

Radiation Protection of the Australian Public via the Introduction of a National Diagnostic Reference Level Scheme.

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Abstract

Diagnostic imaging is required to be undertaken using the constraints of appropriate referral, justification and optimisation strategies to ensure a positive risk-benefit outcome for the patient. While the radiation insult from the high dose imaging procedures may give rise to some limited increase in stochastic risk and the expression of deterministic damage particularly in the case of high dose interventions, the additional risk to the patient remains supportable when compared to the risk of not having the investigation(s). However, there may be an impact at the national level contributing to an increase of radiation risk at a population health level.

Australia currently does not have a state/territory or national patient medical record system. It is therefore very difficult to gain any complete and accurate information on a patient's exposure history as they move across medical institutions. In the absence of this information, one compensatory strategy is to support the imaging practices in ensuring that the doses that are delivered are within a reasonable range when compared to that of their peers. This support can be achieved with the application of diagnostic reference levels at a national level.

The Australian Radiation Protection And Nuclear Safety Agency (ARPANSA) national Diagnostic Reference Level is the 75th percentile (third quartile) of the spread of the median doses of common protocols from a national survey of imaging practices. A local practice reference level (PRL) is defined as the median value of the spread of doses for common protocols surveyed at the local radiology practice for 20 patients. The development of DRLs will be derived from a nationwide survey of local PRLs which, it is assumed, have produced images of acceptable diagnostic quality as defined by the reporting specialist.

It is envisaged that future practice submissions to the NDRL survey should reflect an appropriate dose reduction.

Key Words

Diagnostic reference level, caput dose, optimisation

Introduction

It is well recognised that the greatest source of patient dose from diagnostic imaging is from multi-detector computed tomography (MDCT) [1].

MDCT has many advantages to offer radiology investigations and its uses and applications are significantly increasing. The rapidly increasing growth of applications of MDCT scanning has the unwanted outcome of a significant increase in population cumulative effective dose [2]. The development of the technology in terms of its power, flexibility, utility, ease of use and image quality has resulted in an exponential increase in its application in virtually all fields of clinical practice. While the dose to the individual and the consequent risk is relatively low, the increasing imaging and therapeutic applications across the population is becoming an increasing public health concern due to the escalating risks of the expression of stochastic effects¹.

In the Australian context (fig.1), based on data from the Medicare Australia [3], there has been a steady increase in the number of MDCT procedures over the past 17 years.

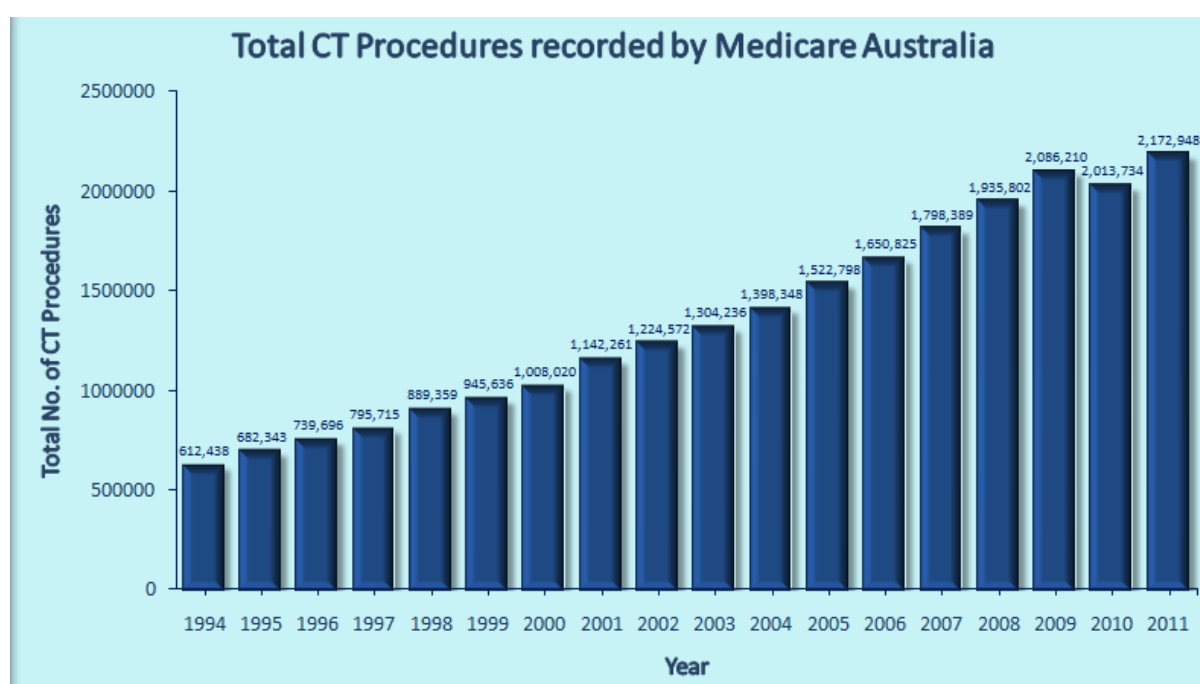


fig. 1 Total number of MCDT procedures from 1994 to 2011 in Australia as recorded by Medicare Australia.

To assist with the efficient application of ionizing radiation in medicine it has become common practice for regional dosimetry surveys to be undertaken to measure the spread of doses that are used for similar radiological investigations across various institutions. This range of average doses is statistically ranked and a value² is calculated that represents a dose that 75% of practices may deliver to accomplish the particular procedure. The agreed value is termed the Diagnostic Reference Level (DRL) and is conditional upon its application resulting in an adequate diagnostic quality image. By definition, 75% of all surveyed practices can achieve a diagnostic outcome for a dose that is at or below the calculated value.

¹ Carcinogenic disease and genetic mutations arising from the exposure to ionizing radiation are referred to in radiation protection as 'stochastic effects'.

² 75th percentile

Various organisations, regulatory authorities and individual practices have carried out limited CT dose surveys [4] (fig 2).

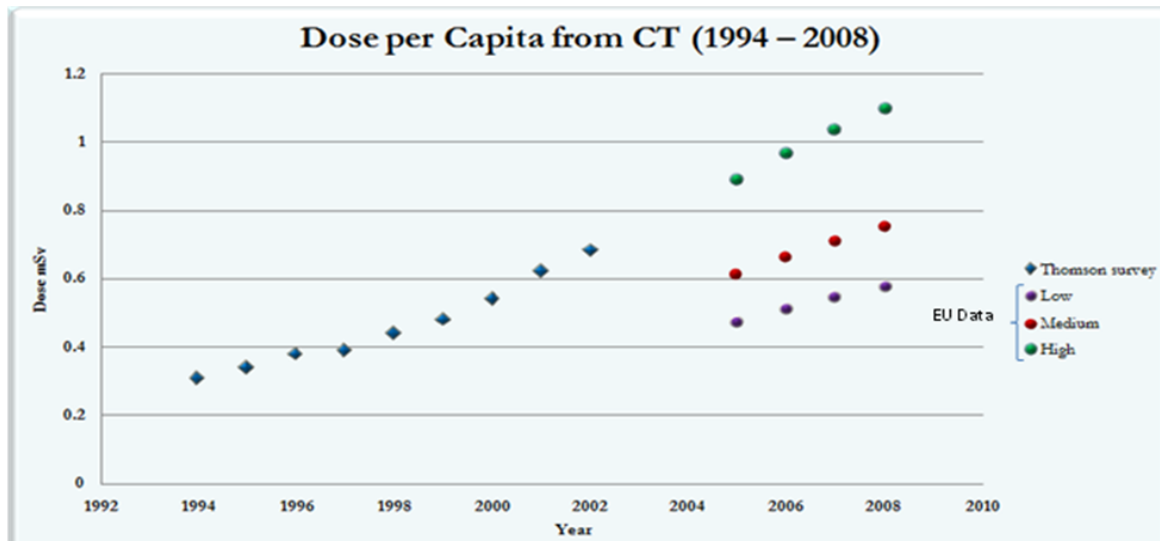


fig. 2 Relative doses for MDCT from early ARPANSA survey's compared to various European data.

The recent introduction of the *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation RPS14 (the Code)* [5], has amplified the need for Australia to develop and use national DRL's

The Code states that:

*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.

Via the implementation of Code in the various jurisdictions in Australia it is envisaged that national DRLs will be established over the coming years.

ARPANSA and National Surveys

ARPANSA has been charged with the task of carrying out national DRL surveys for the Australian Government. ARPANSA is aware that the DRLs should be 'owned' by the respective professions and can only be constructed with appropriate consultation and 'buy in' from the relevant stakeholders. Consequently ARPANSA has been working with Royal Australian & New Zealand College of Radiologists, Australasian College of Physical Scientists & Engineers in Medicine, Australian Institute of Radiography, Australian & New Zealand Society of Nuclear Medicine, Department of Health & Ageing and the various State/Territory radiation regulators to achieve this goal.

To obtain a clearer assessment of the risk it is imperative that a review of the doses delivered from common radiology procedures are undertaken at the site of practice and then subsequently consolidated into a national scheme. DRLs can then be constructed and used as a comparative indicator of radiation efficiency at an individual practice, as well as at regional, national and international levels. Once site DRLs are established they can be regularly reviewed and used as a baseline for the implementation of an optimisation program to maximise the efficient use of radiation while maintaining diagnostic image quality.

Measurement Quantities

DRL's should be expressed as a simple and efficient measured patient dose-related quantity for various imaging modalities (table 1). The ARPANSA survey is initially concentrating on MDCT, other modalities will be coming on stream in the future.

Modality	Metric
MDCT	Volume computed tomography dose index (CTDIvol, mGy) [6,7] and the dose-length product (DLP, mGy.cm) [6,7]. New CT scanners in accordance with Australian Standards, AS/NZS 32002.44 [8], should display the CTDIvol and/or the DLP on the operator's console after the selection of technique factors and prior to the initiation of X-rays. Average CTDIvol and total DLP should be available at the end of the scan procedure [7].
Fluoroscopic examinations	Dose area product (DAP, mGy.cm ²), screening time (sec), number of acquired frames [6,7].
Mammography	Mean glandular dose (MGD, mGy) [6,7]
General Radiographic examinations (film-screen CR & DR)	Either entrance skin dose (ESD, mGy) [7] or the dose area product (DAP, mGy.cm ²) [7].
Nuclear Medicine	Adult reference activity (MBq) [7].

table 1 Imaging modalities to be incorporated in DRL survey and quantities to be obtained

ARPANSA has designed and constructed an online survey to collect the required data to produce local practice reference levels (PRLs) and hence national DRLs. The survey has initially concentrated on MDCT and as such all the parameters recorded are associated with computer tomographic machines.

The survey asks for data on six common protocols.(fig 3) These are

- CT Abdo/Pelvis
- CT Chest
- CT Chest, Abdo Pelvis
- CT Lumbar Spine
- CT Neck

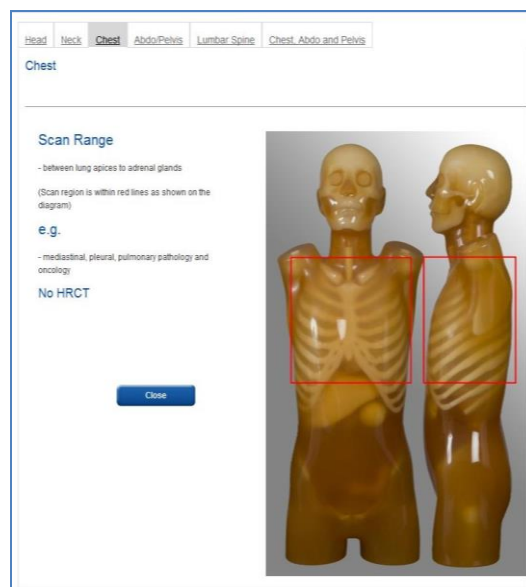


fig 3 Phantom indicating scan area for MDCT acquisitions

Results

As of the 31 December 2011, 80 on-line registrations had been received by ARPANSA from practices across Australia (fig 6).

2011 Registered Practices by State

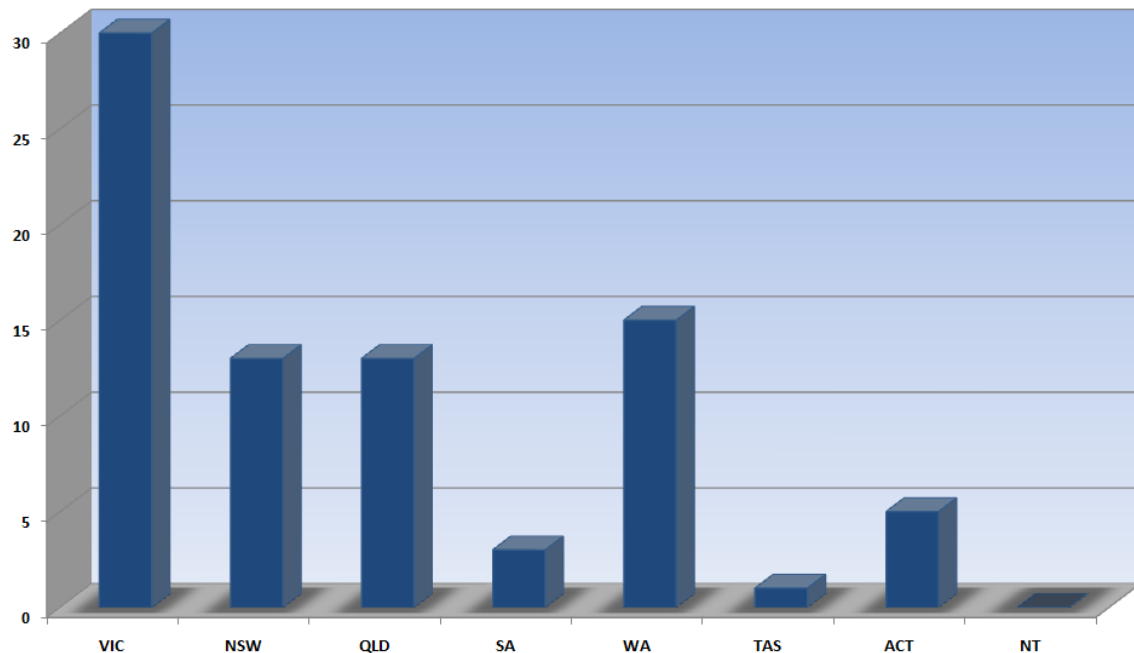


fig 6

An estimation of dose for the various protocols was made based on completed surveys and compared with the European data (fig 7).

2011 Australian & Dose DataMed 1 Effective Dose Comparison (mSv)

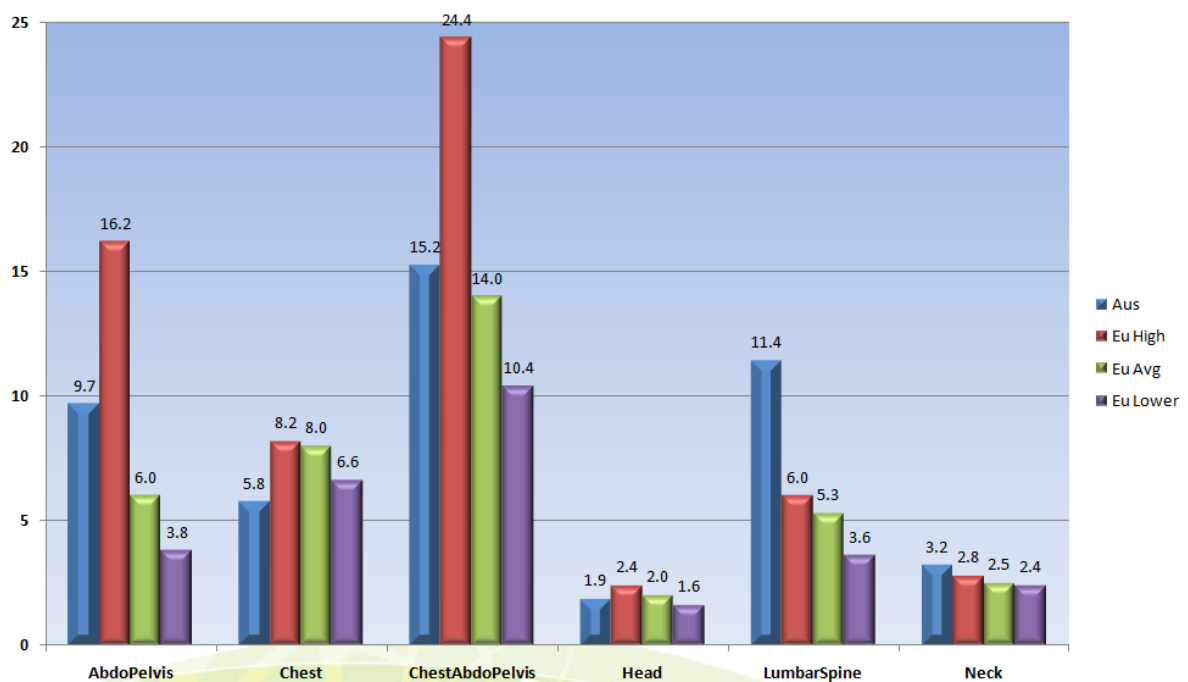


fig 7

ARPANSA has now produced a proposed set of national DRL's for MDCT (fig 8) that once accepted by the different stakeholders will become the levels by which all clinical practice can measure themselves against.

Habitus	CTDI _{vol} (mGy)	DLP (mGy.cm)
Head	60	1000
Neck	30	600
Chest	15	450
Abdomen Pelvis	20	700
Chest Abdomen Pelvis	35	1200
Lumbar Spine	45	900

(fig 8) proposed Australian national DRL's

Discussion

The ARPANSA national DRL survey began in August 2011, with an online registration being made available via its web site. It was estimated that there was about 1000 CT machines Australia in approximately 850 practices. The survey was advertised in relevant professional journals and associated web sites. It was hoped that there would be substantial uptake of practices to participate in the survey given the requirements outlined in *the Code*. However this proved not to be the case. From the practices that have been part of the survey and the data that has been supplied, ARPANSA has developed and a proposed national a DRL scheme for Australia. These DRL's, once adopted will provide a measure by which practices can meet there regulatory requirements of the Code. That is, individual clinical practices can periodically compare their DRL's against national established ones. Subsequently if the individual clinical practices find that their DRL's are consistently high than those set nationally a optimisation program can be initiated.

Population Risk

The contribution of radiation dose from radiological investigations to the population is increasing. This is due to the following reasons:

- The increasing power, utility and applications of the various imaging platforms.
- The increasing number of procedures, including those which may now be attempted non-surgically.
- The increasing referral base from physicians and surgeons.
- The increasing number of screening programs initiated as a public health response.

While the radiation risk to the individual from a radiology procedure is very small, the consequent population risk from the steadily increasing number of radiology procedures is of consequence. If the linear no threshold (LNT) model of radiation detriment is a reasonable representation of the risk then the tens of thousands of person-sievert delivered each year from radiology procedures should carry with it some additional potential long-term risk of carcinogenesis to the population. The LNT theory of carcinogenesis is based on the risk of DNA mutations deriving from cellular effects in germ cells. This additional stochastic risk should be compensated by the benefit of undergoing the investigation in either confirming the presence, or absence, of underlying disease, or therapeutic intervention.

Dose & Image Quality

A complicating factor in the use of the ALARA principle in diagnostic imaging is that any variation in delivered dose will have a consequent impact on diagnostic image quality. So it is not appropriate to simply lower the exposure factors and thus reduce the dose. Appropriate levels of diagnostic image quality must be maintained. The first cost of any non-diagnostic scan is usually a repeat scan which immediately negates any initial dose saving strategy.

In diagnostic imaging it is of critical importance to recognise that:

- Dose and image quality are opposite sides of the same coin and cannot be separated.
- The minimum required outcome of any imaging investigation is a diagnostic quality image.
- A diagnostic quality image can be achieved with a range of doses.
- This range of dose is amenable to an optimisation process where a diagnostic image can be obtained for a reasonable radiation risk.

Optimisation

Successful optimisation is the process where a balance is achieved between minimising the dose delivered and maintaining adequate diagnostic image quality. It is a multidisciplinary and labour intensive task that requires a detailed understanding of:

- image quality
- dosimetry
- imaging system parameters.

It can be undertaken using the simple method of dose survey, review of imaging equipment protocol parameters, image review, protocol adjustment if required followed by dose and image quality re-survey to establish a successful optimisation outcome. This process is carried out for each modality and for each of the agreed protocols for that modality. The consequent doses are recorded and the average dose is displayed as the local reference level for that procedure. Regional and national DRLs can be built up from practice data and used for international reference.

Conclusion

It is assumed that radiologists are satisfied with the diagnostic image quality demonstrated by their various imaging platforms. Comparing European dose data with generic Australian dose data leads to the question, 'At what dose cost are these images being produced and has the process been optimised?' The answer to this question can be found with a comprehensive national dose survey of radiological practices that include all forms of diagnostic imaging modalities that employ ionizing radiation.

The development of Australian DRLs will provide a measure of the efficiency with which radiation is used in diagnostic radiology and nuclear medicine and as such provide a measure that can be used to optimise its application. The successful introduction of this process will assist in the establishment of best practice medical radiations and consequent dose savings to the Australian population.

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