AUSTRALIAN ACHIEVEMENTS IN NUCLEAR & RELATED TECHNOLOGIES IN MEDICAL IMAGING

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Department of Nuclear Medicine • Royal North Shore Hospital
Professor in Medical Radiation Sciences • University of Sydney
Sydney • AUSTRALIA
Ionising Radiation in Medicine

Australian annual per capita radiation dose from natural and medical sources

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

Source: ARPANSA
Where is Ionising Radiation Used in the Hospital?

DIAGNOSTIC IMAGING
Where is Ionising Radiation Used in the Hospital?

MONITORING

TREATMENT

Pre-Tx  Lymphoma  +9 months

Pre-RTx  +3 months

Pre-Tx  +4 months

Lung Cancer
Where is Ionising Radiation Used in the Hospital?

THERAPY
Where is Ionising Radiation Used in the Hospital?

INTERVENTIONAL PROCEDURES
Where is Ionising Radiation Used in the Hospital?

GUIDING SURGERY & BIOPSY
Where is Ionising Radiation Used in the Hospital?
AAEC (1953-1983)
ANSTO (1984-)
KURSUS NASIONAL APLIKASI TEKNIK NUKLIR
DALAM BIDANG KEDOKTERAN
BANDUNG, 23 MEI - 3 JUNI 1988
MEDICAL ISOTOPE PRODUCTION WITHOUT HIGHLY ENRICHED URANIUM

Committee on Medical Isotope Production Without Highly Enriched Uranium
Nuclear and Radiation Studies Board
Division of Earth and Life Studies
NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES
THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

Summary

This report is the product of a congressionally mandated study to examine the feasibility of eliminating the use of highly enriched uranium (HEU) in reactor fuel, reactor targets, and medical isotope production facilities. The report focuses primarily on the use of HEU for the production of the medical isotope molybdenum-99 (Mo-99), whose decay product, technetium-99m (Tc-99m), is used in the majority of medical diagnostic imaging procedures in the United States, and secondarily on the use of HEU for research and test reactor fuel.

This summary is organized around the four study charges provided by Congress and a fifth study charge negotiated between the National Academies and the study sponsor, the Department of Energy’s National Nuclear Security Administration (DOE-NNSA). The fifth charge was formally approved by the sponsor and the National Academies prior to the start of the study. The complete study charge is given in Sidebar 1.2.

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1The study was mandated by Section 630 of the Energy Policy Act of 2005 (Public Law 109-58). See Appendix A.

2HEU is uranium enriched in uranium-235 (U-235) to concentrations greater than or equal to 20 weight percent. Uranium enriched in U-235 to concentrations less than 20 weight percent is low enriched uranium (LEU); see Sidebar 1.1.

3The “m” denotes that this radionuclide is metastable.
ACHIEVEMENTS - Radiopharmaceuticals

- “Skeltec”: AAEC Radioisotopes Division -1972
  - One of the first $^{99m}$Tc labelled bone scanning agents
  - Revolutionised bone scanning in nuclear medicine

- “Technegas” – $^{99m}$Tc labelled “carbon soot”
  - <200 nm nanoparticle – Tc in a carbon cage
  - Developed by William ‘Bill’ Burch at ANU Curtin School of Medicine - 1984
  - To date over 3,000,000 ventilation scans performed world-wide

Lung Ventilation Scan
Yttrium-90:
• Half-life: 64 hrs
• β- emitter (0.93 MeV average energy)

“first Australian product to gain FDA approval for a cancer therapy” (2002)
ACHIEVEMENTS – Image Reconstruction

- Mathematician, physicist & radio-astronomer
- University of Sydney: BSc (1941) ME (1943)
- Cambridge University: DPhil (1949)
- Tomographic image reconstruction from projections
- Fellow Royal Astronomical Society
- U.S. National Academy of Sciences in 1992 honoured Bracewell with foreign membership to its Institute of Medicine - the first Australian to achieve the distinction

Ron Bracewell (1921-2007)

Illustration of the 2D central-section theorem.
ACHIEVEMENTS – Image Reconstruction

Maximum Likelihood Reconstruction for Emission Tomography
L. A. SHEPP and Y. VARDI
1982 – Bell Labs

Accelerated Image Reconstruction using Ordered Subsets of Projection Data
H. Malcolm Hudson, Richard S. Larkin

Abstract – We define ordered subset processing for standard algorithms (such as Expectation Maximization, EM) for image restoration from projections. Ordered subsets methods group projection data into an ordered sequence of subsets (or blocks). An iteration of ordered subsets EM is defined as a single pass through all the subsets, in each subset using the current estimate to initialize application of EM within that data subset.

This approach is similar in concept to block-Kaczmarz methods introduced by Kaczmarz et al [1] for iterative reconstruction. Simultaneous iterative reconstruction (SIRT) and multiplicative algebraic reconstruction (MART) technique are well known special cases. Ordered subsets EM (OS-EM) provides a restoration imposing a natural positivity condition and with close links to the EM algorithm.

OS-EM is applicable in both single photon (SPECT) and positron emission tomography (PET). In simulation studies in SPECT the OS-EM algorithm provides an order-of-magnitude acceleration over EM, with restoration quality maintained.

Keywords – EM algorithm, emission tomography, MART, OSL algorithm.

2014 IEEE Marie Sklodowska-Curie Award to Larry Shepp (d. Apr 2013), Malcolm Hudson and Brian Hutton
ACHIEVEMENTS – ‘Hybrid’ Imaging

• ANSTO produced $^{153}$Gd in HIFAR for SPECT transmission source – 1984
• First simultaneous measurement of body density (“low quality CT”) and radionuclide distribution

Development of a cost-effective modular SPECT/CT scanner

Dale L. Bailey • Paul J. Roach • Elizabeth A. Bailey • James Hewlett • Ronnie Keijzers

CT: 130kVp, 30mA, 4mm slices
SPECT: 30 min acq

Post left adrenalectomy  \(^{[131I]}\)-mIBG
2008

Quantitative SPECT reconstruction using CT-derived corrections

Kathy Willowson\textsuperscript{1,2}, Dale L Bailey\textsuperscript{1,2,3} and Clive Baldock\textsuperscript{1}

\textsuperscript{1} Institute of Medical Physics, School of Physics, University of Sydney, Camperdown, NSW 2006, Australia
\textsuperscript{2} Department of Nuclear Medicine, Royal North Shore Hospital, St Leonards, NSW 2065, Australia
\textsuperscript{3} Faculty of Medicine and Discipline of Medical Radiation Sciences, Faculties of Health, University of Sydney, Lidcombe, NSW 2141, Australia

2013

An Evidence-Based Review of Quantitative SPECT Imaging and Potential Clinical Applications

Dale L. Bailey\textsuperscript{1,2} and Kathy P. Willowson\textsuperscript{3}

\textsuperscript{1} Department of Nuclear Medicine, Royal North Shore Hospital, St. Leonards, Australia; \textsuperscript{2} Discipline of Medical Radiation Sciences, University of Sydney, Sydney, Australia; and \textsuperscript{3} School of Physics, University of Sydney, Sydney, Australia

Learning Objectives: On successful completion of this activity, participants should be able to (1) review the current status of SPECT imaging, with an emphasis on clinical applications for quantitative interpretations; (2) consider the requirements for quantitative SPECT imaging—instrumentation, software, and image calibration; and (3) acquire knowledge of the capabilities of quantitative SPECT with a view to developing new clinical applications.
ACHIEVEMENTS – Education & Training

1989

1991

2009

National Imaging Facility

FOUNDATIONS OF PET-CT

Sixth annual comprehensive training course for nuclear medicine professionals

2013
ACHIEVEMENTS – Education & Training

IAEA African Training Course 2009

IAEA Latin American Training Course 2011

Department of Technical Cooperation (TC)
End-of-Mission Report

<table>
<thead>
<tr>
<th>Title:</th>
<th>Fact finding mission on current status of clinical practice of Nuclear Medicine and Diagnostic Imaging</th>
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<tr>
<td>Project Number:</td>
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<tr>
<td>Project Title:</td>
<td>Urgent Needs for Diagnostic Imaging &amp; Therapeutic Oncology services in Oman</td>
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<tr>
<td>Name of Expert:</td>
<td>(1) Dale Bailey (Sydney) (2) Giuliano Mariani (Pisa)</td>
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<td>Dates of Mission:</td>
<td>Dec 5-9, 2009</td>
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| Counterpart:      | Professor Hadj Slimane Cherif
|                   | Head-Peaceful Nuclear Technology Office                                                        |
|                   | Ministry of Foreign Affairs                                                                    |
|                   | Sultanate of Oman                                                                              |
Meeting the Challenges of Global Nuclear Medicine Technologist Training in the 21st Century: The IAEA Distance Assisted Training (DAT) Program

Heather E. Patterson, CNMT, Margarita Nunez, PhD, CNMT, Geraldine M. Philotheou, MSc, and Brian F. Hutton, PhD

Table 2 Number of Students and Locations Participating in the DATOL Program (Estimated Mid 2012)

<table>
<thead>
<tr>
<th>Regions/Countries</th>
<th>Part 1</th>
<th>Part 2</th>
<th>Part 1 Offline</th>
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<tr>
<td>Total</td>
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</table>

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TRAINING & SERVICE PROVISION
- Medical Training – second-to-none, often complemented by overseas training
- Physics training – improving, always strong in R&D
- Allied health technologists – world-leading in education; have exported our training programmes throughout SE Asia and continue to do so
- Pharmaceutical and radiochemical sciences – historically not university based, built around ANSTO (not CSIRO) or research institutes

RESEARCH OUTPUT
- “punching above our weight”

IMAGING EQUIPMENT AND FACILITIES
- Generally good but, due to the capital sums involved, can be left wanting when solely funded by State Governments

REGIONAL VARIATIONS
- State-based funding means very different treatments can be offered between states (e.g., NSW vs VIC); geography imposes further constraints (e.g., NT)

ACCESS TO DIAGNOSTIC IMAGING AGENTS
- Trailing rest of world
Australia is starved of contemporary practice in radiopharmaceuticals:

- Many diagnostic imaging tests are tightly restricted even for approved radiopharmaceuticals
  - e.g., cannot use FDG PET in breast cancer where indications are very strong
- Extremely difficult & expensive process for Medicare funding (TGA, Medical Services Advisory Committee approval usually takes many years)
- Demand to replicate expensive randomised clinical trials in Australia when product already approved in USA and Europe (often impossible due to small population)
- No training programme or accreditation for radiopharmacy practitioners
We Need to be SMART

› **S**elect the most appropriate radiopharmaceutical available to answer the clinical question – not just the one that has the Medicare approval

› **M**ove to a funding model that allows cost savings in downstream areas (e.g., planned surgery that would be futile) to be incorporated into overall cost analysis of the imaging study

› **A**llow collection of data for potential new indications with partial funding under agreements to contribute to larger data collection exercise

› **R**eview high-level clinical data with solid evidence as it becomes available from overseas studies without requiring replication in clinical trials locally

› **T**rain the next generation of radiopharmaceutical scientists
“The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them.”

- Sir W. Lawrence Bragg