Dental drill: doses to patients II

The last issue of The Source *discussed entrance surface dose – a measure of the amount of radiation incident upon the patient's skin – and concluded that entrance surface dose fell short of fully describing the irradiation. To provide a more complete description of the 'dose' we first need to introduce a specialised form of dose – known as equivalent dose.*

Equivalent dose

Equivalent dose is used in radiation protection to enable comparisons to be made of biological effects per dose between different types of radiation (such as x-rays, gamma rays, neutrons, alpha particles). Equivalent dose is the absorbed dose multiplied by a weighting factor that depends on the type of radiation. In the case of x-rays this weighting factor is unity, making absorbed dose and equivalent dose numerically equal for all x-rays, including dental x-rays. However to indicate that we are using equivalent dose, a different unit, called the sievert (Sv) after a Swedish physicist, is used. And as with absorbed dose, the submultiples of milli- and micro-sieverts (mSv and µSv) are commonly used in dental radiography.

Equivalent dose is usually used to describe the doses that organs or tissues receive from a given exposure. It is a more meaningful description of the irradiation as any ensuing radiation effects will depend upon the size of the equivalent dose that the various tissues and organs receive.

As the primary beam passes through the body part being x-rayed, tissues and organs in the path of the beam will receive equivalent doses that depend on how much the beam has been attenuated by overlying tissue and how much beam divergence has occurred – the deeper the tissue the lower the equivalent dose. Tissues outside the primary beam receive energy from scattered x-rays only. This means that the distribution of equivalent dose varies markedly throughout the body.

Approximate tissue doses in dental radiography

For example, a single bitewing exposure may result in an exit skin dose of less than 1% of the entrance surface dose, a thyroid dose of a few percent and an average dose to the brain of less than a percent. Most of the body gets effectively no dose.

To give some approximate values for selected organs, a single bitewing is likely to give the following equivalent doses:

the region of skin in the entrance beam	about 2 mSv
salivary tissue	about 50µSv
the thyroid	a few tens of microsieverts
the brain	less than 10µSv
the lungs	less than 1µSv

In a panoramic x-ray examination, example organ equivalent doses will be of the order of 30µSv for the brain, 300µSv for salivary tissue, 50µSv for the thyroid, 3µSv for the lungs, and 0.1µSv for the stomach.

These examples illustrate the wide range of resulting tissue equivalent doses. Doses are used to estimate radiation effects, but working with a multitude of different levels of equivalent doses to different tissues makes risk estimation complex. The next issue of *The Source* will introduce a dose quantity that enables all the different tissue equivalent doses to be combined into a single value, which in turn facilitates estimation of overall risk from radiation effects.

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New directions for the basic principles of radiation protection?

Most parts of the world follow the familiar principles of radiation protection first recommended by the International Commission on Radiological Protection (ICRP) in 1977, and later developed in *ICRP Publication* 60 in 1990. These are:

- Justification: no practice shall be adopted unless its introduction produces a positive net benefit
- Optimisation: all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account
- Dose limits: doses to individuals shall not exceed recommended limits

These principles have served well for nearly a quarter of a century, but now they are under review to determine whether they represent the best system of protection for society in the 21st century. An indication of the new thinking was given in an address by Professor Roger Clarke, Chairman of the ICRP, at a recent meeting of the Australian Radiation Health Committee, on which NRL has observer status.

Professor Clarke said that today's social ethic focuses on the individual rather than society as a whole, and therefore protection needs to be based on egalitarian rather than utilitarian principles. Furthermore the role of the expert was seen as aiding decisions rather than making decisions; stakeholder involvement and local values may also play important roles. Greater simplicity in the protection criteria is intended to facilitate more local participation in decision making. The new direction Professor Clarke has suggested is to replace the old principles with *Justification*, *Protective Action Levels (PAL)*, and *Optimisation*. The concept of PAL gives greater flexibility than the current concept of limits that cannot be exceeded. Instead of being expressed in terms of radiation dose, levels would be graded in terms of multiples of typical natural background radiation, and expressed as *levels of concern*:

Serious	> 100 x normal background
High	> 10 x normal background
Normal background	*(1 – 10 mSv/year)*
Low	< 0.1 x normal background
Trivial	0.01< ... < 0.1 x normal background
Negligible	< 0.01 x normal background

However, these developments are still very much at the discussion stage. Time will tell whether there is sufficient support to lead to a reorientation in ICRP thinking and a new set of recommendations with the same revered status as *ICRP 60*.

MINISTRY OF HEALTH
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Introducing the Radiation Protection Advisory Council (RPAC)

This issue of The Source *contains information on some recent issues that the RPAC have considered. A brief introduction to the Council follows.*

The Radiation Protection Advisory Council (RPAC) is a body set up under the *Radiation Protection Act* to advise and make recommendations to the Minister of Health or the Director-General of Health, as appropriate, on matters and issues arising from administering the *Act* and its *Regulations*. The Council meets on an 'as needed' basis, typically twice a year.

Both the Council's composition and term of office for members are specified in the Act. Current members are:

Chair:

Dr Peter Englert, Dean of Sciences, Victoria University of Wellington

Other members:

Dr Andrew McEwan, Scientific Director, National Radiation Laboratory

Dr Bob Boyd, Ministry of Health – the Director-General of Health's representative

Dr Jann Medlicott, radiologist, based in the Bay of Plenty

Dr Ross Marshall, rural general practitioner, based in Otorohanga

Mr Ian Ross, medical physicist, based at Wellington Hospital

The position designated for a radiation oncologist is currently vacant due to the recent resignation of the incumbent and will be filled in due course.

NRL's quality goal: ISO 9001

A centre of excellence in radiation safety

NRL is committed to providing and maintaining the highest standards in all its activities, while also ensuring a high level of efficiency. To this end we have implemented a quality system as specified in AS/NZS ISO 9001:2000 *Quality management systems - requirements*. We expect to achieve certification towards the end of this year, and will keep readers informed of developments in future issues of *The Source*.

NRL Codes and Guidance notes: latest update

As advised in the last issue of *The Source*, *NRL C16*: *Code of safe practice for the use of x-ray security and inspection systems* and *C17*: *Code of safe practice for the use of x-ray analytical equipment* and their respective *Guidance notes* were released for public consultation. Comments have been received and these are currently being discussed and, where appropriate, incorporated into the final draft documents. It is then intended to undertake a 'reality check' by performing a trial compliance monitoring audit of an existing facility using the respective new *Code*. Any final modifications will then be made and the *Code* and *Guidance notes* issued to current licensees, whose licence conditions will have been amended to include compliance with the new *Code*.

Another new *Code*, *NRL C14*, *Code of safe practice for the use of sealed radioactive materials for brachytherapy* and *Guidance notes* have also been drafted and sent out for consultation.

Also recently completed is the initial draft of a major revision of the *Code of safe practice for the use of x-rays in veterinary diagnosis*, *NRL C8*, together with its newly developed *Guidance notes*. These are being sent to interested parties for consultation. Check the NRL *What's new* web page for copies of the drafts and more information.

NRL matters no. 9: changes in transport requirements

An overview of anticipated changes to requirements for transport of radioactive materials was included in the last issue of The Source.

All affected parties should have received by now a copy of NRL matters no. 9 *Adoption of Regulations for the Safe Transport of Radioactive Material 1996*. This follows the publication of a Gazette notice on 22 March 2001, formally adopting the latest edition of the International Atomic Energy Agency's *Regulations*. NRL matters no. 9 highlights the practical implications of changes to the requirements for transport of radioactive materials, especially within New Zealand, effective from 1 July 2001. The document also contains tables of selected data from the IAEA *Regulations* to assist compliance.

NRL matters no. 9 is available from NRL (please contact Chris Moir, Chris_Moir@nrl.moh.govt.nz) or from the NRL website (visit the *What's new* page). A revised Shipper's Declaration Form for use with the revised regulations is also now available from NRL. Please contact Murray Robertson (Murray_Robertson@nrl.moh.govt.nz)

RPAC NEWS

Coronary artery calcium scoring: the current score

The efficacy of using electron beam CT scanners, then helical CT scanners and now multi-slice CT scanners for assessing calcium scores for coronary arteries has been debated for several years. With coronary artery calcium scoring many narrow CT slices of the coronary arteries are acquired in a single breath hold. Using special software an estimation of the total calcium burden of the coronary arteries can then be made. This measure of calcium is used as a surrogate for total artherosclerotic plaque, which in turn is claimed to correlate with the likelihood of a sudden coronary event – the higher the calcium score, the higher the risk of such an event.

Part of the debate has centred on whether or not the technique can be used as a screening tool for asymptomatic patients with a view to prospective medical management of those patients who have a 'high score'. And further, whether the asymptomatic patients can be self-referred or whether they must be referred by a medical practitioner following assessment that the patient is in a high risk category.

The *Code of safe practice for the use of x-rays in medical diagnosis, NRL C5*, has as one of its corner-stone radiation protection principles the requirement that all x-ray examinations must be justified – there must be a benefit to exposed persons that outweighs the risks associated with the radiation dose received.

In the case of population-based screening programmes, the *Code* states that such programmes cannot be instituted unless there is proven evidence based on sound epidemiological study that the programme is of net benefit to the screened population.

As a result of a proposal to introduce the technique into New Zealand the Radiation Protection Advisory Council considered the question of coronary artery calcium scoring last year. The estimated patient effective dose for the technique is in the range 2 to 8 millisieverts depending on the scanner and protocol used. This is equivalent in terms of dose to about 100 to 400 chest x-rays. The Council, on the advice of two external experts who had been commissioned to review the then current literature, concluded that there was insufficient evidence to approve the use of coronary artery calcium scoring as a screening tool for either asymptomatic or symptomatic individuals.

Approximately one year later, the Council was again asked to consider the question of coronary artery calcium scoring with particular emphasis on its application to referred patients.

At its 9 May 2001 meeting the Council reiterated its earlier decision that there is insufficient evidence to support the use of coronary artery calcium scoring as a screening tool for the general population or a self-referred population. In particular the Council advised:

- The radiation dose associated with coronary artery calcium scoring makes its use as a population screening test not justified in terms of its potential benefit.
- The use of coronary artery calcium scoring for individuals who have been referred by a medical practitioner can be performed under a licence for medical diagnosis only if the licensee considers in his/her clinical judgement that the procedure will benefit that particular patient. In making that decision the licensee should be guided by the policy statements of relevant professional bodies.

GP licence conditions

Following consultation with interested parties the RPAC has developed new standard licence conditions for rural General Practitioners who hold a licence to use x-rays in medical diagnosis.

Such licences have always been restricted to extremity radiography only, and previously included the requirement to have all films read by a radiologist. This requirement was considered by some to be unduly restrictive. The Council was conscious of the need to avoid imposing unnecessary compliance costs on rural GP licensees, but at the same time wanted to maximize the likelihood that all radiation exposures lead to diagnostically useful images.

The new licence conditions distinguish between a new GP licensee and an experienced GP licensee. For the former, there will be a period of radiologist oversight with all films being reviewed for both diagnostic interpretation and for audit of image quality. The submission of films and reports will need to be timely to allow appropriate clinical intervention if needed as a result of the film review. This timeliness should not prevent some flexibility to 'batch' the week's films and reports, thereby helping to keep courier costs down.

When a new GP licensee is deemed competent by the supervising radiologist, the supervision is replaced by a system of internal and external audit. In all cases internal audit of image quality must use 4 classifications of image quality, ranging from 'unacceptable' to 'visually sharp reproduction'. The external audit is a check on this process and will take place four times per year, with a batch submission of ten consecutive studies and reports to the radiologist. The radiologist will use the guidelines also developed by the Council to perform the audit and provide constructive feedback to the GP licensee. In this role the radiologist is not providing a specialist film-reading service and as such it is envisaged that fees for the service would be kept as low as possible.

The change in licence conditions for rural General Practitioner licensees will be implemented shortly.

Radiological emergency in Panama

On May 22 the International Atomic Energy Agency (IAEA) informed national authorities of an investigation in Panama of patients who had received excessive radiation therapy doses. At a press conference on May 18, representatives from the National Oncology Institute (ION) in Panama announced that 28 patients treated for colon, prostate, and cervical cancer may have received radiation doses between 20 to 100 percent above what was prescribed. A newspaper reported that human error and the failure of the treatment planning software to warn the user of possible errors may have contributed to the event. Five patients treated at ION were reported to have died at that time and the causes of their deaths were under investigation.

The 28 patients received external beam therapy treatments from a Cobalt-60 Theratron 780-C teletherapy unit at the ION between August and December 2000, but the doses were not confirmed by the ION until March 2001. The Government of Panama requested IAEA assistance with an investigation. The team of experts found that the radiotherapy equipment had been working properly and was correctly calibrated. It appears that the problem lay with the entering of data into the treatment planning system. The way the spatial coordinates for shielding blocks were entered was changed, and this led to incorrect calculated treatment times.

The use of radiation for medical therapy is controlled in NZ by the *Radiation Protection Act* and *Regulations*. Any radiotherapy is covered by licensing requirements under the *Act*, and must comply with the *Code of safe practice for the use of irradiating apparatus in medical therapy, NRL C12*. This *Code* has strict requirements to ensure that any steps in the treatment process that may be prone to human error are double-checked, and that an overall quality system approach to patient treatment is adopted. In particular no treatment planning system can be used until it is exhaustively checked for accuracy. NRL audits radiotherapy departments for compliance with the regulatory requirements and the *Code* every two years. The results of previous audits do not suggest that NZ is particularly vulnerable to the type of occurrence reported from Panama. However this incident is a timely reminder that mistakes do happen, and that constant vigilance and observance of the quality system approach of review and continuous improvement are essential. To this end NRL forwarded the notification as soon as it was received to oncology departments in NZ for their information.

Radiation protection of patients: Malaga meeting notes

Along with 650 others, John Le Heron recently attended a conference in Malaga, Spain, which focussed on the largest use of man-made radiation sources: radiation in medicine.

The management of medical radiation is extremely important as this use of radiation continues to grow as technologies develop and access increases. Current issues involving medical radiation included those previously discussed in *The Source* (December 2000): multi-slice CT, CT fluoroscopy, and doses arising from computed and digital radiography. Some additional items of interest that emerged from the Malaga meeting are discussed briefly below.

- The use of CT continues to grow and, in general, doses from CT examinations are still at the higher end of the diagnostic dose scale. There remains considerable scope for optimising scan parameters for particular patients. For example, the mAs per rotation of the scanner for a young child should be considerably less than that for an adult for the same body region being scanned and for equivalent 'signal-to-noise ratios'. However in practice the mAs difference is not as large as it should be, indicating that the child is receiving a higher dose than necessary.
- The high doses associated with CT examinations highlight the need to apply the radiation protection principle of justification with rigour. For example, a request for a woman to undergo a CT chest examination will lead to breast doses that are much larger than those arising from mammography. To illustrate this, a spiral CT of the chest from the diaphragm to the apices of the lungs, with a pitch of 1 and 300 mAs per rotation, would lead to a breast dose of about 30 mGy. This can be compared with about 2 mGy per mammography projection and demonstrates the somewhat paradoxical fact that the dose in a procedure which is not being used for diagnosis of breast disease per se, gives the breasts a much higher dose than does a procedure which images and irradiates only the breasts.
- Training of personnel was considered the key factor in radiation safety in interventional and radiation-guided procedures. In addition local protocols are needed to minimise the risk of deterministic effects arising from prolonged and difficult cases – that is, guidelines for abandoning a procedure, if clinically feasible, when thresholds for deterministic effects are being approached.
- Sub-groups of the population exist that are more sensitive to radiation than the norm. It is estimated that highly sensitive persons make up approximately < 0.1 to 1% of the population. The largest implications of this are in radiotherapy. Current laboratory tests are neither sufficiently reliable nor cost-effective for screening for such persons. It was considered that examination of radiotherapy patients often (each week as a minimum) is necessary to avoid serious complications arising from irradiations of sensitive persons.
- Quality assurance is an essential component in all areas of medical radiation, improving clinical outcome. There was a clear message that because the new dynamic treatments in radiotherapy are using higher target doses there is a corresponding need for a higher level of quality assurance. In the case of diagnosis, image quality and dose assessment are components of quality assurance.

This important conference organised by the International Atomic Energy Agency and co-sponsored by a large number of international organisations concluded that the principles of justification and optimisation continue to be the corner-stones for managing medical radiation use.