RADIO-NUCLIDE STUDIES FOR THE EVALUATION OF KIDNEY FUNCTIONS

DR RIANA NEL
NUCLEAR MEDICINE DEPT
27 Sept 2010
Alive patient

RA + tracers

Tc-99m(86%)
+ MAG 3
DMSA (DTPA)
T½ = 6.5h

Gamma camera ect.

Radio-active patient
RADIONUCLIDE RENOGRAPHY

MAG 3 + Tc-99M
DMSA + Tc-99M
**CORTEX: OUTSIDE 1/3**

Glomeruli, Bowman’s capsule

**MEDULLA: MEDIAL 1/3**

pyramids and nephrons with collecting ducts open in kidney pelvis

**KIDNEY PELVIS:** calyxes is part of the renal pelvis and urine collection takes place here before excretion via the ureters to the bladder
NEPHRONS (cortical and juxta-medullary)
Is a system of small tubes that stretch from the cortex 
(under the kidney capsule) 
to the collection ducts and tubuli in the medulla. 
Formed Filtrate drains through the pyramids and renal calyces to the kidney pelvis. Mostly part of the kidney cortex.

FORMS THE KIDNEY’S FUNCTIONAL UNIT

Urine production takes place here 
Each kidney consists of nearly 1,250,000 nephrons, and produce 100-150 liter filtrate/day

FILTRATE:
Consists mainly of glucose, salts, urea, Urine acid, potassium phosphates en sulphates
PHYSIOLOGY

KIDNEY FUNCTIONS:

1) ULTRA FILTRATION

2) ENDOCRINE FUNCTION

3) OSMOLARITY REGULATION

4) VOLUME REGULATION

5) ACID-BASE REGULATION

URINE AND HORMONE PRODUCTION
Excretion is the process of eliminating metabolic waste products from the body. It involves filtration, secretion, and reabsorption. The equation for excretion is:

\[
\text{Excretion} = \text{Filtration} + \text{Secretion} - \text{Reabsorption}
\]
MAIN KIDNEY FUNCTIONS:

URINE AND HORMONE PRODUCTION

BLOOD FLOW

NEPHRON FUNCTIONS:
- CONCENTRATION
- CLEARANCE
- COLLECTION IN KIDNEY PELVIS, EXCRETION

EXCRETION THROUGH THE URETER AND INTO THE BLADDER

URINARY EXCRETION
WHICH ABNORMALITIES CAN BE EVALUATED WITH THE RN STUDIES?

• ANY PHYSIOLOGICAL/FUNCTIONAL CHANGES WILL BE SEEN

• ALL THREE PHASES/FUNCTIONS CAN SHOW ABNORMALITIES IN THE FUNCTIONS

• LOOK FOR:
  ➔ KIDNEY PRESENCE, SIZES, DIFFERENTIAL FUNCTION % and ANY STRUCTURAL ABNORMALITIES eg SCARS/TUMORS/CYSTS
  ➔ BLOODFLOW TO BOTH KIDNEYS
  ➔ CONCENTRATION FUNCTION
  ➔ PARENCHEMAL CLEARANCE
  ➔ EXCRETION PATTERNS
BLOODFLOW

CORTEX:
GLOMERULI
BOWMAN’S CAPSULE

MEDULLA:
PYRAMIDS with NEPHRONS
COLLECTION TUBULI AND DUCTS
OPEN INTO KIDNEY PELVIS

KIDNEY CALYXES AND PELVIS:
URINE COLLECTION AND EXCRETION

URETERS and
URINARY BLADDER

Blood flow

DTPA - DYNAMIC
DMSA - STATIC

Blood flow
Glomerular filtration

Exchange, secretion and re-absorption off substances to and from blood capillaries
ALSO
Tubular secretion and re-absorption of substances
MAG 3 - DYNAMIC

Urine production and collection in the kidney pelvis

Excretion of the formed urine
Tc-99M labelled Radio-Nuclides

1) DTPA: (3-10mCi)  DYNAMIC STUDY
   - glomerular filtration
   - glomerular excretion imaged
   - measure GFR
2) MAG 3: DYNAMIC STUDY (3-10 mCi)

I) PROXIMAL TUBULAR SECRETION
II) URINARY EXCRETION
III) BEST CLEARANCE FROM THE BLOOD
IV) BEST “TARGET to BACKGROUND RATIO”
V) MEASURE EFFECTIVE RENAL PLASMA FLOW (ERPF) AS WELL AS THE TUBULAR FUNCTION

ALSO RN OF CHOICE IN:

i) PATIENTS WITH IMPAIRED KIDNEY FUNCTION
ii) CHILDREN WHO NEED LOWER RADIATION DOSAGES
NORMAL DYNAMIC RENOGRAM (MAG-3 + Tc-99m) POST IMAGES

NORMAL KIDNEY BLOODFLOW

CONCENTRATION

CLEARANCE

EXCRETION INTO THE BLADDER

RENOGRAM CURVE

FULL BLADDER
POST VOIDING
NORMAL RENOGRAM
TRANSPLANTED KIDNEY
(ANT IMAGES)

PERFUSION PHASE
CONCENTRATION FUNCTION

PARENCHMICAL CLEARANCE

EXCRETION FUNCTION

URINE ACCUMULATION IN BLADDER
3) DMSA: 1-5 mCi

CORTEX: OUTSIDE 1/3
Glomeruli,
Bowman’s capsule

STATIC CORTICAL IMAGES
NORMAL STATIC DMSA IMAGES

CORTICAL UPTAKE OF Tc-99M DMSA
THE Tc-99M LABELLED DMSA (STATIC IMAGES):

BINDING TO THE CORTICAL RENAL TUBULI TAKE PLACE FOR AT LEAST 24H00
ONLY 4-8% POSSIBILITY FOR EXTRACTION AND EXCRETION

INDICATIONS:
I) DETECTION OF FILLING/SPACE OCCUPYING DEFECTS LIKE tumors or cystic lesions
II) DETECTION OF SCARS DUE TO CHRONIC INFECTION/SURGERY
III) CALCULATION OF DIFFERENTIAL FUNCTION %

PLANAR IMAGES CAN BE IMPROVED WITH SPECT

4) I-131 LABELLED HIPORAN

5) Tc -99m LABELLED GLUKONATE

NOT IN USE ANY MORE
INDICATIONS (KIDNEY DISEASES)

• Obstructive uropathy
• Hydronephroses
• Urinary reflux
• Renal vascular hypertension
• Renal artery stenoses
• Cysts and tumors (space occupying lesions)
• Evaluation of transplanted kidney functions (ATN/rejecton reactions) + kidney donor’s kidney functions
• Kidney failure (acute/chronic)
• Reno-parenchyma diseases (HPT and Diabetic pt’s)
• Infections like UTI, Pielonephritis and it’s effects on kidney functions
PATIENT PREPARATION

1) GOOD HYDRATION IS ESSENTIAL (orally/IV)
2) A Highly efficient RN bolus is necessary to evaluate the blood flow to the kidneys effectively.
3) Wait 1 week after contras medium investigations such as IVP, because of the impaired clearance shortly/directly after such an investigation.
4) Urinary catheters must be in place in patients with obstructive uropathy. The full bladder can delay the urinary flow and excretion tempo.
5) Sedation is needed in children (as well as an IV infusion to be put on in the ward already – before the child is send down to us)
6) It is essential for patients to empty their bladders before the investigation is started, especially in patients where Diuretic (Lasix IV) administration is considered/essential.
7) Need information about patients regular anti-hypertensive treatment (can interfere with the Capoten renograms)
8) Need patients weight and height
9) Blood pressure must be checked in patients who need ACE inhibitor administration 1h00 pre-investigation, as part of the Capoten intervention study in Reno-vascular hypertension.
10) No movement is allowed during the 30 min dynamic study.
NORMAL DYNAMIC RENOGRAM
(MAG-3 + Tc-99m)

POST IMAGES
NORMAL KIDNEY BLOODFLOW

CONCENTRATION

CLEARANCE

EXCRETION

EXCRETION INTO THE BLADDER

RENOGRAM CURVE

FULL BLADDER
POST VOIDING
<table>
<thead>
<tr>
<th></th>
<th>1) Bloedvloeifase</th>
<th>2) Konsentrasiefunksie</th>
<th>3) Parenchiemaleopriumingsfunksie</th>
<th>4) Nierbekkenuitskeidingsfunksie</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERFUSIE</td>
<td>L POST R</td>
<td>KONSENTRASIE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1) Perfusie
2) Konsentrasie
3) Parenchiemiale opruiming
4) Nier bekken uitskeidings
PERFUSION

AORTA
CLEARANCE

EXCRETION → BEFORE IV LASIX

URINE IN BLADDER AFTER IV LASIX ADMINISTRATION
SINGLE KIDNEY
**Whole Kidney**

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTG3 Clearance mL/min</td>
<td>99.9</td>
<td>5.8</td>
<td>105.8</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>10.8</td>
<td>0.6</td>
<td>11.4</td>
</tr>
<tr>
<td>REL.FUNCT % (44-56%)</td>
<td>94</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>3.1</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>T MAX min (5cm)</td>
<td>4' 20&quot;</td>
<td>5' 00&quot;</td>
<td></td>
</tr>
<tr>
<td>T MAX -&gt; HALFMAX (N&lt;10cm) (GB&gt;20cm)</td>
<td>9' 00&quot;</td>
<td>9' 20&quot;</td>
<td></td>
</tr>
<tr>
<td>C20/C MAX (N=0.36)</td>
<td>0.36</td>
<td>0.43</td>
<td></td>
</tr>
</tbody>
</table>

**Composite**

1' 00" - 5' 00"

**Function**

- Right
- Left

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Department: Kerngeneeskunde, Universitas, Bloemfontein
strachen p 930407 RENOGRAF 2003.11.19
OBSTRUCTIVE UROPATHY
+
ADMINISTRATION OF IV LASIX
DELAYED KIDNEY PELVIS CLEARANCE AND EXCRETION OF URINE
OBSTRUCTIVE RENOGRAM CURVE
BILAT HYDRONEPHROSIS
(DIURETIC STUDY)
<table>
<thead>
<tr>
<th>1st Plateau</th>
<th>2nd Plateau</th>
<th>3rd Plateau</th>
<th>4th Plateau</th>
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</thead>
<tbody>
<tr>
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<td><img src="image2.png" alt="Image" /></td>
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<td><img src="image7.png" alt="Image" /></td>
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<td><img src="image11.png" alt="Image" /></td>
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<td><img src="image15.png" alt="Image" /></td>
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<td><img src="image19.png" alt="Image" /></td>
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<td><img src="image31.png" alt="Image" /></td>
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<tr>
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<td><img src="image35.png" alt="Image" /></td>
<td><img src="image36.png" alt="Image" /></td>
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<tr>
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<td><img src="image38.png" alt="Image" /></td>
<td><img src="image39.png" alt="Image" /></td>
<td><img src="image40.png" alt="Image" /></td>
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<tr>
<td></td>
<td>LEFT</td>
<td>RIGHT</td>
<td>TOTAL</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>181.3</td>
<td>257.6</td>
<td>448.9</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>18.8</td>
<td>27.8</td>
<td>46.6</td>
</tr>
<tr>
<td>REL. FUNCT %</td>
<td>(44-56%)</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>2.1</td>
<td>2.1</td>
<td>100</td>
</tr>
<tr>
<td>T MAX min (min)</td>
<td>21' 00&quot;</td>
<td>21' 00&quot;</td>
<td></td>
</tr>
<tr>
<td>TMAX -&gt; HALFWAX (N&lt;1 cm)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(OB &gt;20 cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_20/C_MAX</td>
<td>0.99</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Full syringe act.</td>
<td>85.0 MBq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empty syringe act.</td>
<td>0.0 MBq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ante-cubital counts</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net-injected counts</td>
<td>437.750</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Composite:

1' 00" - 5' 00"

**Function**

- Right
- Left

- Height: 89 cm
- Weight: 10 kg
- Body surface: 0.49 sqm
- Age: 0.3 year
- Isotope: UNKNOWN
### Whole Kidney

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>133.0</td>
<td>179.6</td>
<td>312.7</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>13.9</td>
<td>18.7</td>
<td>32.6</td>
</tr>
<tr>
<td>REL. FUNCT % (44-56%)</td>
<td>43</td>
<td>57</td>
<td>100</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>T MAX min (5m)</td>
<td>2' 20&quot;</td>
<td>15' 40&quot;</td>
<td></td>
</tr>
<tr>
<td>TMAX -&gt; HALFMAX</td>
<td>3' 40&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(OB &gt;20m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_20/C_MAX (N&lt;0.36)</td>
<td>0.08</td>
<td>0.83</td>
<td></td>
</tr>
</tbody>
</table>

**Full syringe act.**: 163.0 MBq  
**Empty syringe act.**: 0.0 MBq

**Composite**  
1' 00" - 5' 00"

**Function**

- **Right**
- **Left**

**Height**: 127 cm  
**Weight**: 59 kg  
**Bodysurface**: 1.36 sqm  
**Age**: 26.0 year  
**Isotope**: UNKNOWN
RAS
(RENAL ARTERY STENOSIS)

IMPAIRED KIDNEY FUNCTION
### Functional Kidney Imaging Report

**Composite**

1' 00" - 5' 00"

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Left</th>
<th>Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>8.8</td>
<td>71.2</td>
<td>80.0</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>0.9</td>
<td>7.8</td>
<td>8.8</td>
</tr>
<tr>
<td>REL.FUNCT %</td>
<td>(44-56%)</td>
<td>11</td>
<td>89</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>5.9</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>T MAX min (s)</td>
<td>17' 00&quot;</td>
<td>3' 00&quot;</td>
<td></td>
</tr>
<tr>
<td>TMAX -&gt; HR INTERVAL (N &lt;10m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(OS &gt;20m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_20/C_MAX</td>
<td>(N&lt;0.36)</td>
<td>0.91</td>
<td>0.62</td>
</tr>
</tbody>
</table>

- **Full syringe act.**: 160.5 MBq
- **Empty syringe act.**: 0.0 MBq
- **Ante-cubital counts**: 0
- **Net-injected counts**: 827568

**Function**

- **Right**
- **Left**

**Additional Details**

- **Height**: 176 cm
- **Weight**: 70 kg
- **Body surface**: 1.85 sqm
- **Age**: 81.6 years
- **Isotope**: UNKNOWN
RENO-PARENCHYMAL DISEASE

IMPAIRED CLEARANCE
### Whole Kidney

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>25.3</td>
<td>20.5</td>
<td>45.9</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>2.9</td>
<td>2.3</td>
<td>5.3</td>
</tr>
<tr>
<td>REL. FUNCT % (44-56%)</td>
<td>55</td>
<td>45</td>
<td>100</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>8.0</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>T MAX min (5m)</td>
<td>3' 20''</td>
<td>2' 40''</td>
<td></td>
</tr>
<tr>
<td>TMAX -&gt; HALFMAX (N&lt;10m)</td>
<td>11' 40''</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>C_20/C_MAX (N&lt;0.36)</td>
<td>0.45</td>
<td>0.51</td>
<td></td>
</tr>
</tbody>
</table>

**Composite**

1' 00'' - 5' 00''

### Function

![Function Graph]

- **Height**: 166 cm
- **Weight**: 92 kg
- **Body Surface**: 1.99 sqm
- **Age**: 48.6 years
- **Isotope**: UNKNOWN
CHRONIC KIDNEY FAILURE
CHRON NVS
UREUM = 43   KREATININEN = 1213
<table>
<thead>
<tr>
<th></th>
<th>LEFT</th>
<th>RIGHT</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WHOLE KIDNEY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>9.6</td>
<td>9.5</td>
<td>19.1</td>
</tr>
<tr>
<td>UPTAKE %</td>
<td>1.3</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>REL.FUNCT % (44-56%)</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>5.9</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>T MAX min (5m)</td>
<td>2'00&quot;</td>
<td>1'40&quot;</td>
<td></td>
</tr>
<tr>
<td>TMAX -&gt; HALFMAX: (N &lt;10m) (OB &gt;20m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_20/C_MAX (N&lt;0.36)</td>
<td>0.71</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Full syringe act.</td>
<td>167.0 MBq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empty syringe act.</td>
<td>0.0  MBq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ante-cubital counts</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net-injected counts</td>
<td>2276210</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Composite**

1'00" - 5'00"

**Function**

- **Right**
- **Left**

- **Height**: 180 cm
- **Weight**: 72 kg
- **Body surface**: 1.90 sqm
- **Age**: 57.3 year
- **Isotope**: UNKNOWN
DIFFERENTIAL FUNCTION
MAG3
Bilat hidro-nefrose

Diff telling met mag3:
L nier : R nier
55% : 45%
TRANSPLANT RENOGRAMS

(ANT IMAGING)
NORMAL RENOGRAM
TRANSPLANTED KIDNEY
(ANT IMAGES)

PERFUSION PHASE

CONCENTRATION FUNCTION

PARENCHEMAL CLEARANCE

EXCRETION FUNCTION

URINE ACCUMULATION IN BLADDER
IMPAIRED FUNCTION
TRANSPLANT KIDNEY

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>MAG3 Clearance ml/min</td>
<td>24.4</td>
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<tr>
<td>UPTAKE %</td>
<td>3.1</td>
</tr>
<tr>
<td>KIDNEY DEPTH cm</td>
<td>7.9</td>
</tr>
<tr>
<td>T MAX min: (5m)</td>
<td>0' 26&quot;</td>
</tr>
<tr>
<td>TMAX -&gt; HALFMAX: (N &lt;10m)</td>
<td>0' 10&quot;</td>
</tr>
<tr>
<td>(QB &gt;20m)</td>
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</tr>
<tr>
<td>C_20/C_MAX (N&lt;0.36)</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Full syringe act. : 99.8 MBq
Empty syringe act. : 0.0 MBq
Ante-cubital counts : 0
Net-injected counts : 1360399

Function

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Height : 182 cm
Weight : 100 kg
Body surface : 2.21 sqm
Age : 41.7 year
Isotope : UNKNOWN
STATIC DMSA IMAGES
NORMAL
IMPAIRED KIDNEY FUNCTIONS
DETECTION OF KIDNEY “SCARS”
CALCULATION OF DIFFERENTIAL FUNCTION

WHICH ONE IS THE NORMAL ONE???

A

B