Renal Nuclear Medicine

John Buscombe
Why bother? CT can do it
Concomitant Stenoses
Why bother? MR can do it.

ARTERIAL PHASE

VENOUS PHASE
NUCLEAR MEDICINE
Is
Functional Imaging

- To visualise an organ needs a contrast with the surrounding tissue.
- Radiography/CT needs difference in density.
- MRI needs difference in protons.
- Ultrasound needs difference in reflectivity.
- Nuclear Medicine needs difference in function.
Tracers

• Tracer is substance added to a physiological pathway, which is handled by that pathway but does not disturb it.
• Requires small chemical amount of material, but high contrast with tissue which does not contain pathway.

- Tc-99m-DTPA is a tracer for glomerular filtration
- Intra-coronary angiographic contrast is not a tracer for coronary flow.
Functional Imaging

- FUNCTIONAL IMAGING NEEDS TRACERS
- Need to study whole organ over an appropriate time interval.
Renal Function?
Total renal function

- No pure imaging method works
- Best is to measure GFR with Cr-51-EDTA or Tc-99m-DTPA and blood sampling.
- Single-kidney GFR from total + divided function.
Renal Blood Flow

- No good measure of absolute RBF.
- Various *indices* of renal blood flow.
  - Peters RBF/CO
  - Transplant perfusion index
  - \((\text{ERPF}/\text{MAG3})\)
Imaging Function

Which Function?
Which Agent?

- Glomerular Filtration
  - Tc-99m-DTPA
  - Tc-99m-MDP
- Glomerular Filtration + Tubular Function
  - Tc-99m-MAG3
- Tubular Function
  - Tc-99m-DMSA
MDP (Medronate) renal imaging
Imaging divided function

- Rate of uptake of dynamic tracer
  - Integral/slope methods
  - Rutland/Patlak plot
- Degree of retention of static tracer
- NB Need to correct for background activity
Function involves time

Radiation Dose in Nuclear Medicine does not depend on time - therefore:

- Can image time-dependent changes
  - Transit
  - Ureteric peristalsis
- Can measure changes
  - Response to stimulus
    - Frusemide
    - Captopril
    - Aspirin
    - Exercise
Functional Imaging

Dynamic renal imaging

- Assess relative renal perfusion
- Estimate divided function
- Estimate parenchymal clearance and retention
- Assess drainage
- Measure response to diuresis
- Image ureteric peristalsis
Normal renal study MAG3
The renogram

- **Activity**
  - **Perfusion spike**
  - **Uptake phase**
  - **Peak or plateau phase**
  - **Excretory phase**

- **Frame rate**
  - 0.5-1 sec for 30-60 secs
  - 10 sec for 20 minutes

- **Time**
Renal impairment
We can only show current, not potential, function
Functional Imaging

Response to Stress

- Frusemide-induced Diuresis
- Renal Vascular Stress
  - Captopril
  - Aspirin
  - Exercise
- Prostaglandin Inhibitors
  - Diclofenac (Voltarol)
Stress Response

Diuresis

• Definition of obstruction
  < Inability to cope with urine flow
• ^ Need adequate diuresis
  • Adequate hydration
  • Lasix 15 min before (F-15)
  • Measure diuresis
• Quantitate response
  • Cumulative output
F-15
Functional Imaging

Static renal imaging

- Images localisation of function (and of loss of function)
- Estimate divided function
- Allows localisation of kidney tissue
- SPECT gives better impression of shape
- BUT is non-specific (what is a scar?)
- Does it happen in adults? If so whom?
Use of DMSA

- In children most commonly used to look for scars
- Can be used to look for acute infection (which is why 4-6 months must elapse after last UTI till DMSA)
- Use in children liver 5 and adults less clear
- But can be combined with GFR to predict GFR after nephrectomy
Patters of activity

- Convex defect
- Concave defect
- Fuzzy edge
- Will need re-scanning 6 months later to see if scars
POST

2 week old only one kidney seen on intra-uterine ultrasound

RPO
5 year old with Hx of UTIs
Scars in right kidney
Who to scan?

- Controversy re-started
- Was any child under 6 with one episode of UTI
- Now less clear the we can justify radiation
- Now needs more than one infection unless with an organism other than \textit{e.coli}
- No evidence that old or new approach WILL reduce adult hypertension
Functional Imaging

Isotope Cystography

- Direct cystography is not functional (even if it gives some functional/volume answers).
- Indirect cystography is functional.
  - Good in children with bladder control
  - Good for follow-up
  - Doesn't show anatomy
  - Needs good patient co-operation for acquisition
Reflux study
Reflux in a duplex kidney

Arrows show episodes of yo-yo reflux from lower to upper moiety.
Functional Imaging

Single Kidney GFR

- Probably most useful parameter for looking at change.
- Needs total + divided function
- Proven value in RAS and UTI
Captopril renography

- To look for renovascular disease
- 2 peaks young FMD and older AthScl
- Do base line study if abnormal then do not do post captopril
- If baseline normal give 25mg captopril
- If RVD captopril will shut down ACE drive on affected kidney
- Delayed peak, reduced divided function and delayed parenchymal transit
Renogram in RAS (on ACEI)

- Parenchymal retention
- Delayed peak
- Reduced divided function
FIG 4—Sequential $^{99m}$Tc-DTPA kidney scans in patient with unilateral renal artery stenosis (case 3; table I) before captopril, after four weeks of captopril 150 mg daily, and one week after stopping captopril. Time after radioisotope injection indicated.
Effect of chronic Captopril Wenting 1984

Fig 3—Effect of long term captopril 150 mg daily on blood pressure and single kidney uptake of \(^{99m}\)Tc-DTPA in 14 patients with unilateral renal artery stenosis and 17 patients with essential hypertension. Patients with renal artery stenosis divided into two groups according to change in DTPA uptake (see table III for statistics). Values in patients with essential hypertension presented as means and SEM. Mean arterial pressure calculated as diastolic pressure + 0.3 x pulse pressure. London School of Hygiene sphygmomanometer used. Three consecutive readings with patient in recumbent position were averaged. Effect of captopril on mean arterial pressure in patients with essential hypertension was not different from effect in two groups of patients with renal artery stenosis.
Selection of hypertensive patients

- Presented to hospital
- Asymmetric renal size
- Unexpected renal failure
  - especially after ACE inhibitor therapy
- Diabetes
- Difficulty in control of hypertension
- “Flash” pulmonary oedema
European Multicentre Study

- 454 patients from 19 centres
  - ALL had angiography
- 244 with renal artery stenosis
- Tc-99m-DTPA
  - 183 normal
  - 197 stenosis
  - 124 (33%) > 70% stenosis
European Multicentre Study

• Interventions:
  – 76 angioplasty
  – 39 surgical bypass
  – 6 nephrectomy

• Follow-up
  – 87 3 months
  – 57 6 months
  – 36 12 months
European Multicentre Study

- Best sensitivity:
  - Post-Captopril DTPA – 95%

- Best specificity:
  - Change in function or transit – 85%

- Correlation with blood pressure normalisation – 90%
Selection of hypertensive patients

- Presented to hospital
- Asymmetric renal size
- Unexpected renal failure – especially after ACE inhibitor therapy
- Diabetes
- Difficulty in control of hypertension
- “Flash” pulmonary oedema
Captopril protocol 1

- Baseline renogram (DTPA or MAG3)
- Repeat study 60-90 min after 25 mg oral Captopril
  - Stop oral ACEI / Losartan 3-5 days
  - Stop diuretics 5 days
  - Avoid sodium depletion
  - Clear fluids only for 4h
Captopril protocol 2

- On arrival, check compliance
- Put on couch
  - check veins
  - put on b/p cuff
  - check doctor present
- Give captopril (?)crushed) + fluids
- Monitor blood pressure
- Give i/v saline (if necessary).
Captopril renography

- Patient voids - time noted
- Supine renography with MAG3 or DTPA
- Bolus injection
- 1/sec for 40 secs; 1/20 secs for 20 min
- Erect image
- Patient voids - time and volume noted
Data analysis

- Summed images, displayed on absolute scale
  - 0-2 min
  - 4-6 min
  - 12-14 min
  - 18-20 min
- Automatic renal ROIs based on 2-min image
- Peri-renal background
- Basic curve analysis
Criteria for analysis

• 5% or greater change in divided function
• >1 grade change in renogram = high probability
• 1 grade change in cortex = high probability
Consensus meeting grading of renogram curves for Captopril
It’s not always so easy.....
Renal transplantation
Where can imaging help?

- Donor assessment
- Acute post-operative complications
- Early post-transplant period
- Late post-transplant period
Since 1976

• FNA/biopsy have become safer

• New drugs have slowed down rejection
Results

CHANGE Is Important
“Black Holes”
Lymphocoele
Leaks
Figure 18a. Severe transplant rejection. (a) Duplex color Doppler US image shows a spectral waveform in which the arterial flow in diastole is reversed. Differential diagnosis for this finding includes acute tubular necrosis and renal vein thrombosis. (b) On another duplex image, the spectral waveform shows that the renal vein is patent, thus the diagnosis of renal vein thrombosis is excluded. Findings from biopsy confirmed transplant rejection.

Figure 18b. Severe transplant rejection. (a) Duplex color Doppler US image shows a spectral waveform in which the arterial flow in diastole is reversed. Differential diagnosis for this finding includes acute tubular necrosis and renal vein thrombosis. (b) On another duplex image, the spectral waveform shows that the renal vein is patent, thus the diagnosis of renal vein thrombosis is excluded. Findings from biopsy confirmed transplant rejection.

MAG3 vs Doppler US

- MAG3
  - Quantifiable and reproducible
  - Can reliably identify infarcted kidney
  - Able to find slow leaks

- Doppler US
  - No radiation
  - Bed side test
  - Resistive index correlates well with rejection but not reproducible
## TABLE 2. Comparison of 99m Tc-DMSA SPECT findings in renal allograft recipients with and without a history of recurrent urinary tract infection.

<table>
<thead>
<tr>
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<th>Recurrent UTIs (%)</th>
<th>Controls (%)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Reflux</td>
<td>No reflux</td>
<td>CAN</td>
<td>Vascular occlusion</td>
</tr>
<tr>
<td>N</td>
<td>15</td>
<td>17</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>No scars</td>
<td>2 (13)</td>
<td>6 (33)</td>
<td>8 (73)</td>
<td>0 (0)</td>
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<tr>
<td>One focal defect</td>
<td>5 (33)</td>
<td>3 (18)</td>
<td>3 (27)</td>
<td>0 (0)</td>
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<tr>
<td>Two focal defects</td>
<td>2 (13)</td>
<td>3 (18)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>&gt;Two focal defects</td>
<td>6 (40)</td>
<td>5 (29)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Any focal defect</td>
<td>13 (87)</td>
<td>11 (65)</td>
<td>3 (27)</td>
<td>0 (0)</td>
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<tr>
<td>Segmental defect</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>8 (100)</td>
</tr>
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</table>
A=scar, B=rejection, C=vascular damage
Chinese Proverb

"It's not what a cat looks like that matters, it's how well he catches mice"