Nuclear Medicine in Australia

Shaun Jenkinson
Landmark Infrastructure for Australian Science

OPAL Research Reactor
Australian Synchrotron
Camperdown Cyclotron
Bragg Institute
Centre for Accelerator Science
Other Science Facilities
OPAL Research Reactor

20MW Open Pool Australian Light water reactor

Replaced the 10MW HIFAR research reactor (1958 - 2007)

Reached criticality in August 2006

Low enriched fuel

Safe and productive operation for 8 years
OPAL – Multipurpose Reactor

Radioisotope production

Neutron science research

Silicon irradiation
2 million doses of nuclear medicine are manufactured each year at ANSTO
Ionising Radiation in Medicine

- **Medical diagnostic**
  - 0.8 mSv
  - 35%
- **Potassium-40 in the body**
  - 0.2 mSv
  - 9%
- **Uranium / Thorium in the body**
  - 0.2 mSv
  - 8%
- **Radon progeny**
  - 0.2 mSv
  - 9%
- **Terrestrial**
  - 0.6 mSv
  - 26%
- **Cosmic rays**
  - 0.3 mSv
  - 13%

**Australian annual per capita radiation dose from natural and medical sources**

Source: ARPANSA
Monitoring Treatment
Therapy
Comparison of Radiotherapy Treatments

- X-rays (20 MeV)
- X-rays (4 MeV)
- Electrons (4 MeV)
- Protons (200 MeV)
- Carbon Ions (4.8 GeV)
Interventional Procedures
# Nuclear Medicine scans

<table>
<thead>
<tr>
<th>Type of Diagnostic Scan</th>
<th>Used for</th>
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<tr>
<td>Bone scan</td>
<td>Bone pain, musculo-skeletal problems, metastatic cancer (lung, breast, prostate, etc)</td>
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<tr>
<td>Lung scan</td>
<td>Blood clots in lungs, lung function</td>
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<tr>
<td>Renal scan</td>
<td>Individual kidney function, obstruction, post-transplant function of implanted organ</td>
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<tr>
<td>Thyroid scan</td>
<td>Goitre, thyroid function (hypo- &amp; hyper-), thyroid cancer</td>
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<tr>
<td>Gastric emptying</td>
<td>Measure transit of food through stomach – gastric motility disorders</td>
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<tr>
<td>PET FDG scan</td>
<td>Mostly staging cancer – lung, colon, brain, head and neck, uro-gynae, lymphoma</td>
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<tr>
<td>Myocardial perfusion scan</td>
<td>Detecting compromises in blood flow (perfusion) at rest and during exercise</td>
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<tr>
<td>Liver scan</td>
<td>Measure liver function – bile duct obstruction? Hepatic failure?</td>
</tr>
<tr>
<td>Adrenal scan</td>
<td>Distinguish between hyperactive adrenal gland(s) and functioning tumour</td>
</tr>
<tr>
<td>PET DOTATATE scan</td>
<td>Assess function of tumours of neuro-endocrine origin</td>
</tr>
<tr>
<td>Cardiac function</td>
<td>Measure pumping ability of heart – often compromised by some chemotherapy (eg Herceptin)</td>
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</table>
Why do we need different radiopharmaceuticals?
ANSTO produces the different medical isotope products that are needed for different indications

<table>
<thead>
<tr>
<th>Product</th>
<th>Indication</th>
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<tr>
<td>Mo-99</td>
<td>Bulk export to other countries for production of Technetium generators</td>
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<tr>
<td>Gentech /Tc-99m</td>
<td>Organ imaging of the liver, lung, bone, kidney &amp; heart</td>
</tr>
<tr>
<td>(Technetium generators)</td>
<td></td>
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<tr>
<td>Sodium Iodide I-131</td>
<td>Treatment of hyperthyroidism &amp; thyroid cancer</td>
</tr>
<tr>
<td>Quadramet Sm-153</td>
<td>The relief of bone pain in patients with painful osteoblastic skeletal metastases</td>
</tr>
<tr>
<td>Chromium Cr-51</td>
<td>The determination of GFR rate (renal function)</td>
</tr>
<tr>
<td>Lutetium-177</td>
<td>Treatment of neuroendocrine tumours</td>
</tr>
<tr>
<td>Gallium: Ga-67</td>
<td>Scans for Hodgkin’s Disease, lymphomas and bronchogenic carcinoma. Acute infections</td>
</tr>
<tr>
<td>Gallium: Ga-68</td>
<td>Scans for neuroendocrine tumours – diagnosis, staging and monitoring of therapy</td>
</tr>
<tr>
<td>mIBG I-123</td>
<td>Detection, staging and follow-up of neuroblastomas.</td>
</tr>
<tr>
<td>Thallium TI-201</td>
<td>Myocardial perfusion imaging</td>
</tr>
<tr>
<td>^18F-FDG</td>
<td>Diagnosis, staging and monitoring of cancer treatment</td>
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## Supply chain

<table>
<thead>
<tr>
<th>OPAL Reactor</th>
<th>Processing Plant (ANM)</th>
<th>Global distribution</th>
<th>Local distribution of finished goods</th>
<th>Hospital and Pharmacy</th>
<th>Clinical Imaging</th>
<th>Health Outcomes</th>
</tr>
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<tr>
<td>LEU $^{235}$ targets irradiated in OPAL</td>
<td>Mo-99 separated and purified</td>
<td>Bulk Mo-99 shipped to meet global demand</td>
<td>Tc-99m Generators dispensed and transported</td>
<td>Tc-99m eluted and combined with cold kits</td>
<td>Product administered to patients for imaging</td>
<td>Imaging helps diagnosis &amp; leads to appropriate treatments</td>
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### Supply Chain Challenges
- **LEU $^{235}$ targets irradiated in OPAL:** 7-12 days
- **Mo-99 separated and purified:** 1 day
- **Bulk Mo-99 shipped to meet global demand:** 1 day
- **Tc-99m Generators dispensed and transported:** 1 day
- **Tc-99m eluted and combined with cold kits:** 5 minutes
- **Product administered to patients for imaging:** -
- **Imaging helps diagnosis & leads to appropriate treatments:** -
World supply under threat

- Canada: 40% - NRU
- Netherlands: 30% - HFR
- Belgium: 10-15% - BR
- South Africa: 10-15% - SAFARI
- Poland: 5% - Maria
- Australia: < 5% - ANSTO
- France: 10-15% - OSIRIS
- NRU: 40% - Closing
- Other facilities: 10-15% - Closing
ANSTO’s Nuclear Medicine Project

The Australian Nuclear Medicine Facility will supply Mo-99 to Australian and global communities. Australian Government investment of $168.8 M was announced in 2012.
**What are Neuroendocrine Tumours (NETs)?**

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<th>Relatively rare tumours that arise from the diffuse neuroendocrine system</th>
<th>Many are clinically silent or have non-specific symptoms, leading to delayed diagnosis</th>
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<td>Patients often have tumours that are indolent and progress slowly over several years.</td>
<td>Therefore majority of patients present with metastatic disease (&gt;60–80%)</td>
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![Pie chart showing the distribution of NETs by location](chart.png)

- **Small intestine**
- **Rectum**
- **Appendix**
- **Colon**
- **Stomach**
- **Pancreas**
So how well does it work?

Baseline FDG PET | Post-Lu-177 octreotate | 2 years later
So how well does it work?

Serial FDG PET/CT

baseline
post chemo
mid-LuTate
+3 months
ANSTO will be producing Lu-177 from the middle of 2014
Refractory Neuroblastoma

Prior multiple lines of chemotherapy \((\text{NBL06/TVD})\), phase 1 trial \((\text{hedge-hog inhibitor})\), MIBG

**Progressing rapidly**

 Courtesy Dr Michael Hofman, Peter Mac
Response to Lu-177 + temozolomide

Baseline

2 months post LuTate + temozolomide

Returned to school

Courtesy Dr Michael Hofman, Peter Mac
Response to Lu-177 + temozolomide

Sustained response with 18 months follow-up

Courtesy Dr Michael Hofman, Peter Mac
Thank you