Renal

Prof John Buscombe
Renal nuclear Medicine

- Only consistent test of kidney function
- Many good tests for renal anatomy
- Ultrasound good looking at cysts and renal pelvis
- CT can look at perfusion, size and shape of kidneys
- MRI increasing use can combine some features of anatomy and function
3-D CT of renal vasculature

Concomitant Stenoses
MRI with contrast can look at renal function
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.
Renal Function? 24hrs GFR
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 from DMSA.
Structure of the nephron

- Glomerulus ("capillary bed" = network of blood capillaries)
- Efferent arteriole
- Proximal Convoluted Tubule (PCT)
- Distal Convoluted Tubule (DCT)
- Collecting Duct (leading to the pelvis of the kidney, also known as the "renal pelvis")
- Vasa Recta
- Descending limb of Henle
- Loop of Henle
- Ascending limb of Henle
- Bowmans Capsule
- Afferent arteriole
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
Structure of the nephron

- Glomerulus ("capillary bed" = network of blood capillaries)
- Afferent arteriole
- Efferent arteriole
- Bowmans Capsule
- Proximal Convoluted Tubule (PCT)
- Distal Convoluted Tubule (DCT)
- Collecting Duct (leading to the pelvis of the kidney, also known as the "renal pelvis")
- Renal Cortex
- Renal Medulla
- Descending limb of Henle
- Loop of Henle
- Ascending limb of Henle

Radioisotopes:
- Tc-99m MAG3
- Tc-99m DTPA
- Tc-99m DMSA
- Cr-51 EDTA
Even Tc-99m MDP in 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
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
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 despite Furosemide
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?
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 over 5 and adults less clear
• But can be combined with GFR to predict GFR after nephrectomy
5 year old with Hx of UTIs
Quantifying uptake
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
• For girls 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
Horseshoe kidney
Functional Imaging

Isotope Cystography

- Contrast 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 cooperation
Reflux study
Reflux in a duplex kidney

Arrows show episodes of yo-yo reflux form lower to upper moiety
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 ACEdrive on affected kidney
• Delayed peak, reduced divided function and delayed parenchymal transit
Renogram in RAS (on ACEI)

- Parenchymal retention
- Delayed peak
- Reduced divided function
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 for captopril study

- 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
- Erect image post-void
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
Perfusion Index
Hilson 1976!

Since 1976
• FNA/biopsy have become safer
• New drugs have slowed down rejection
Results

CHANGE Is Important
Early phases
ATN – MAG3
“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>
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<th>Recurrent UTIs (%)</th>
<th>Controls (%)</th>
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<tr>
<td></td>
<td>Reflux</td>
<td>No reflux</td>
</tr>
<tr>
<td>N</td>
<td>15</td>
<td>17</td>
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<tr>
<td>No scars</td>
<td>2 (13)</td>
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<td>One focal defect</td>
<td>5 (33)</td>
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<tr>
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<td>2 (13)</td>
<td>3 (18)</td>
</tr>
<tr>
<td>&gt;Two focal defects</td>
<td>6 (40)</td>
<td>5 (29)</td>
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<tr>
<td>Any focal defect</td>
<td>13 (87)</td>
<td>11 (65)</td>
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<tr>
<td>Segmental defect</td>
<td>0 (0)</td>
<td>0 (0)</td>
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Dupont et al
DMSA SPECT in Tx

A=scar, B=rejection, C=vascular damage
How many transplants?
Summary

• Renal nuclear medicine provides unique functional information
• Different studies assess different aspects of renal function
• Studies are quantifiable and so can be used to compare patients and over time within a patient
• Does not need fancy equipment like PET