CT Urography

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CT Urography

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Disclosure of financial relationship with relevant commercial interest

Siemens Medical Solutions
Malverne, PA – Consultant
Outline

- How to do a CT urogram
- When it should be performed
- Why CT urography is the test of choice (with case examples)
- Summary
**BWH CT Urography Protocol**

**64 – Channel**

<table>
<thead>
<tr>
<th></th>
<th>Unenhanced</th>
<th>Nephrographic</th>
<th>Excretory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>Abd/Pel</td>
<td>Kidneys</td>
<td>Abd/Pel</td>
</tr>
<tr>
<td><strong>Delay</strong></td>
<td>--</td>
<td>100 s</td>
<td>10 - 15 min</td>
</tr>
<tr>
<td><strong>Collimation</strong></td>
<td>1.2 mm</td>
<td>1.2 mm</td>
<td>0.6 mm</td>
</tr>
<tr>
<td><strong>Axial Recon/Incr</strong></td>
<td>3/3</td>
<td>3/1.5</td>
<td>3/3</td>
</tr>
<tr>
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<td>Cor / Sag / MIP / CPR / VR</td>
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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
Problem Imaging the Urothelium

It is difficult to obtain a single image of all urinary collecting system segments in an opacified and distended state.

...The ureters peristalse!
Use Furosemide...

Furosemide diuresis is predominantly due to inhibition of NaCl reabsorption in the thick ascending limb of Henle.

Increases urinary flow rate
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 (300 mgI/ml); 0.5 s rotation time
- AEC w/ quality reference 200 mAs, 120 kVp

McTavish et al Radiology 2002
Safety Record at BWH

- Both IV furosemide and IV saline are safe
- No adverse events with over 8 years of use of IV saline (> 3000 administrations), and over 5 years of IV Furosemide (> 2000 administrations)
Evaluating the Urothelium

It’s not just about depicting the anatomy. Opacification and distension helps detect small cancers!
Evaluating the Urothelium

“Why be concerned about opacifying and distending the ureters? If a tumor is present, it will cause obstruction, won’t it?”
71 yom w/ Gross Hematuria

Papillary tumor (in cross-section) in ureteral lumen

Don’t assume unobstructed collecting systems are normal!

Note space for urine to flow around the tumor
Evaluating the Urothelium

What about the bladder? Bladder cancer is the most common malignancy of the urinary tract, by far.
Bladder issues...

- **Distension** is needed to assess for masses and wall thickening.
- **Opacification** of urine maximizes CNR and helps detect masses.
- **Mixing** of contrast media and urine provides homogeneous background from which masses can be detected.

Furosemide and saline help with all three...
Patient Preparation

- None needed prior to arriving (no bowel preparation)
- Drink 900 cc water instead of oral contrast
- VOID prior to exam!
BWH CTU Protocol for pts < 40 y.o.

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

**Unenhanced**

- Range: Abd/Pel
- Delay: --
- Collimation: 2.5 mm
- Axial Recon/Incr: 3/3
- Post Processing: --

**CM (40cc)**

- Delay: 6 min
- Collimation: 2.5 mm
- Axial Recon/Incr: 3/3
- Post Processing: Cor / Sag / MIP / CPR / VR

**NP + EP**

- Delay: 100 sec
- Collimation: 2.5 mm
- Axial Recon/Incr: 3/3
- Post Processing: Cor / Sag / MIP / CPR / VR

Obtaining NP and PP during one scan reduces radiation dose

Modified from Chow and Sommer AJR 2001
BWH CTU Protocol for pts < 40 y.o.

**Split dose** 370 mg/ml

<table>
<thead>
<tr>
<th>Unenhanced</th>
<th>CM (40cc)</th>
<th>(80 cc)</th>
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<td>Abd/Pel</td>
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</tr>
<tr>
<td>Delay</td>
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<td>6 min</td>
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**Furosemide**

Cor / Sag / MIP / CPR / VR

Obtaining NP and PP during one scan reduces radiation dose

Modified from Chow and Sommer AJR 2001
Why not split-dose contrast?

- Fractionates contrast effects: less contrast available to opacify collecting system
- Ureters and bladder not imaged optimally (needs supplementation)
- Beam hardening in kidneys (if no furosemide)
- Modest dose savings
Radiation Dose

- Three-phase acquisition CTU compared to IVU with full nephrotomography
- Measured (TLD) skin and calculated eff. dose (mGy)
- Mean eff. dose for CTU (14.8 mGy) is 1.5 x that for IVU (9.7 mGy)

Nawfel et al, Radiology 2004
Radiation Dose

- BWH specific data
- Results not generalizable; techniques for IVU and CTU differ across institutions
- Need institution-specific data or standardized protocols
- Data obtained without current modulation
Automatic Exposure Control (AEC)

- **Variable mA both In-plane AND Z-axis**
- **Can decrease mean mAs**

165 mAs reduced to 35 mAs
AEC reduces radiation dose in small patients, however, dose may actually increase in large patients to compensate for the increase in image noise. When AEC is used, variation in dose depends on “initial reference mAs” (or the noise factor setting) and patient thickness.

Nawfel et al, AAPM 2006
**CT Urography Definition**

- A CT urogram is a CT examination of the entire urinary tract before and after the administration of IV contrast material and includes excretory phase images.

- It is NOT any CT scan performed for a urinary tract complaint!

Silverman, Leyendecker, Amis. Radiology 2009
Van Der Molen et al (ESUR) European Radiology 2007
Urinary Tract CT Protocols

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

UP = unenhanced phase; NP = nephrographic phase
AP = arterial phase; VP = venous phase
**Urographic Tests of Choice: Historical Perspective**

<table>
<thead>
<tr>
<th>Condition</th>
<th>&lt;'85</th>
<th>'85-'95</th>
<th>&gt;'95-2000</th>
<th>&gt; 2000</th>
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</thead>
<tbody>
<tr>
<td>Hematuria</td>
<td>IVU</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
</tr>
<tr>
<td>Renal Donor</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
<td>CT</td>
</tr>
<tr>
<td>Colic (stones)</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
<td>CT</td>
</tr>
<tr>
<td>Obstruction</td>
<td>IVU</td>
<td>IVU</td>
<td>US</td>
<td>CT</td>
</tr>
<tr>
<td>Trauma</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
<td>CT</td>
</tr>
<tr>
<td>Renal masses</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
<td>CT</td>
</tr>
<tr>
<td>Fever / Infection</td>
<td>IVU</td>
<td>IVU</td>
<td>CT</td>
<td>CT</td>
</tr>
</tbody>
</table>

- **CT is the test of choice for most urinary tract complaints.**
- **There is no longer a condition or problem for which IVU is needed.**
Indications: CT Urography

- Hematuria
- Suspected urothelial cancer (e.g., positive urine cytology)
- Follow-up urothelial cancer
- Hydronephrosis etiology
- Others (e.g., ablation)
Risk Factors for Urologic Disease

- Age > 40 years
- Smoking
- Gross hematuria
- Irritative voiding symptoms
- Urinary tract infections
- Exposure to carcinogens: pelvic irradiation, analgesic abuse, cyclophosphamide, chemicals/dyes (benzenes, aromatic amines)
AUA 2001: High Risk Patients

One positive urine sediment ≥ 3RBC/hpf

Upper tract imaging, cytology, cystoscopy

If negative, repeat W/U every yr x 3 yrs

AUA 2001: Low Risk Patients

2 of 3 positive urine sediments > 3RBC/hpf

Upper tract imaging, cytology, cystoscopy

If negative, further W/U optional

AUA 2001: High Risk Patients

- Upper tract imaging, cytology, cystoscopy

AUA 2001: Low Risk Patients

- Upper tract imaging, cytology, cystoscopy

Imaging for Hematuria: AUA ‘01

Upper tract imaging recommendation:

IVU or CTU

## Imaging for Hematuria: ACR ‘05

<table>
<thead>
<tr>
<th>Exam</th>
<th>Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Urography</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>IVU</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>US (renal/bladder)</td>
<td>6</td>
<td>May miss urothelial lesions</td>
</tr>
<tr>
<td>Retro Pyelography</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>MR Urography</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>CT (A/P)</td>
<td>4</td>
<td>May follow IVU or US</td>
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<tr>
<td>Angiography</td>
<td>4</td>
<td>To detect AVM</td>
</tr>
<tr>
<td>KUB</td>
<td>2</td>
<td>May be coupled with US</td>
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<tr>
<td>MRI (A/P)</td>
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<td></td>
</tr>
<tr>
<td>Scintigraphy</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Virtual cystoscopy</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Choyke et al, ACR 2005
Imaging Algorithm for Hematuria

This simple, effective imaging algorithm is rapidly becoming accepted in clinical practice.
CTU in pts < 40 w/ Hematuria

- Significant findings found uncommonly [44 (22%) of 204]
- Of 44 significant causes found, 33 (75%) were due to urolithiasis
- All but 3 significant findings were seen on unenhanced CT alone
- All 3 cases had predisposing conditions!
- 4 false positive CT urograms would not have been found on unenhanced CT

Sadow et al RSNA 2007
Findings not seen w/ unenhanced CT

- Only 3 CT urograms needed to detect:
  - **Papillary necrosis** (pt w/ known neurogenic bladder)
  - **Renal lymphoma** (pt w/ known lymphoma who had extensive disease in the thorax)
  - **Ureteral disruption**: S/P hysterectomy, fluid seen, but excretory phase needed to confirm urinary source

All had predisposing conditions

Sadow et al  RSNA 2007
CTU in pts < 40 w/ Hematuria

Unless there is a predisposing condition, it may be appropriate to perform only unenhanced CT in pts < 40 with hematuria

But more data are needed…

Sadow et al  RSNA 2007
Tailor Use and Protocols further?

Patients with risk factors for malignancy

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

Patients with no risk factors for malignancy

- Split bolus, two phase – abdomen and pelvis, supplemented with 250 cc saline IV
- Unenhanced CT alone if ≤ 40 years of age?
### CTU vs RP for Upper Tract TCC

#### CT Urography

<table>
<thead>
<tr>
<th></th>
<th>Tumor positive</th>
<th>Tumor negative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n = 151</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTU positive</td>
<td>31</td>
<td>8</td>
</tr>
<tr>
<td>CTU negative</td>
<td>1</td>
<td>111</td>
</tr>
</tbody>
</table>

- **Sensitivity** = 0.97, **PPV** = 0.79
- **Specificity** = 0.93, **NPV** = 0.99

#### Retrograde Pyelography

<table>
<thead>
<tr>
<th></th>
<th>Tumor positive</th>
<th>Tumor negative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n = 143</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP positive</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>RP negative</td>
<td>1</td>
<td>112</td>
</tr>
</tbody>
</table>

- **Sensitivity** = 0.96, **PPV** = 0.87
- **Specificity** = 0.97, **NPV** = 0.97

**NPV (0.97) > PPV (0.79)**

Cowan et al 2007 BJUInt ePUB
Is CTU Good in Detecting UT TCC?

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

True Positive: 43
False Positive: 39

PPV: 43/82 = 52%

Wheeler S et al, SUR 2008
Is CTU Good in Detecting UT TCC?

- Large Mass (>5 mm): CTU + = 36, True + = 29, PPV = 81%
- Small Mass (≤5 mm): CTU + = 17, True + = 0, PPV = 0%
- Urothelial Thickening: CTU + = 29, True + = 14, PPV = 48%

Wheeler S et al, SUR 2008
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.

Wheeler S et al, SUR 2008
Imaging Algorithm for Hematuria

- Renal cyst
- Renal mass
- Normal
- Urothelial abn

MDCTU

MRI

Retro Pyelogram

Note. - Retrograde pyelography may still be needed when CTU is positive.
Bladder Ca Detection (n=838)

Negative Predictive Value of CTU

- Microscopic Hematuria: 0.984, n=249
- Gross Hematuria: 0.971, n=373
- Urothelial CA: 0.769, n=158

Sadow et al Radiology 2008
AUA 2001: Low Risk Patients

2 of 3 positive urine sediments > 3RBC/hpf

CT urography, cytology, cystoscopy

If negative, further W/U optional

Possibly in the future...

CT Urography: How?

- CT with MDCT alone
- Three phases if $\geq 40$ yo
- Two phases if $< 40$ yo
- IV furosemide (or saline)
CT Urography: When?

- Hematuria
- Suspected TCC
- TCC follow-up
- Hydronephrosis ?etiology
- Others (e.g., ablation)
CT Urography: Why?

- CT is the imaging test of choice for most urologic conditions
- CTU is comprehensive
- Radiation dose may be comparable to IVU
CT Urography: Future

- CTU will play a greater role in bladder cancer detection
- CTU doses will be reduced via dose modulation, and possibly dual energy CT (virtual unenhanced scan)
Thank You