A Rough Guide to the Renogram

Dr Brian Huey
MB ChB MRCP FRCR
My background

• Consultant Radiologist since 2012
• 15 months radionuclide radiology during training

• No conflicts of interest
For discussion

• Diuretic renography in suspected urinary tract obstruction
  – How?
  – Primary purpose?
• Interpretation
• Example cases
• Reference to available guidelines
• Future direction
Hydronephrosis +/- hydroureter

- Hydronephrosis is one of the most frequently detected abnormalities on routine prenatal ultrasound
  - Can be unexplained and transient
- PUJ anomaly is the most common obstructive cause of antenatal hydronephrosis
  - Intrinsic stenosis or valve, peripelvic fibrosis or crossing vessel
- Different spectrum of pathology in adults

How?

• Adequate hydration and empty bladder at outset (if possible)
  – ? Intravenous fluids
  – ? Bladder catheter
• Tubular agent
  – 99mTC-mercaptoacetyltriglycine (MAG3)
    • Approximately 50% extraction fraction
• Dynamic imaging
  – Time-activity curve
  – Differential renal function
• Augment with diuretic
  – Furosemide
    • Dose?
    • Adequacy of diuresis?
    • Timing?
• Effect of gravity +/- micturition?

Furosemide dose and adequacy of diuresis

• Relies on tubular secretion to reach its site of action and a poorly functioning kidney may not therefore adequately respond
• Argument for larger diuretic dose in patients with known renal impairment to attain an effective level of diuretic in the tubular fluid
• Measuring the voided volume +/- calculation of urine flow rate can provide evidence of adequate diuresis
  – 200–300 ml of urine should be produced within 20–30 mins after 40 mg of furosemide
  – A urine flow rate of approximately 20 ml/min should be produced within 3–6 mins after 40mg of furosemide but maximum diuresis may not be achieved until 15–18 min after injection
• Dynamic imaging should continue for at least 15 minutes post diuretic

Timing of furosemide

• Anytime from 15 mins before to 20 mins following radiopharmaceutical administration

• The F 0 protocol is certainly the most convenient

<table>
<thead>
<tr>
<th></th>
<th>For</th>
<th>Against</th>
</tr>
</thead>
</table>
| F +20  | Assess kidney without diuretic effect  
         | Traditional criteria of curve interpretation readily applicable | Maximum diuretic effect may not be reached  
         | More equivocal studies |
| F 0    | Convenient | Urinary flow isn’t in a steady state |
| F -15  | State of maximum diuresis | Fully dilated renal pelvis  
         | More incomplete studies |
Effect of gravity and micturition

• Gravity aids drainage
  – Potential for poor drainage of a normal kidney when supine

• Drainage of a normal kidney can certainly be delayed in the presence of a full or poorly compliant urinary bladder

• Young children cannot be expected to void upon demand
  – Often do so in response to diuretic
  – Usually can at least be held upright for a period (about 5 mins)

Effect of gravity and micturition

Pelviureteric junction obstruction. The value of a post-micturition view in 99mTc DTPA diuretic renography  
6
• 31 children post pyeloplasty
• F +20 renograms x 81
• 45 kidneys potentially obstructed based on T75 (> 5 minutes)
• 20 sec post micturition image excluded obstruction in 33 of these 45

Diuretic renography with the addition of quantitative gravity-assisted drainage in infants and children  
7
• 200 children
• Hydronephrosis or hydroureteronephrosis
• F +0 or F +20
• Upright for ~ 5 mins +/- post micturition after diuretic phase
• Interested in kidneys with T ½ > 10
• Deemed obstructed if > 50% kidney retention
  – Last 5 mins of diuretic phase compared with 5 min image post gravity assisted drainage +/- micturition
• 19 of 62 kidneys with T ½ > 20 mins deemed negative for obstruction (14 true negatives)
• 35 of 52 kidneys with T ½ 10-20 mins correctly deemed negative for obstruction

Facilitate drainage by maximizing the pressure differential between the renal pelvis and urinary bladder

(minimise number of indeterminate studies)
Primary purpose of diuretic renography

• Almost never encounter completely obstructed kidney at renography
• To identify poorly draining kidneys with a sufficiently high resistance to outflow which, if left untreated, will result in loss of function (obstructive uropathy to obstructive nephropathy)
• The goal of intervention is to preserve +/- improve renal function and relieve symptoms (i.e. pain)
PUJ obstruction beyond salvage

Male
Early 20s
Left testicular pain
Incidental discovery of hydronephrosis
Right kidney = 10%

3 minute
Normal

- Early peak
- Rapid descension
- Differential renal function 45 – 55%
- Obstruction can often be confidently excluded by review of the shape of the curve

T max approximately 3 minutes
T ½ < 10 minutes
Parapelvic cyst

Left kidney = 44%
Right kidney = 56%
Vesicoureteric reflux

Left kidney = 50%
Right kidney = 50%
Activity

Diuretic

Obstructed

? T1/2 > 20 mins
= obstruction

Normal

Non
obstructed

Time
Determination of delayed drainage

- Debatable
- Visual assessment + quantitative indices
- $T\frac{1}{2}$ on the diuretic renogram has probably been the most used quantitative parameter for defining the adequacy of renal drainage
- SNMMI procedure standard for diuretic renography in children 2008
  - Obstruction if $T\frac{1}{2} > 20$ mins
- EANM guideline for standard and diuretic renogram in children 2011
  - Assessment of renogram curve alone is inadequate
  - Late post micturition image (at 50 to 60 mins post tracer injection) and calculation of output efficiency or normalised residual activity
Normalised residual activity

- Measure of renal output thought to not be greatly influenced by overall renal function
- Validation by simulated model and clinical cases
- Renal counts acquired over 1 minute at a given moment divided by the renal counts between 1 and 2 mins post tracer injection
- Whatever the timing of furosemide injection, the quality of renal drainage remains the same on the late post micturition view
- Kidneys with post micturition NORA < 1.5 unlikely to be obstructed

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Dilated unobstructed (post pyeloplasty)</th>
<th>Dilated</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre furosemide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post furosemide</td>
<td>0.2</td>
<td>0.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Post micturition</td>
<td>0.1</td>
<td>0.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

90th percentile values

EANM vs SNMMI guidelines

- Limited study\(^{11}\)
- 45 children with hydrenephrosis or severe reflux (90 kidneys)
- F 0
- Drainage assessment with T ½
  - Normal if < 10 mins
  - Equivocal if 10 to 20 mins
  - Obstruction if > 20 mins
- Drainage assessment with NORA
  - Good if < 0.5
  - Partial if 0.5 to 1.8
  - Poor if > 1.8

<table>
<thead>
<tr>
<th></th>
<th>T1/2</th>
<th>NORA</th>
<th>OE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>39</td>
<td>78</td>
<td>90</td>
</tr>
<tr>
<td>Equivocal</td>
<td>20</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Obstructed</td>
<td>31</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Successful right pyeloplasty?

Before

Right kidney = 29%

After

Right kidney = 32%

Symptomatic male in early 20s
Successful right pyeloplasty?

Before

Pre mict | Post mict

93% post micturition retention

After

Pre mict | Post mict

50% post micturition retention
Once satisfactory drainage has been achieved at any point in the study then obstruction is excluded and the risk to the kidney is small.
PUJ obstruction?

**Male**
- Early 20s
- Left loin pain
- Left = 47%

**Female**
- Antenatal hydronephrosis
- Ultrasound surveillance
- Asymptomatic
- 1st renogram 5 yrs old
- Left = 49%

**Female**
- Mid 20s
- Right loin pain
- Right = 48%
Symptomatic young man
Left = 47% initially
Left = 40% at 6 months
Left = 36% at 12 months

Girl with antenatal hydronephrosis
Left = 49% when 5 yrs old
Left = 49% when 8 yrs old

Symptomatic young woman
Right = 48% initially
Right = 49% at 4 years
What if satisfactory drainage isn’t achieved?

• True or false positive?
• Poor emptying is not necessarily due to significantly restricted flow through a narrowed segment
  – Dilated renal collecting system acting as a reservoir
  – Immature or poorly functioning kidney
  – Dehydration
• EANM suggest that a kidney is not described as obstructed simply because one is dealing with poor emptying of a dilated renal pelvis
• Surveillance of a seemingly obstructed kidney may well be appropriate, especially if differential renal function is entirely normal
Impaired drainage on diuretic renography using half-time or pelvic excretion efficiency is not a sign of obstruction in children with a prenatal diagnosis of unilateral renal pelvic dilatation\textsuperscript{12}

- 24 asymptomatic children
- Unilateral hydronephrosis
- F +20
- > 3 diuretic renograms per child
- Total of 91 diuretic renograms
- No significant worsening of relative function or hydronephrosis and no need for surgery
- 62 of 91 (68\%) hydronephrotic kidneys had T $\frac{1}{2}$ > 20 minutes
- 40 of 91 (44\%) hydronephrotic kidneys had post micturition pelvic excretion efficiency < 71\%
- Variability in drainage demonstrated by sequential studies
- Impaired drainage doesn’t mean obstruction

\textsuperscript{12} Amarante, Anderson and Gordon. J Uro 2003;169:1828-31
Female
7 yrs old
Recurrent UTIs
Ultrasound revealed left hydronephrosis +/- hydroureter
Left kidney = 52%
T½ = 23 mins
Post open ureteric re-implantation

Left kidney = 48%
(52% pre-op)
T ½ = 13 mins
(23 mins pre-op)
Post micturition retention = 39%
Role for cortical transit time?

- Proposed as a parameter to help distinguish between hydronephrotic kidneys that do and do not require an intervention
  - Identify those likely to have significant functional improvement with surgery or those at high risk of functional deterioration without surgery
- Assessment of parenchymal rather than whole kidney transit
- Sophisticated techniques developed to measure cortical transit, but visual inspection seems adequate
  - An almost perfect agreement in the qualitative identification of delayed cortical transit among physicians with experience at observing renographic images\(^1\)
  - Appearance of tracer in subcortical structures (medulla and calyces)
- Not thought to be influenced by the reservoir function of a dilated collecting system

Image of normal rapid cortical transit on the right giving rise to a more or less homogeneous kidney filling in ~ 2 mins vs retention in the outer cortical rim for several minutes on the left.

Predicting functional improvement after surgery

Diuretic renography in hydronephrosis: renal tissue tracer transit predicts functional course and thereby need for surgery\textsuperscript{15}

- 50 patients with unilateral hydronephrosis
- F +10 or F +20
- CTT > 8 mins = delayed
- 8 out of 10 kidneys with impaired CTT had a significant improvement in relative function after surgery

Predictors of renal functional improvement after pyeloplasty in ureteropelvic junction obstruction: Clinical value of visually assessed renal tissue tracer transit in 99mTc-MAG3 renography\textsuperscript{16}

- 126 patients who had already had pyeloplasty
- F +20
- CTT > 2 mins = delayed
- 37 delayed CTT
- Delayed CTT (for kidneys with relative function < 45%) was a significant predictor of a > 5% improvement in function
  - ~ $\frac{1}{4}$ had > 10% improvement

\textsuperscript{16} Song, Park, Chae, Moon, Park and Kim. Urology 2017;108:149-54
Predicting need for surgery

Can severely impaired cortical transit predict which children with pelvi-ureteric junction stenosis detected antenatally might benefit from pyeloplasty?\textsuperscript{17}

- 19 children
- 26 pairs of data
- > 2 F0 renograms per child
- CTT > 3mins = delayed
- 10 of 16 (61%) patients who underwent pyeloplasty had > 5% improvement in function
- 4 of 10 (40%) patients initially treated conservatively had significant deterioration in relative function during follow-up period of 2 to 7 months

Predictive value of cortical transit time on MAG3 for surgery in antenatally detected unilateral hydronephrosis caused by ureteropelvic junction stenosis\textsuperscript{18}

- 33 children with initial MAG3 at 1 to 3 months after birth
- F +20
- CTT > 3 mins = delayed
- 12 of 16 (75%) with delayed CCT required surgery
- 1 of 17 (5.9%) with normal CTT required surgery
- Delayed CTT on initial study an independent predictor for need for surgery

\textsuperscript{17} Piepsz, Tondeur, Nogarede, Collier, Ismaili, Hall, Dobbeleir and Ham. Nucl Med Commun 2011;32:199-205
\textsuperscript{18} Lee, Kang, Jeong, Lee, Cho, Ha, Kim, Kim, Yoo, Kwon and Chung. J Pediatr Urol 2018;14:55.e1-55.e6
Poor drainage
+ reduced relative function
+ prolonged cortical transit
= surgery?
Decision support systems

- Decision support systems for imaging analysis and interpretation are being developed.
- iRENE uses 116 different clinical and quantitative parameters to distinguish between an obstructed and a nonobstructed kidney.
Indications for surgical intervention?

• Significant symptoms attributable to obstruction i.e. pain
• Recurrent UTIs
• Development of stones
• Severe and/or worsening hydronephrosis (with parenchymal thinning)
• Poor drainage
• Initial low relative function (? < 40%)
• Persistent stable low relative function
• Progressive deterioration in relative function (? > 5% or 10%)
Successful left pyeloplasty for symptomatic female in her late 30s

Left kidney = 46%  

Before

Left kidney = 47%  

After
Remember

• Deterioration in relative function occurs in only a minority of those with antenatally detected hydronephrosis
  – 10% based upon a wide meta-analysis of cases managed conservatively\(^\text{19}\)
• Risk of late intervention is low in the case of normal differential function\(^\text{19}\)
• No solid evidence for demonstrating that a kidney with impaired function at outset has a greater risk for deterioration than a kidney with normal function, whilst only a limited percentage of kidneys with impaired function will improve function after surgery\(^\text{20}\)

Summary

• Prolonged T1/2 should not be used as the sole criterion for determining delayed drainage
  – Need to incorporate an assessment of post micturition drainage

• Yet to discover a reliable means of identifying those kidneys at risk of losing function if left untreated
  – No straightforward relationship between the quality of drainage and the risk of functional deterioration
  – If satisfactory drainage is achieved then obstruction is excluded and the risk to the kidney is small

• Deterioration of relative function is the sole solid renographic indicator available to support intervention
  – A conservative approach to antenatally detected hydronephrosis is appropriate in a large majority of cases

• More sophisticated approach is required
Any questions?