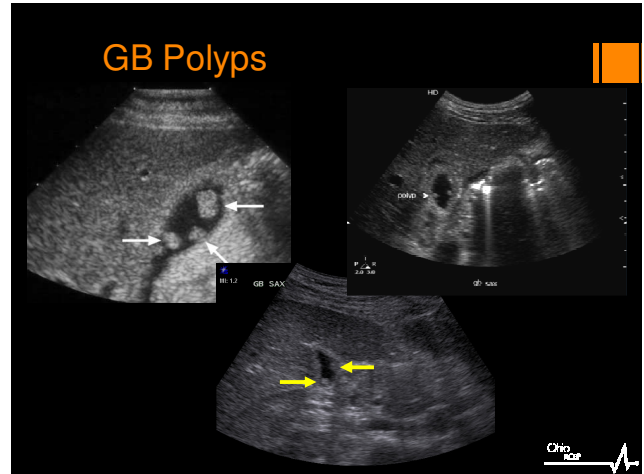
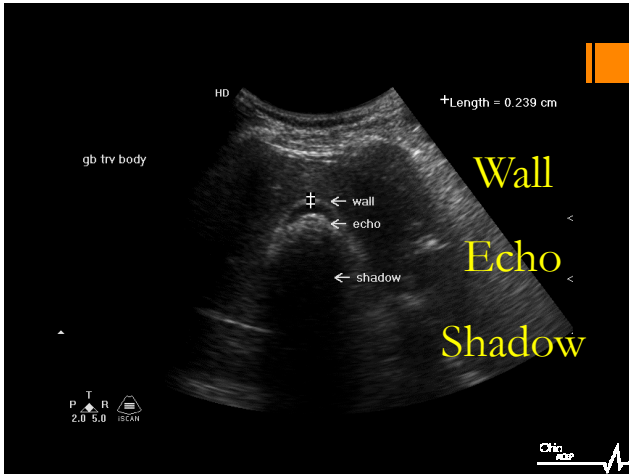
## Cholelithiasis



## Packed Gallbladder



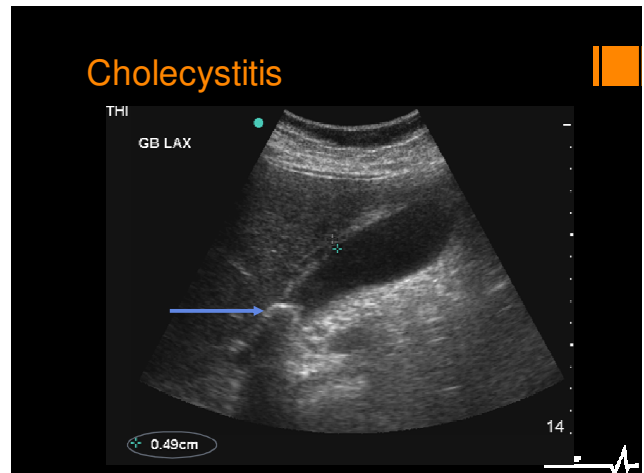


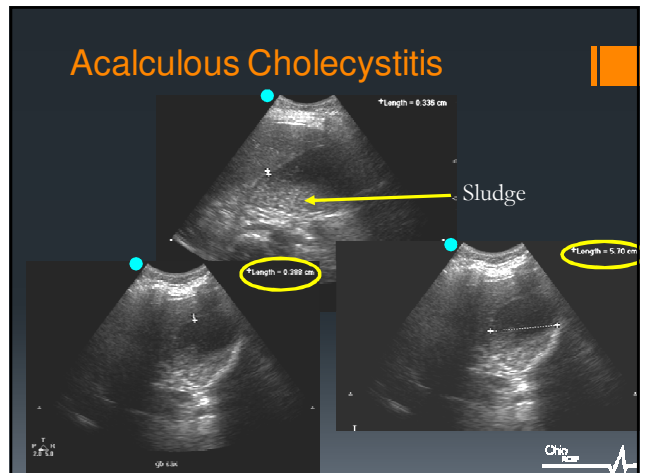
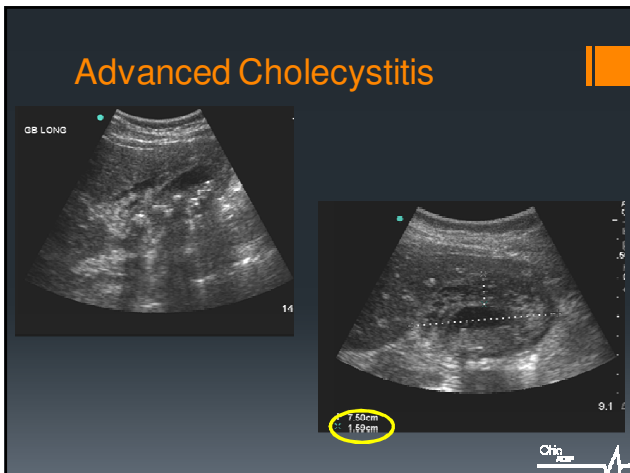
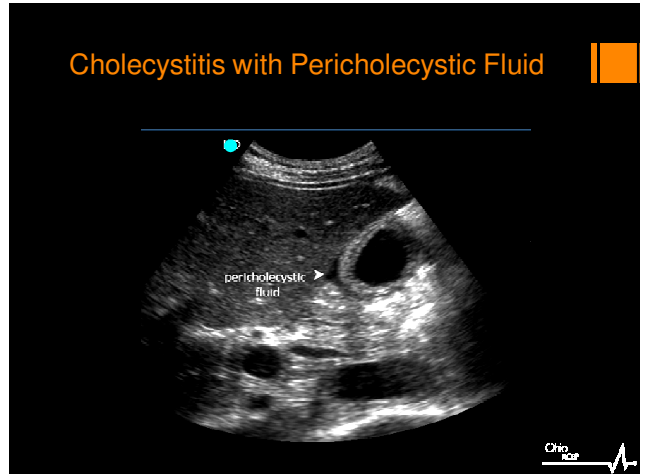
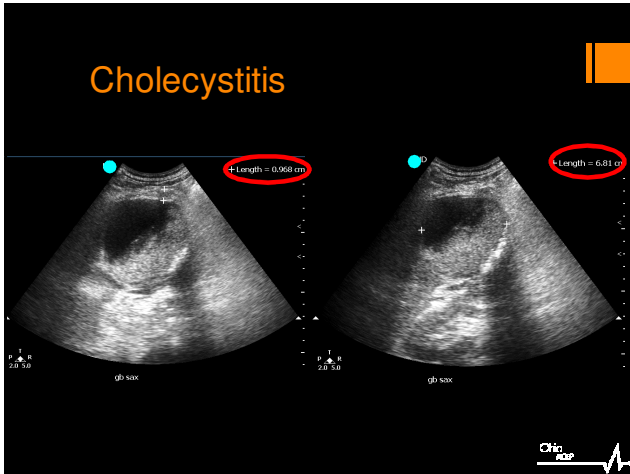


## Cholecystitis

- Cholelithiasis plus
  - Gallbladder wall edema
  - Pericholecystic fluid
  - Gallbladder distension
- Sonographic Murphy's sign
  - Point of maximal tenderness to transducer pressure is directly over the sonographically located gallbladder
- Think acalculous cholecystitis in elderly or chronically ill patients with distended, +/- sludge filled gallbladders

Chin RCP





## GB Ultrasound

- No single US finding predictive of cholecystitis
  - Stones + Sono Murphys has PPV of 92.5%
  - Stones + wall edema has PPV of 95%



## Renal



## Renal

- Goals:
  - Identify obstructive uropathy
  - Estimate bladder volume
- Indications:
  - Flank pain or decreased urine output
  - Bladder exam
    - Bilateral hydro
    - ? high post-void residual
  - Pediatric patients

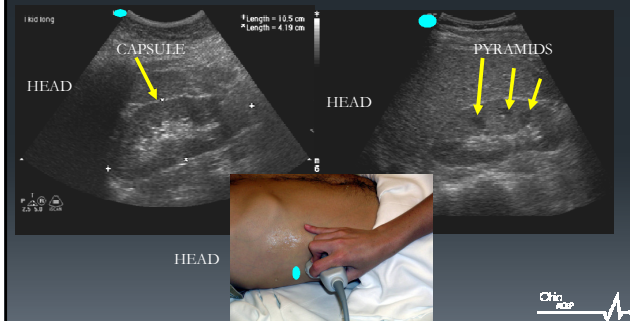


## Imaging Technique Comparison

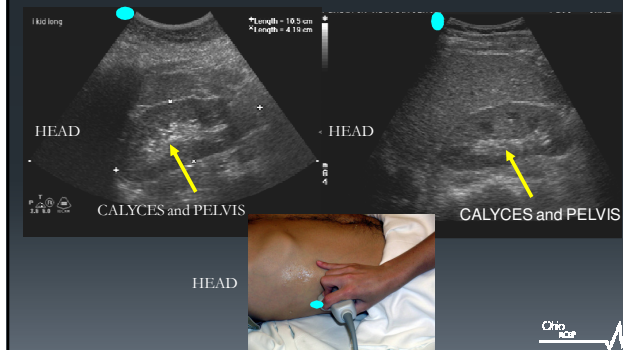
- US
  - Rapid, bedside, no radiation, sensitive for hydronephrosis
  - Usually cannot identify cause of hydro
  - insensitive for non-obstructive hydro
- IVP
  - Sensitive for delayed emptying, may identify stone
  - Contrast and minimal radiation
- CT
  - Noninvasive, relatively rapid, sensitive for cause
  - Radiation exposure, not bedside



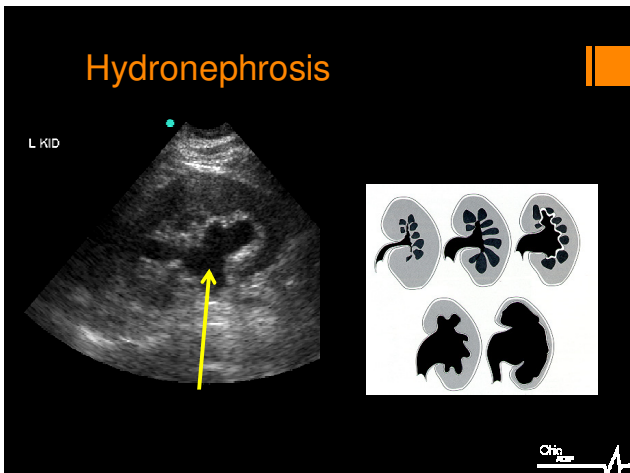
### Normal Sonographic Appearance



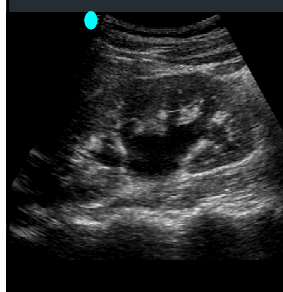
### Normal Sonographic Appearance



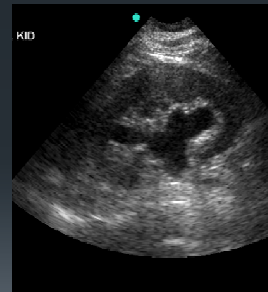
### Hydronephrosis



### Moderate Hydro



### Moderate/Severe Hydro



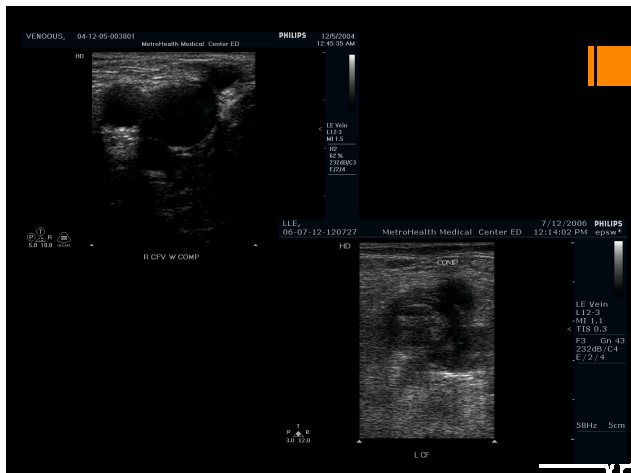
## Renal

- Scan both kidneys for comparison
- Don't confuse renal cysts with hydronephrosis
- Can't always identify cause of obstruction
- Hydro make take several hours to develop
- Renal colic cannot be ruled out based on the absence of hydronephrosis



## Limited DVT Scanning

- Lower extremity DVT study
  - Scanning CFV to Popliteal Fossa
  - DVT doesn't compress
  - Sensitivity and Specificity of up to 95%
  - Follow up recommended to exclude calf
  - Any vein can develop a clot
  - Compress veins prior to cannulation

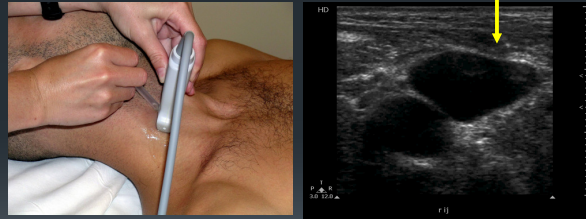


## Procedural Ultrasound

- Central Vascular Access
  - US guided central lines
    - fewer complications
    - higher first pass success rates
- Techniques
  - Static (US assisted)
  - Dynamic (US guided)

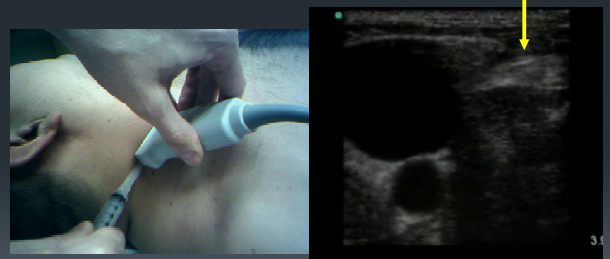


## CVP Placement: Transverse (Middle) Approach



Chin  
Rice

## CVP Placement: Posterior Approach



Chin  
Rice

## Procedural Ultrasound

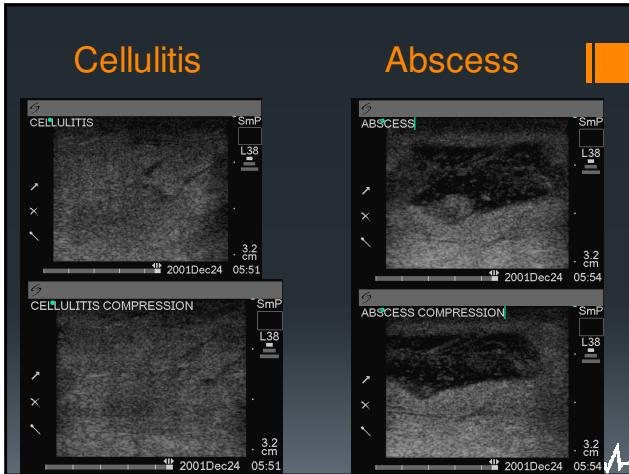
- Peripheral Vascular Access
  - Veins not easily seen/palpated
  - Basilic and cephalic often utilized

Chin  
Rice

## Abscess vs Cellulitis

- Adding US to physical exam
  - Increased PPV from 81% to 93%
  - Increased NPV from 77% to 97%
- Use of US changed management in 17-56% of skin infection cases

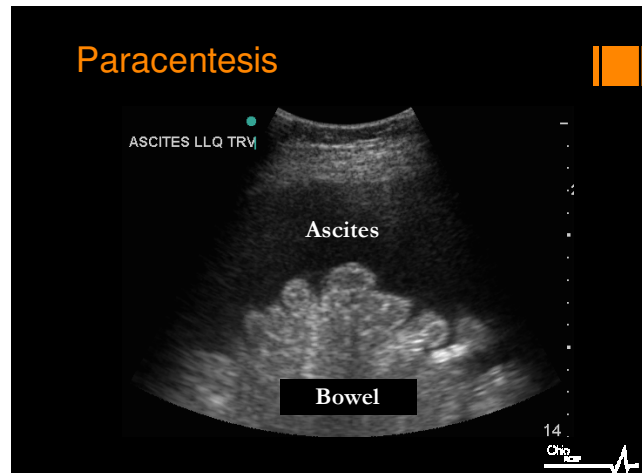
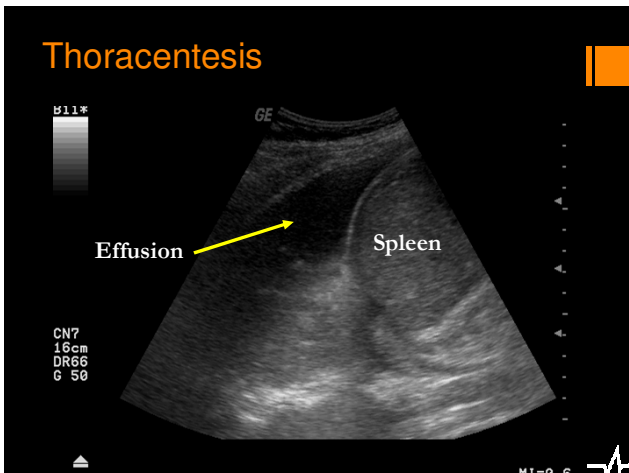
Chin  
Rice



## Procedural Ultrasound

- Identification/Drainage of fluid from body cavities
  - Pericardiocentesis
  - Thoracentesis
  - Paracentesis
  - Suprapubic bladder aspiration

Chiro  
RCP

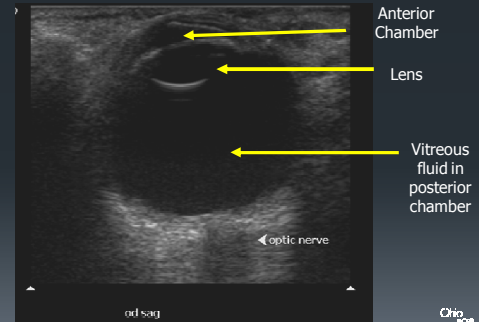


## Procedural Ultrasound

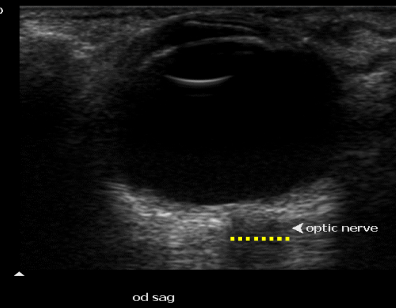
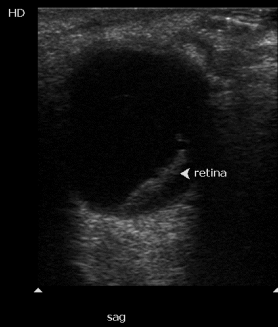
- Ocular Ultrasound
  - Retinal Detachment
  - Vitreous Hemorrhage
  - Optic Nerve Measurement



## Ocular anatomy



## Retinal Detachment



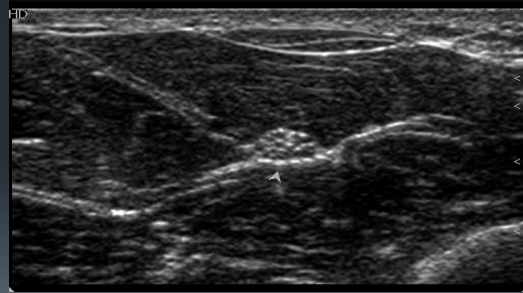


## Procedural Ultrasound

- MSK
  - Nerve blocks
  - Foreign body detection and removal
  - LP landmark marking
  - Fracture identification and reduction



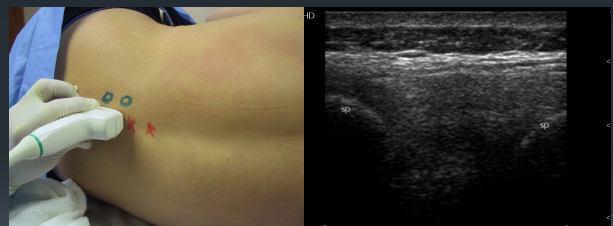
## Median Nerve in Mid Forearm



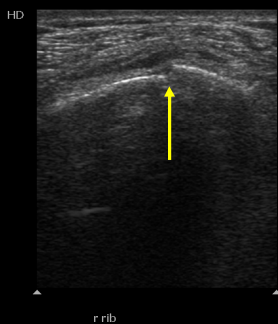
## Foreign Body Localization/Detection



## Lumbar Puncture



## Fracture Identification



## EM Ultrasound Summary

- Bedside US indicated for emergent and urgent conditions as well as procedural applications
  - Performed to answer a specific question
  - Multiple procedural uses
- Bedside US should be used in conjunction with radiology scanning and other imaging techniques as indicated by the findings, and in accordance with the EPs ultrasound training and ability.



## This is?

- The END!

