CT Urography

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Ureter
CT Urography

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Disclosure of financial relationship with relevant commercial interest

Siemens Medical Solutions
Malverne, PA – Consultant

Ureter
Outline

• CT urography technique
• Ureter variants
• Ureter: benign vs malignant
• Dual energy applied to ureter
• Summary
BWH CTU Protocols

**Patients > 40 years old**

- Three phase – UP (abdomen and pelvis), NP (kidneys only), EP (abdomen and pelvis), supplemented with 10 mg furosemide IV

**Patients < 40 years old**

- Split bolus, two phase – abdomen and pelvis, supplemented with 250 cc saline IV
**BWH CT Urography Protocol**

**64 – Channel MDCT with 3 phases**

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Iodinated contrast material (300 mgI/ml); 0.5 s rotation time

AEC w/ quality reference 200 mAs, 120 kVp

Silverman et al Radiology 2006
# BWH CT Urography Protocol

## 64 – Channel MDCT with 3 phases

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- Iodinated contrast material: 370 mg/ml; 0.5 s rotation time
- AEC w/ quality reference 200 mAs, 120 kVp

Silverman et al Radiology 2006
IV Furosemide Withheld

- Furosemide allergy
- Sulfa allergy
- SBP < 90 torr

IV Saline is suitable alternative
**BWH CT Urography Protocol**

**64 – Channel MDCT with 3 phases**

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Iodinated contrast material (370 mgI/ml); 0.5 s rotation time
AEC w/ quality reference 200 mAs, 120 kVp
McTavish et al Radiology 2002
BWH CTU Protocol for pts < 40 y.o.

**Split dose** 370 mg/l/ml

CM (40 cc)  (80 cc)

Unenhanced

Range Abd/Pel

Delay --

Collimation 2.5 mm

Axial Recon/Incr 3/3

Post Processing --

Saline 2.5 mm 3/3

Cor / Sag / MIP / CPR / VR

Obtaining NP and EP during one scan reduces radiation dose

Modified from Chow and Sommer AJR 2001
Chai et al Australas Radiol 2001
Indications: Full CT Urogram

- Hematuria
- Suspected urothelial cancer (e.g., positive urine cytology)
- Follow-up urothelial cancer
- Hydronephrosis etiology
- Others?
Urinary Tract CT Protocols

- Flank pain -> UP ("Stone protocol")
- Renal mass -> UP, NP, Excretory (Kidney)
- Congenital anomalies -> Excretory
- Partial nephrectomy -> AP, VP, Excretory
- Post-operative Complications -> Excretory
- Trauma -> NP, Excretory

UP = unenhanced phase; NP = nephrographic phase; AP = arterial phase; VP = venous phase

None is a CTU protocol!
Ureteral Mass-like findings

- Lumenal – stone, clot, myceloma, sloughed papilla, mucus
- Mucosal – tumor, stricture
- Mural – ureteritis cystica, met, leiomyoma
- Extramural – RPF, LN, mass
More Ureteral Ca Look-Alikes

- Endometriosis
- Leukoplakia
- Cholesteatoma
- Malacoplakia
- Tuberculosis
Is CTU Good in detecting UT TCC?

- UT TCC is uncommon
- UT TCC occur in up to 6.5% of pts w/ known or prior bladder ca.
- Upper tract needs to be evaluated at the time bladder cancer is diagnosed and periodically in surveillance.

Is CTU Good in Detecting UT TCC?

82 (3%) positive CT urograms (n=2602)

PPV: 43/82 = 52%

Sadow et al AJR (in press)
Is CTU Good in Detecting UT TCC?

PPV = 81%  
CTU +  True +

PPV = 0%  
Large Mass (>5 mm)

PPV = 48%  
Small Mass (<=5 mm)

Sadow et al AJR (in press)
Is CTU Good in Detecting UT TCC?

- The PPV (52%) of CTU for detection of upper tract malignancies is moderate, as benign findings mimic cancer.
- Large (> 5 mm) masses are likely to be cancers.
- Small (≤ 5 mm) masses are unlikely to be cancers.
- Urothelial thickening is just as likely to be benign as malignant.

Sadow et al AJR (in press)
Imaging Algorithm for Hematuria

Renal cyst → MDCTU → MRI

Renal mass → MDCTU → MRI

Normal

Urothelial abnormality

Retrograde Pyelogram

Note: Retrograde pyelography may still be needed when CTU is positive...
Single Energy CT

CT-value (HU)

Materials differentiated based on attenuations

One x-ray tube, one acquisition...

Courtesy Christianne Leidecker SMS
Dual Energy CT

**Dual source method...**

- Two x-ray tubes – kVp same or different
  - Tube A = 140 kVp, FOV= 50 cm
  - Tube B = 80 kVp, FOV 26 cm (33 cm)
Dual Energy CT

X-ray beams are polychromatic!

Number of photons x 10^17

- 140 kVp, mean 76 keV
- 80 kVp, mean 56 keV

Mean Energy:
- 56 keV
- 76 keV

Peak Energy:
- 140 kVp
- 80 kVp

Photon Energy (keV)
Basic concepts...

- X-ray attenuation is determined by two independent absorption processes, Compton scatter and photoelectric effect.

Photoelectric effects are greater at lower kVp and soar at the k-edge.
**Basic concepts...**

- Total attenuation decreases with increasing energy.
- Attenuation depends on energy (keV) and material density.
- X-ray absorption depends on the inner electron shells.
- DECT is sensitive to atomic number and density.
Dual Energy CT

Photon Energy (keV)

0.01 0.1 1 10 100 1000

Attenuation (cm²/g)

Iodine
Calcium
Water
Fat

56 keV
76 keV

Large increase
Small increase
**Dual Energy CT**

*Basic concepts...*

- DECT can be used to determine concentration of three known materials
- DECT cannot be used to determine the chemical composition of an unknown material
Dual Energy CT - Stones

HU @ 80 kV

HU @ 140 kV

Iodine

Soft Tissue

Fat

+200

+65

0

-100

-90

0

+60

+100
Stone Composition – Why?

- Uric acid stones managed with urine alkalinization; prevented with allopurinol
- Calcium stones managed with SWL, PCNL, or ureteroscopy; prevented with thiazides
- Calcium monohydrate (high HU and homogeneous), brushite, and cystine (particularly >15 mm) stones are resistant to ESWL

Kim et al Urol Res 2007
Perks et al Urology 2008
CT Attenuations – Why not?

- Overlapping attenuation ranges
- Stones are typically mixed
- HU measurements are variable and dependent on CT technique (including dose, collimation, section thickness)

Kambadakone et al RadioGraphics 2010
Dual Energy CT - Stones

- Attenuation depends on density, atomic number, and the energy of the X-ray beam.
- The higher the atomic number, the higher the attenuation.
- Calcium oxalate (CaC$_2$O$_4$), calcium phosphate (Ca$_3$(PO$_4$)$_2$), and cystine (C$_6$H$_{12}$N$_2$O$_4$S$_2$) contain elements with high atomic numbers (Ca = 20, S = 16, P = 15) or ‘heavy’ chemical elements.
- Uric acid (C$_5$H$_4$N$_4$O$_3$) and struvite (MgNH$_4$PO$_4$·6H$_2$O) are composed of elements with low atomic numbers, or ‘light’ chemical elements (H,C,N,O).

Thomas et al. Eur Rad 2009
Primak et al. Acad Rad 2007
Dual Energy CT - Stones

- As a consequence, uric acid (UA) stones have higher attenuations at higher kVp than at lower kVp, whereas non-UA stones have a higher attenuation at lower kVp than at higher kVp.
- Most non-UA stones contain calcium.
- A three-material decomposition first assumes that all voxels contain a mixture of water (urine), calcium, and UA.
- If the voxel exhibits DE behavior similar to calcium, it is assigned a blue color, UA red, and voxels that show a linear density at both tube potentials remain gray (Graser Invest Rad 2007).

Thomas et al Eur Rad 2009
Primak et al Acad Rad 2007
Dual Energy CT - Stones

- Commercially available software uses a three-material decomposition algorithm (Syngo DE Viewer, SMS).

- Stone is considered a mixture of a hypothetical "pure" stone with no pores (such a stone would have high attenuation) and the material that fills the pores, urine.

- On a plot of attenuations @ 80 kVp vs 140 kVp, a real stone has to lie somewhere, depending on its porosity, between urine and a pure stone.

Primak et al Acad Rad 2007
Dual Energy CT - Stones

Calcium stones have more attenuation at lower kVp, hence DE ratio (HU @80 kVp / HU @ 140 kVp) will be higher.

Hence the slope can be correlated w/ stone composition.

All stones of a particular type will be represented along this line, depending on the porosity...

"Urine"

"Pure" stone

Primak et al Acad Rad 2007
Dual Energy CT - Stones

Stones below angle bisector are characterized as UA stones, above as non-UA or calcium stones.

"Pure" calcium stone

"Pure" uric acid stone

Single average slope represents different calcium-containing stones

"Urine"

Primak et al Acad Rad 2007
Dual Energy CT - Stones
Summary

- MDCT urography supplemented with IV furosemide can be used to evaluate the ureter.
- Thin (3 mm) sections and multiplanar reformations, particularly CPR, are helpful when evaluating the ureter.
- Beware of benign entities that mimic cancer.
- DECT can be used to differentiate urate stones from non-urate stones.