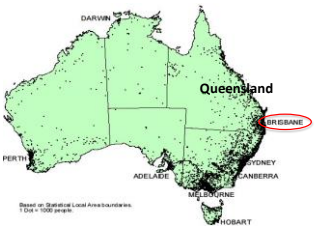
Radiation dose optimisation in medical imaging – an Australian Perspective

Daniel Schick

Some context



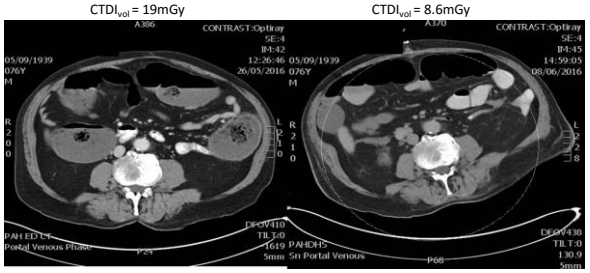
Source: http://rgths.unisa.edu.au/student/prep_rural_prac/1-major_issues.htm

- Biomedical Technology Services – Queensland Health (Government)
- 16 (imaging) medical physicists across Queensland (pop. 4.7 million)
- 5 certified by ACPSEM
- Australia - New Zealand: 36 certified/registered in radiology
- About 1000 CT scanners across Australia

Outline

- History and what motivates us
- Current status and projects
  - CT
    - National DRLs
    - Profession led projects
    - Local work
  - Interventional Fluoro
  - Nuclear Medicine

$CTDI_{vol}$ = 19mGy $CTDI_{vol}$ = 8.6mGy



Same patient (WED 33cm) – Imaged 2 weeks apart on
Siemens Definition Flash units in ED then Main Department

Australian Law

ARPANSA RPS No.14 (Code of Practice)

3.1.8 The Responsible Person must establish a program to ensure that radiation doses administered to a patient for diagnostic purposes are:

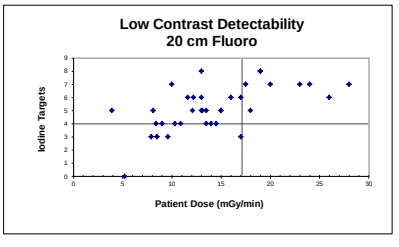
(a) periodically compared with **diagnostic reference levels (DRLs)** for diagnostic procedures for which DRLs have been established in Australia; and

(b) if DRLs are consistently exceeded, reviewed to determine whether radiation protection has been optimised.

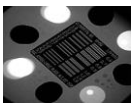
Australian MDCT DRLs Est. 2011/12
NM, Interventional Fluoro and Mammography "Late 2016"

5

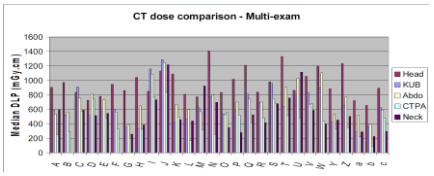
Fluoroscopic dose variation – Cardiac Cath Lab Benchmarking Program (2004-2011)



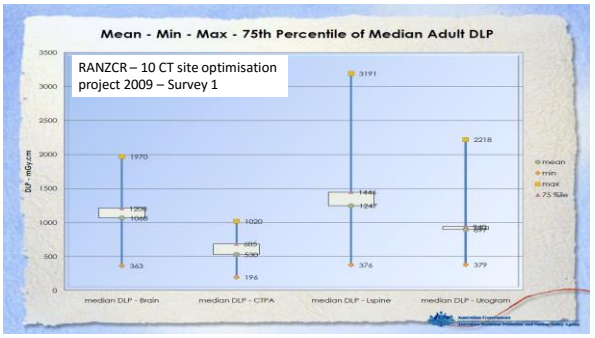
NEMA XR-21 Phantom

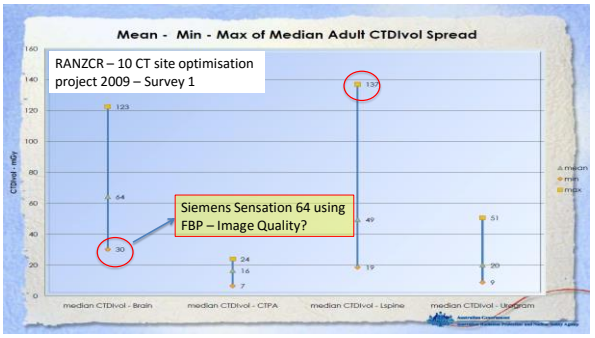


CT dose variation – Queensland (Australia) Public Hospital Survey – 2010



Exam	Min. DLP	Max. DLP	Range
Head	654	1407	x 2.2
Abdo/pelvis	388	1249	x 3.2





Landmark Australian CT Risk Research

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

OPEN ACCESS

BMJ 2013;346:f2360 doi: 10.1136/bmj.f2360

John D Mathews *epidemiologist*[1], Anna V Forsythe *research officer*[1], Zoe Brady *medical physicist*[1,2], Martin W Butler *data analyst*[1], Stacy K Goergen *radiologist*[3], Graham B Byrnes *statistician*[1], Graham G Giles *epidemiologist*[4], Anthony B Wallace *medical physicist*[5], Philip R Anderson *epidemiologist*[6,7], Tenniel A Guiver *data analyst*[8], Paul McGale *statistician*[9], Timothy M Cain *radiologist*[10], James G Dowty *research fellow*[1], Adrian C Bickerstaffe *computer scientist*[1], Sarah C Darby *statistician*[1]

Conclusions The increased incidence of cancer after CT scan exposure in this cohort was mostly due to irradiation. Because the cancer excess was still continuing at the end of follow-up, the eventual lifetime risk from CT scans cannot yet be determined. Radiation doses from contemporary CT scans are likely to be lower than those in 1985-2005, but some increase in cancer risk is still likely from current scans. Future CT scans should be limited to situations where there is a definite clinical indication, with every scan optimised to provide a diagnostic CT image at the lowest possible radiation dose.

Computed Tomography
How is Australia Faring?

DLP/CTDI$_{vol}$ National DRLs

	Brain	Abdo-Pelvis	Note
Australia	***1000/60***	***700/15***	
Japan	1350/85	1000/20	50-60kg patient
United Kingdom	970/60	745/15	
USA	NA/75	NA/25	NCRP 172

Representative of all scanners ?

Australian CT radiation doses

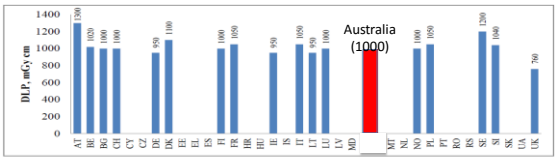


Figure 2.15. Comparison of DRLs for CT head in terms of DLP, mGy·cm.

RADIATION PROTECTION N° 180

Diagnostic Reference Levels in Thirty-six European Countries

Part 2/2

Current CT NDRLs

Australian Adult (15+ years) MDCT Diagnostic Reference Levels

Adult Protocol	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)
Head	1000	60
Neck	600	30
Chest	450	15
AbdoPelvis	700	15
ChestAbdoPelvis	1200	30
Lumbar Spine	900	40

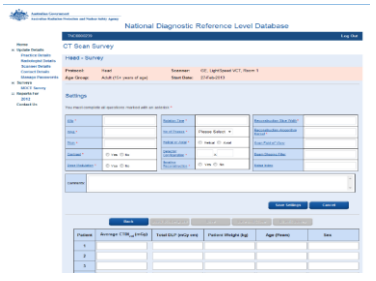
Australian Child (5-14 years) MDCT Diagnostic Reference Levels

Child Protocol	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)
Head	600	35
Chest	110	5
AbdoPelvis	390	10

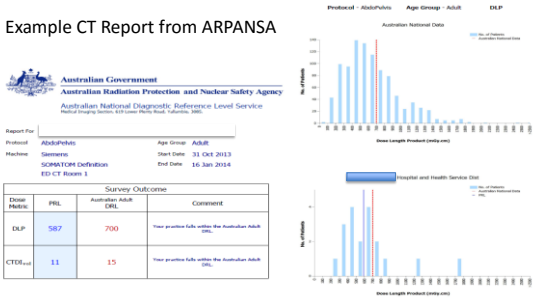
Australian Baby (0-4 years) MDCT Diagnostic Reference Levels

Baby Protocol	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)
Head	470	30
Chest	60	2
AbdoPelvis	170	7

- Australian CT DRL interface
- Manual data entry
- Up to 20 patients



Example CT Report from ARPANSA



Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Australian National Diagnostic Reference Level Service

Report For:

Protocol	AbdoPelvis	Age Group	Adult
Machine	Siemens	Start Date	31 Oct 2013
	SOMATOM Definition	End Date	16 Jan 2014
	ED CT Room 1		

Survey Outcome

Dose Metric	PRL	Australian Adult DRL	Comment
DLP	587	700	Your practice falls within the Australian Adult DRL.
$CTDI_{vol}$	11	15	Your practice falls within the Australian Adult DRL.

Australian CT DRL data – Dose changes

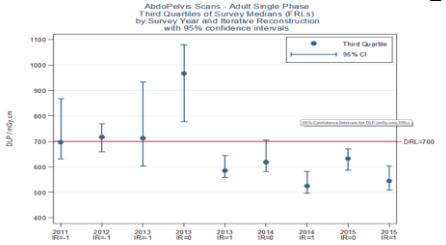


Figure 6: 95% Confidence Intervals for DLP (mGy.cm) DRLs - AbdoPelvis Scans - Adult Single Phase

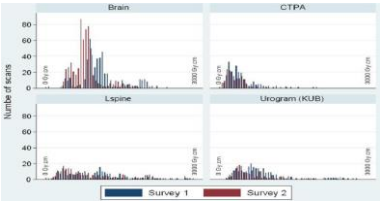
Professional college initiatives: Royal Australian and New Zealand College of Radiologists (RANZCR)

- State based CT dose optimisation projects
- Conducted 2009-2012 in Queensland, Victoria and South Australia (10 to 20 sites each)
- Intensive data collection/ one day workshop/ re audit
- Funded approximately $200K per state

Multidetector CT Dose: Clinical Practice Improvement Strategies From a Successful Optimization Program

Anthony B. Wallace, MS[a], Stacy K. Goergen, MBBS[b], Daniel Schick, MS[c], Tina Soblusky, MS[a], Damien Jolley, PhD[a]

J Am Coll Radiol 2010;7:614-624.



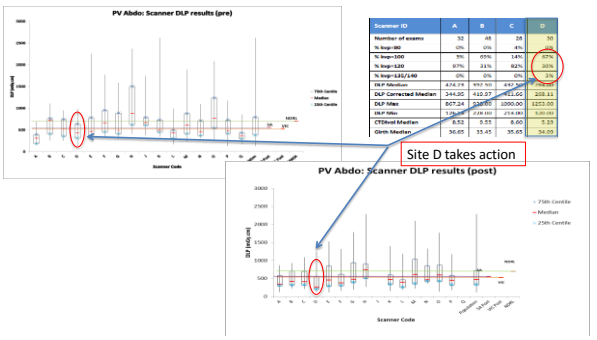
- Successful in achieving substantial dose reductions
- Unsustainable as a large scale intervention

AOCR 2012 (RANZCR led)

- Aims
  - To determine whether
    - Very limited but clinically achievable dose data collection
    - Benchmarking against peers
    - Brief face to face educational feedback with generic optimisation advice
    - **Site specific feedback material**

    Can result in clinically important CT dose reduction
- 16 sites from across Australia and New Zealand
- Vendor sponsored – free participation

Site Specific Feedback



What about the children?

- Big problem with:
  - Numbers of scans (non-specialist sites)
  - Data submission to national surveys
- Answer: Phantom scans

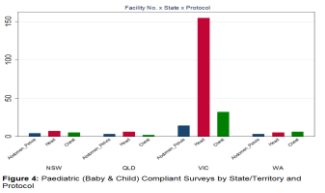
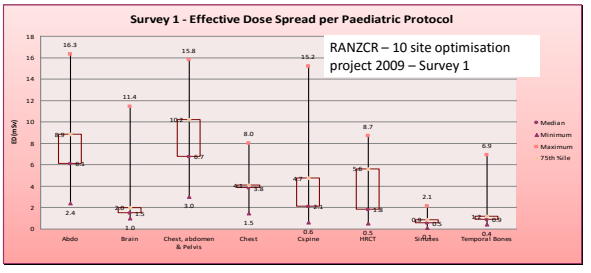
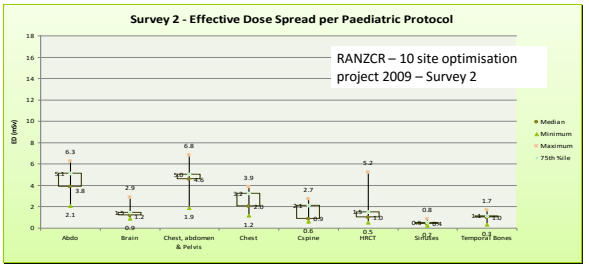


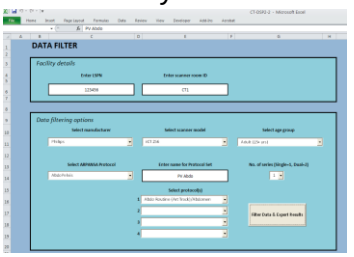
Figure 4: Paediatric (Baby & Child) Compliant Surveys by State/Territory and Protocol



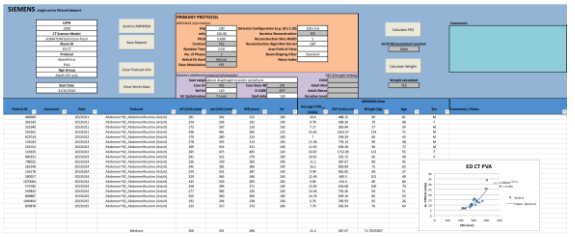


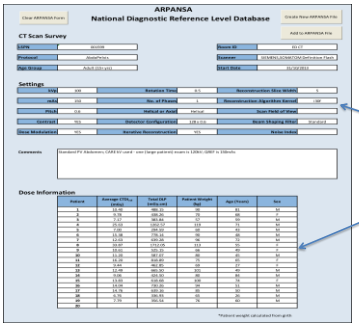
Local Projects - Improving data collection and analysis

- CT – Dose Survey Program (DSP)
- Australian government funded project
- Data from DoseUtility (David Clunie) or CARE Analytics (Siemens)



CT-DSP processing



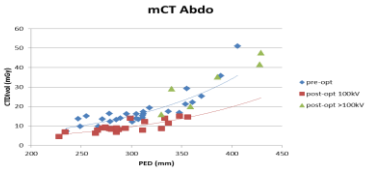


CT-DSP for ARPANSA NDRLD

Format and data cells exactly match ARPANSA WEB interface

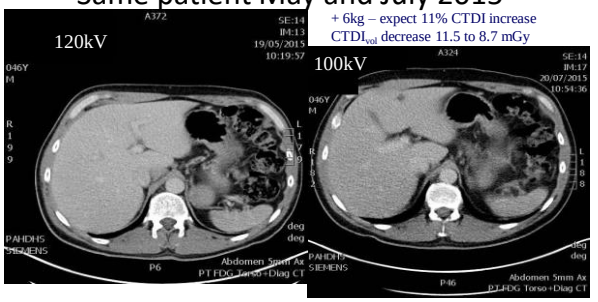
Local work - Pre and post optimisation data

- QRef reduced 250 to 200mAs (20% reduction)
- kV optimisation – most patients at 100kV with increased QRef for noise compensation.

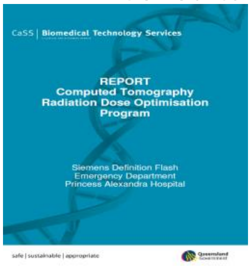


Same patient May and July 2015

+ 6kg – expect 11% CTDI increase
$CTDI_{vol}$ decrease 11.5 to 8.7 mGy



Consultancy service



CTCA

CTCA radiation dose cannot be definitively benchmarked against other sites due to a lack of (local) available data.

A total of 6 protocols are currently utilised for CTCAs. There are 3 body mass index ranges and these are applied across both Flash Spiral and conventional step and shoot (Sequence) protocols.

Optimisation of these protocols may be feasible through automatic kilovoltage adjustment by turning CarekV "on". Appending of a CarekV based series to the end of each existing protocol (but not scanning that series) will facilitate a process of recording the kV and dose outcomes expected with the introduction of CarekV versus the dose outcomes with existing protocols. It has been resolved through discussions with PAH representatives Dr John Coucher and Jit Pratap that this be implemented as a preliminary step to adjusting the existing protocols. It is anticipated that this process may provide confidence to implement CarekV such that a single Flash Spiral and single Sequence protocol can adequately accommodate any body size. In the first instance, the CarekV "bone" protocol is recommended for both Flash Spiral and Sequence with QRef set to the current 25-30BMI value of [redacted] for Flash and [redacted] for Sequence protocols.

A re-survey service is available for the purposes of demonstrating and quantifying changes in radiation dose associated with protocol optimisation work. For more information, clarification of the report details, or to arrange re-survey please contact the undersigned on 07 3406 8094 or daniel_schick@health.qld.gov.au.

Daniel Schick
Principal Medical Physicist
Biomedical Technology Services

16th March 2012

Acknowledgements

Thanks to Mr Gordon Mander for his assistance in the production of this work

Interventional fluoroscopy

- Preliminary survey from 2013 – very limited range of exams
- (Official) NDRLs not yet published

	Sex	Age (yrs)	Weight (kg)	Fl Time (sec)	Fr Rate (fr/sec)	DA Time (sec)	Frames	DAP (Gy.cm^2)	Ref Dose (Gy)	Access Site (R/F)
Patient 1	Female	78	74	230	15	56	761	27	0.379	Radial
Patient 2	Male	74	85	629	15	81	995	112	1.346	Femoral
......										
Patient 30	Female	85	55	464	15	100	1077	42	0.782	Femoral

- Difficulty with procedure definition

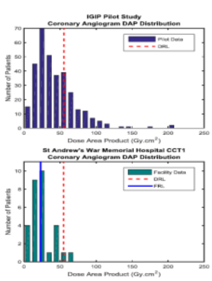
> "Patients with 'Normal' Coronaries. For purposes of definition, 'normal' coronaries are defined as those with no or physiologically insignificant diameter stenosis (<50% coronary diameter narrowing) by visual inspection in patients studied specifically to assess coronary anatomy."

Example IGIP report from ARPANSA

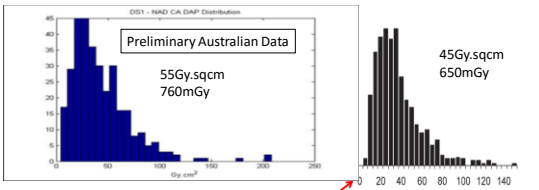
Australian Government
Australian Radiation Protection and Nuclear Safety Agency
Australian National Diagnostic Reference Level Service
Image Guided Interventional Procedures Survey

Report For			
Protocol	Coronary Angiogram	Age Group	Adult (15+ years)
Machine	Toshiba Infinix Cci	Room	CCT1
Submission Date	12/05/2015	Report Date	15/05/2015

Survey Outcome			
Dose Metric	FRL*	Draft DRL	Comment
DAP (Gy.cm²)	22.9	55	Your facility falls within the Draft Australian Adult DRL.
Ref Dose (Gy)	0.26	0.76	Your facility falls within the Draft Australian Adult DRL.



Coronary Angiogram KAP distribution



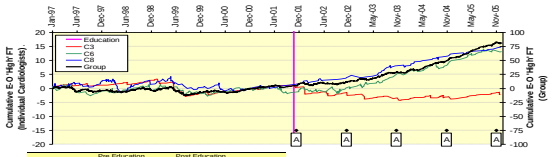
REFERENCE LEVELS AT EUROPEAN LEVEL FOR CARDIAC INTERVENTIONAL PROCEDURES

R. Padovani[1]*, E. Vano[2], A. Trianni[3], C. Bokou[2], H. Bosmans[4], D. Bor[5], J. Jankowski[6], P. Torbica[7], K. Kepka[8], A. Dowling[9], C. Milu[10], V. Tsapaki[11], D. Sulej[12], J. Vassileva[13] and K. Faulkner[14]

Figure 4. Frequency distribution of air KAP for CA procedures.

Radiation Protection Dosimetry (2008), Vol. 129, No. 1–3, pp. 104–107

CCL clinician performance impact – Fluoro time exceeding 75th percentile

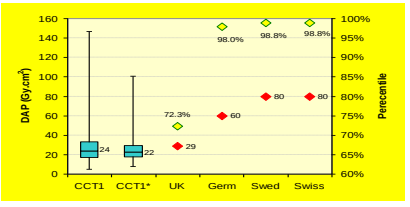


Cardiologist	Pre Education n	Pre Education FT (min)	Post Education n	Post Education FT (min)	p Value
C1	69	2.1 (1.7-2.7)	75	1.7 (1.5-2.1)	<0.001
C2	56	2.7 (2.2-3.5)	102	2.3 (1.9-3.5)	0.006
C3	123	1.4 (1.2-1.9)	131	1.3 (1.1-1.8)	ns
C4	152	2.1 (1.8-2.8)	160	1.6 (1.4-2.4)	<0.001
C5	154	1.8 (1.5-2.5)	106	1.5 (1.3-2.0)	<0.001
C6	124	2.1 (1.8-2.8)	199	1.8 (1.4-2.4)	<0.001
C7	63	2.1 (1.9-3.2)	50	2.0 (1.6-2.4)	ns
C8	160	2.0 (1.6-2.7)	100	1.5 (1.3-1.9)	<0.001
C9	87	2.5 (2.1-3.4)	78	2.0 (1.8-2.5)	0.005
C10	24	2.4 (1.9-3.2)	16	2.2 (1.8-3.1)	ns
Overall	1012	2.1 (1.6-2.8)	1017	1.7 (1.4-2.4)	<0.001

A = Clinician performance feedback

Courtesy of Ian Smith, St Andrew's Medical Institute, Brisbane Australia

Clinician feedback influence



Courtesy of Ian Smith, St Andrew's Medical Institute, Brisbane Australia

Nuclear Medicine and PET – National preliminary survey (ARPANSA)

Diagnostic Nuclear Medicine:

Oncology	Skeletal	Cardiovascular	Endocrine
Iodine whole body	3-phase bone	Rest/Stress MPI*	Parathyroid
MIBG	Limited bone	Gated heart pool	Thyroid - uptake
Bone	Whole body bone	Tl heart perfusion	Thyroid - imaging
Octreotide	Bone marrow		
Scintimammography			
Gallium scan			
Thallium			
DMSA(V)			
Sestamibi			
Infection	**Lymphatic**	**Pulmonary**	**Gastrointestinal**
Gallium scan	Sent. node (breast)	VQ**	Colonic transit
WBC	Sent. node (mel.)	VQ SPECT**	GI bleed
Indium oxine	Drainage/Flow	Lung reduction scan	Gastric emptying
			Hepatobiliary
			Meckel's diverticulum
			Small bowel transit
			Oesophageal transit
Nervous_System	**Genitourinary**	**Other**	
CSF shunt	DMSA renal		
CSF leak	DTPA renal		
Cerebral perfusion	MAG3 renal		
Brain	GFR		
	Cystography		

PET categories
Primary oncology
Metastatic oncology
Skeletal
Cardiovascular
Infection
Endocrine
Nervous system
Other (please specify)

Therapy Categories
131I for thyroid ablation
131I for hyperthyroid
Therapy with 131I MIBG
Peptide Receptor Radionuclide Therapy (PRRT)
Selective Internal Radiation Therapy (SIRT)
Polycythaemia vera
Bone metastases (palliation)
Radiosynovectomy
Radioguided surgery
Other (please specify)

* If possible, please make the two activities that were administered to an individual patient clear. e.g. rest/stress MPI 300/900 MBq

** Only record the perfusion agent in the survey

Please help us complete the UNSCEAR survey by using the specified categories and scan types.

NM data collection

Diagnostic Nuclear Medicine Procedures

*Please use the entries from the drop down lists (where appropriate). If a suitable value isn't listed, enter it manually in an equivalent format.

Date	Category*	Scan Type*	Isotope*	Chemical form*	Activity (MBq)	Gender	Age	Weight (kg)	CT (DLP)		
									Diagnostic	Attenuation	Body Region
18/08/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	MIBI	250/600	F	42	55		250	Torso
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	198.1	M					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	215	M					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	193.7	F					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	218	M					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	198.6	F					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	220	M					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	220	F					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	196.3	M					
3/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	837	M					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	202	F					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	196	F					
3/11/2014	Genitourinary	MAG3 renal	Tc_99m	MAG3	217	F					
3/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	862	M					
3/11/2014	Lymphatic	Sent. node (breast)	Tc_99m	Nanocolloid	26.6	F					
3/11/2014	Lymphatic	Sent. node (breast)	Tc_99m	Nanocolloid	26.6	F					
4/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	311/968	M				198	chest
4/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	324/973						
4/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	397	M				112	sarcoid - rest
4/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	316/971	F					
4/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	843	F					
4/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	807						
4/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	870	M					
5/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	842	M					
5/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	404/1157	M				494	chest
5/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	325/943	F					
5/11/2014	Cardiovascular	Rest/Stress MPI*	Tc_99m	Tetrafosmin	325/959	M					
5/11/2014	Skeletal	Whole body bone	Tc_99m	MDP/HDP	841					289	Bone - SIJ

Attenuation = Atttenuation + Localisation

Isotopes	Forms
Tc_99m	Chloride
	Colloid
	DMSA
	DMSA(V)
	DTPA
	HIDA
	HMPAO
	MAA
	MAG3
	MDP/HDP
	MIBI
	Nanocolloid
	Pertechnetate
	PYP
	RBCs
	WBC-colloid
In_111	DTPA
	Leucocytes
	Octreotide
Ga_67	Citrate
Tl_201	Chloride
I_123	Iodide
	MIBG
I_131	Iodide
	MIBG

Australian Government
Australian Radiation Protection and Nuclear Safety Agency
National Diagnostic Reference Level Service
Nuclear Medicine Survey

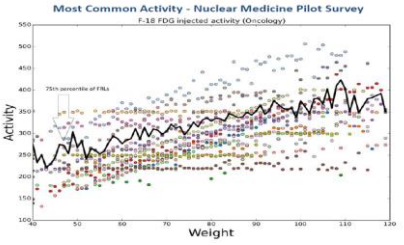
Preliminary Report

Facility Name:
LSPN: 001599
Survey Period: 03/11/2014 - 28/11/2014
Report Generated on: 09/07/2015

Most common activity (MCA) and reference activity (RA)

Category	Scan	Isotope	Form	# Scans	Activity (MBq)		MCA (MBq)	RA (MBq)
					Mean	σ		
Cardiovascular	Rest/Stress MPI*	Tc-99m	Tetrofosmin	33	1274.5	60.0	1200 - 1400	1430 - 1740
	Single phase MPI	Tc-99m	Tetrofosmin	2	353.5	61.5	600	900
Endocrine	Parathyroid	Tc-99m	MIBI	5	822.0	23.4	800	900
	Thyroid	Tc-99m	Pertechnetate	9	209.8	10.7	200	200
Gastrointestinal	Gastric emptying	Ga-67	Citrate	1	10.1		8	20
	Hepatobiliary	Tc-99m	HIDA	4	209.7	8.0	200	200

Collated PET data



Courtesy of ARPANSA

Summary/Conclusions

- Australia has law requiring CT dose review
- Other modalities soon to be included
- Media has caught on much like elsewhere
- Some/limited evidence of widespread dose reduction – particularly in CT
- Limited knowledge of typical doses for other modalities
- Much to do!