Imaging of Urinary System – An Overview

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CONSULTANT RADIOLOGIST, HQE
Components of Urinary System
There are several functions of the Urinary System:

- Removal of waste product from the body (mainly urea and uric acid)
- Regulation of electrolyte balance (e.g. sodium, potassium and calcium)
- Regulation of acid-base homeostasis
- Controlling blood volume and maintaining blood pressure
Imaging Modalities for Urinary Tract

- Plain radiography – KUB
- Intravenous Urography
- Fluoroscopic Examinations
  - Cystography: Micturating cystography
  - Urethrography
- Ultrasound
- CT
- MRI
- Radionuclide Studies
KUB Radiograph

- Provide general information about kidney shape and size.
- Not sensitive enough in picking up tumour of kidney or urothelial tract
- Low sensitivity and specificity in detecting stones
Is the KUB radiograph redundant for investigating acute ureteric colic in the non-contrast enhanced computed tomography era?

S.J. Kennish\textsuperscript{a}, P. Bhatnagar\textsuperscript{a}, T.M. Wah\textsuperscript{a,}\textsuperscript{*}, S. Bush\textsuperscript{b}, H.C. Irving\textsuperscript{a}

\textsuperscript{a}Departments of Radiology, and \textsuperscript{b}Emergency Medicine, St James’ University Hospital, Leeds, UK

CONCLUSION: NCCT should be the initial imaging examination for acute ureteric colic. Up to 50\% of patients with clinical suspicion do not have stone disease, and therefore, preliminary KUB radiographs with attendant radiation and cost implications are unjustified. Preliminary KUB radiographs can be omitted from the imaging pathway with no resultant indication creep or increase in demand for NCCT examinations.
Is KUB radiograph still relevant?

<table>
<thead>
<tr>
<th>Clinical Condition:</th>
<th>Acute Onset Flank Pain — Suspicion of Stone Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variant 1:</td>
<td>Suspicion of stone disease.</td>
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<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT abdomen and pelvis without contrast</td>
<td>8</td>
<td>Reduced-dose techniques preferred.</td>
<td>⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>CT abdomen and pelvis without and with contrast</td>
<td>6</td>
<td>If CT without contrast does not explain pain or if without has abnormality that should be further assessed with contrast (ex. stone versus phleboliths).</td>
<td>⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>US kidneys and bladder retroperitoneal with Doppler and KUB</td>
<td>6</td>
<td>Preferred examination in pregnancy, in patients who are allergic to iodinated contrast, and if NCCT is not available.</td>
<td>⭐⭐</td>
</tr>
<tr>
<td>X-ray intravenous urography</td>
<td>4</td>
<td></td>
<td>⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>MRI abdomen and pelvis without contrast (MR urography)</td>
<td>4</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>MRI abdomen and pelvis without and with contrast (MR urography)</td>
<td>4</td>
<td>See statement regarding contrast in text under “Anticipated Exceptions.”</td>
<td>O</td>
</tr>
<tr>
<td>CT abdomen and pelvis with contrast</td>
<td>2</td>
<td></td>
<td>⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>X-ray abdomen and pelvis (KUB)</td>
<td>1</td>
<td>Most useful in patients with known stone disease.</td>
<td>⭐⭐</td>
</tr>
</tbody>
</table>

**Rating Scale:** 1, 2, 3 Usually not appropriate; 4, 5, 6 May be appropriate; 7, 8, 9 Usually appropriate

*Relative Radiation Level*
Is KUB radiograph still relevant?

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<tr>
<td>X-ray abdomen and pelvis (KUB)</td>
<td>6</td>
<td>Good for baseline and post-treatment follow-up.</td>
<td></td>
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*Relative Radiation Level*
ACR Guideline

The indications for an EU examination include, but are not limited to, the following:

1. Evaluation of patients with suspected or known ureteral obstruction

2. Assessment of the integrity of the urinary tract following trauma or therapeutic interventions, especially when cross-sectional imaging is inappropriate or unavailable. One example of such an indication is an examination performed in the operating room when a trauma patient is too unstable to undergo cross-sectional imaging prior to surgery.

3. Assessment of the urinary tract for suspected congenital anomaly, when thought to be more appropriate than cross-sectional imaging.
ACR Guideline

The indications for an EU examination include, but are not limited to, the following:

4. Assessment of the upper urinary tract (renal collecting systems and ureters) for urothelial lesions that may explain hematuria and for identification of urinary tract abnormalities that may predispose to infection, especially when cross-sectional examinations using US, CT, or MRI are either unavailable or felt to be inappropriate for the clinical circumstance

5. Follow-up of patients with recurrent renal/ureteral calculi, with a limited number of images obtained pre and postcontrast administration. Such limited studies may reduce the patient’s radiation burden compared with repetitive CT studies.
Intravenous (Excretory) Urography

- Preliminary
- Immediate
- Compression (5 minutes)
- Release
- Post-micturation
## Intravenous (Excretory) Urography

<table>
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<tr>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Preliminary imaging: KUB radiograph, scout tomogram (to ascertain technique and level). Optional: oblique images, additional tomograms</td>
</tr>
<tr>
<td>2</td>
<td>Contrast material administration</td>
</tr>
<tr>
<td>3</td>
<td>Nephrographic images (obtained 1–3 min after contrast material administration): nephrotomograms or images collimated to the kidneys. Optional: oblique nephrographic images, oblique nephrotomograms, KUB radiograph</td>
</tr>
<tr>
<td>4</td>
<td>KUB radiograph (obtained 5 min after contrast material administration)</td>
</tr>
<tr>
<td>5</td>
<td>Abdominal compression (applied immediately after review of 5-min radiograph)</td>
</tr>
<tr>
<td>6</td>
<td>Pyelographic image collimated to the kidneys (5 min after compression, 10 min after contrast material administration). Optional: oblique images, repeat tomograms, early bladder filling images</td>
</tr>
<tr>
<td>7</td>
<td>Ureter-bladder images (obtained 15 min after contrast material administration and immediately after release of compression): KUB radiograph, fluoroscopic spot images of ureters. Optional: oblique KUB radiographs, prone images, upright images, delayed KUB radiograph</td>
</tr>
<tr>
<td>8</td>
<td>Bladder image (bladder may be adequately seen on ureter images). Optional: delayed, oblique, prone, or postvoid images</td>
</tr>
</tbody>
</table>
Intravenous (Excretory) Urography

- Protocol used in HKL
- PROTOCOL FOR INTRAVENOUS UROGRAM[1][1].doc
Is bowel preparation necessary?

MEDLINE
A trial to assess the effectiveness of bowel preparation prior to intravenous urography.

Bailey SR, Tyrrell PN, Hale M. - Clin Radiol - November 1, 1991; 44 (5); 335-7

Abstract
A randomized prospective trial was undertaken to compare the relative effectiveness of two commonly used bowel preparations (senna tablets and sodium picosulphate powder) administered to patients before they underwent out-patient intravenous urography. Their 'control' films were compared with plain 'kidneys, ureters, and bladder' (KUB) radiographs of patients who had had no bowel preparation. The results show no significant difference in the degree of faecal shadowing between those receiving a bowel preparation and the unprepared patients. Nor is there any difference between the two laxatives. We conclude that the routine administration of a bowel preparation is unlikely to improve the diagnostic quality of out-patient intravenous urograms. In addition, 40% of the urogram patients found the effects of the laxatives to be unpleasant or very unpleasant.
Is bowel preparation necessary?


Bowel preparation before intravenous urography: is it necessary?
George CD¹, Vinnicombe SJ, Balkissoon AR, Heron CW.

Abstract
Whether or not bowel preparation should be used before intravenous urography (IVU) remains a controversial issue. Despite strongly held views on both sides there is little scientific evidence to support either viewpoint. We have conducted a prospective randomized study designed to test the hypothesis that adequate bowel preparation before IVU facilitates better quality studies requiring fewer films and consequently less time and a lower radiation exposure. Data on 188 patients were analysed; 90 patients received bowel preparation and 98 received no bowel preparation. There was no difference between the groups in terms of the number of films taken, the duration of the procedure, the visibility of the renal tracts or the overall quality of the studies. The prepared group did have significantly less faecal residue than the unprepared group. However, the renal tract visibility was no greater, as the combination of gas and haustral folds seen after bowel preparation obscured fine detail of the urinary tract as effectively as faecal residue. The hypothesis that adequate bowel preparation before IVU facilitates better quality studies must therefore be rejected.
Is bowel preparation necessary before kidney-ureter-bladder radiography and intravenous urography?

Dadkhah F, Satarinejad MR, Amini E, Soleimani M, Lashay AR. - Urol J - January 1, 2012; 9 (3); 600-5

Abstract
To assess whether bowel preparation prior to kidney-ureter-bladder (KUB) radiography and intravenous urography (IVU) are of value in improving visualization of the urinary system.

A total of 186 patients participated in this study. Thirty-nine patients with chronic constipation based on Rome III criteria and 147 patients with normal bowel habits were included. All the patients were randomly divided into two groups. Patients in group 1 received castor oil before imaging and had to eat or drink nothing after midnight. Patients in group 2 were allowed to eat and drink before the examination and received no bowel preparation. Kidney-ureter-bladder radiographies were obtained in all the patients and IVUs were indicated in 77 patients. To assess the image quality, radiographic images were divided into 5 anatomical regions and each region was scored from 0 to 3 based on obscurity of the images by the bowel gas or fecal residue.

Mean total score for visualization of the urinary system on plain and contrast images did not differ significantly between the two groups (P = .253). However, patients with chronic constipation who received bowel preparation revealed a significantly better visualization score on plain images (P = .001).

Bowel preparation prior to KUB and IVU does not improve the quality of the images in patients with normal bowel habits. However, a significantly better visualization of KUB was noted among patients with chronic constipation who had received bowel preparation.
Table 1: Steroid premedication has been found to significantly reduce self-limiting mild adverse reactions in patients receiving non-ionic contrast media, but there is no statistically significant difference for moderate and severe reactions, which are potentially life-threatening.
Contrast Medium Reaction – Role of Steroid Premedication

<table>
<thead>
<tr>
<th>Summary Table:</th>
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<tbody>
<tr>
<td><strong>Opinions about value of steroid premedication are divided:</strong></td>
</tr>
<tr>
<td>There is no conclusive evidence of benefit for the prophylactic use of steroids in the prevention of severe reactions of contrast administration, hence some do not advocate steroid premedication</td>
</tr>
<tr>
<td>Some believe patients at higher risk of acute allergic-like reactions may potentially benefit from steroid premedication:</td>
</tr>
<tr>
<td>● Prior history of allergic-like reaction to iodinated contrast media <em>(the most substantial risk factor)</em></td>
</tr>
<tr>
<td>● Atopic individuals with multiple or severe allergies</td>
</tr>
<tr>
<td>● Asthmatics</td>
</tr>
</tbody>
</table>

Predictive value of specific allergies, e.g. shellfish or dairy products, is now recognized to be unreliable

Patients with prior physiological reactions to contrast media, e.g. arrhythmias, cardiogenic pulmonary oedema, and seizures, would not require steroid premedication

Corticosteroids should be used with caution in certain patients
Contrast Medium Reaction – Role of Steroid Premedication

Risk of Corticosteroids

The use of steroids is not entirely without risk. Although the risk of a few doses of oral corticosteroids is extremely low, the ACR Manual on Contrast Media advised that corticosteroids should be used with caution in patients with uncontrolled hypertension, diabetes, tuberculosis, systemic fungal infections, peptic ulcer disease or diverticulitis.
Contrast Medium – Iso-osmolar (Iodixanol) vs Low Osmolar CM

Studies have failed to establish a clear advantage of IV iso-osmolality iodixanol over IV LOCM with regard to CIN. A 2009 meta-analysis using data pooled from 25 trials found no difference in the rate of CIN between iodixanol and low osmolality agents after intravenous administration.

Indications of renal ultrasonography are as follows:

- Evaluation of cystic kidney disease
- Diagnosis of hydronephrosis
- Measurement of kidney size and echogenicity as part of an evaluation of chronic kidney disease
- Detection of renal artery occlusive disease via Doppler images

Main Advantages

- No exposure to ionising radiation
- Portable or Bedside examination
Ultrasound

Right kidney
Longitudinal

Dilated Renal Pelvis
Ultrasound
Computed Tomography

- Noncontrast helical CT scanning is the procedure of choice to evaluate kidney stones.
- CT scanning is also used to differentiate malignant from nonmalignant renal masses.
- CT scanning is essential to evaluate the local spread of a renal malignancy.
- High-resolution CT angiography is excellent in defining the anatomy of the renal arteries and veins.
- Multiphase CT urography has a higher diagnostic yield in evaluating the etiology of hematuria and identifying urothelial tumors than intravenous urography.
The primary limitation of CT scanning is the risk of radiation and a medium administration of contrast medium.
Computed Tomography

Technique

- In the precontrast phase, a scan is obtained for baseline calcifications, stones, and space-occupying lesions in the kidney and urinary tract.

- Corticomedullary phase within 70 seconds after injection of contrast, the renal vasculature is identified and renal cell carcinoma can be accurately staged.

- In the nephrographic phase (ie, up to 180 seconds after contrast injection), renal masses can be differentiated from simple cysts, as malignant masses will enhance with contrast.

- In the excretory phase (5 minutes after contrast injection), the ureter, bladder and pelvicaliceal system is imaged.

- Limited CT urography (with an excretory phase only) can be performed to minimize radiation exposure.
Computed Tomography

- Protocols used in HKL
- PROTOKOL MSCT- RENAL updated[1][1].doc
Magnetic Resonance Imaging

- Magnetic resonance imaging (MRI) provides a useful alternative to CT scanning in individuals at risk for toxicity from intravenous contrast.
- It may also offer an advantage in the evaluation of small renal masses.
- Magnetic resonance angiography has proven useful in the evaluation of stenosis in the mid and proximal renal arteries.
Nephrogenic Systemic Fibrosis

- Nephrogenic systemic fibrosis (NSF) is a fibrosing disease, primarily involving the skin and subcutaneous tissues but also known to involve other organs, such as the lungs, esophagus, heart, and skeletal muscles. Initial symptoms typically include skin thickening and/or pruritis. Symptoms and signs may develop and progress rapidly, with some affected patients developing contractures and joint immobility. In some patients, the disease may be fatal.

- In 2006 several groups noted a strong association between gadolinium-based contrast agent (GBCA) administration in patients with advanced renal disease and the development of NSF [1,2], and it is now generally accepted that GBCA exposure is a necessary factor in the development of NSF.
# Nephrogenic Systemic Fibrosis

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Group I: Agents associated with the greatest number of NSF cases:</strong></td>
</tr>
<tr>
<td>Gadodiamide (Omniscan® – GE Healthcare)</td>
</tr>
<tr>
<td>Gadopentetate dimeglumine (Magnevist® – Bayer HealthCare Pharmaceuticals)</td>
</tr>
<tr>
<td>Gadoversetamide (OptiMARK® – Covidien)</td>
</tr>
<tr>
<td><strong>Group II: Agents associated with few, if any, unconfounded cases of NSF:</strong></td>
</tr>
<tr>
<td>Gadobenate dimeglumine (MultiHance® – Bracco Diagnostics)</td>
</tr>
<tr>
<td>Gadoteridol (ProHance® – Bracco Diagnostics)</td>
</tr>
<tr>
<td>Gadoteric acid (Dotarem® – Guerbet [as of this writing not FDA-approved for use in the U.S.])</td>
</tr>
<tr>
<td>Gadobutrol (Gadavist® – Bayer HealthCare Pharmaceuticals)</td>
</tr>
<tr>
<td><strong>Group III: Agents that have only recently appeared on the market:</strong></td>
</tr>
<tr>
<td>Gadofosveset (Ablavar® – Lantheus Medical Imaging)</td>
</tr>
<tr>
<td>Gadoxetic acid (Eovist® – Bayer HealthCare Pharmaceuticals)</td>
</tr>
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There is limited data for group III agents, although, to date, few, if any, unconfounded cases of NSF have been reported.
Radionuclide Studies

- Radionuclide scanning has been successfully used to evaluate renal perfusion in various settings, including renal artery stenosis and thrombosis.
- A radionuclide study can provide an assessment of renal tubular function, it is however nonspecific and therefore cannot establish a definitive renal diagnosis.
- Radionuclide cystography is widely used by pediatric nephrologists to detect early vesicoureteral reflux in children.
Summary

- Briefly introduce on urinary system and various imaging modalities used to study it
- Discuss on some of the controversies and latest concern
- Prime you all to more detail discussion that to be covered by subsequent speakers and lectures
Thank You