Incidents involving ionising radiation

Major radiation accidents reported worldwide

A major accident can be defined as an incident involving radiation sources (either radioactive material or irradiating apparatus) that leads directly to the death of people, or causes serious and disabling injuries, or results in substantial environmental damage and possibly considerable financial costs and penalties.

Between 1980 and 1998 thirty-six radiation accidents, reported in the open literature and rated by the International Atomic Energy Agency (IAEA) as major, have occurred. The most well known of these is of course the Chernobyl disaster in 1986. Using figures published by the IAEA (IAEA, 1999) the table below summarises the four most serious accidents ranked in terms of the number of deaths directly attributable to radiation exposure.

Date	Location	Type of accident	Deaths	Overexposure
1986	Chernobyl	Nuclear reactor	28	134
1996	Costa Rica	Cobalt-60 radiotherapy source	13	115
1990	Spain	Radiotherapy accelerator	11	27
1984	Morocco	Iridium-192	8	11

It is instructive to note that apart from the Chernobyl disaster all of the accidents mentioned above involved discrete sources of radiation.

In many accidents, the root cause is that the control over a radioactive source has been relinquished or improperly transferred. Lapses in the so-called 'security' of a radioactive source can result in the source being lost, stolen or simply abandoned. The National Regulatory Commission (NRC) in the United States annually receives about 200 reports of lost, stolen or abandoned radioactive sources (IAEA, 1999) and it has been acknowledged that this may well only represent the tip of the iceberg. These so called 'orphaned sources', although usually of relatively low activity, can find their way into scrap metal destined for recycling with considerable financial penalties as a consequence of liabilities and clean-up costs.

The World Customs Organisation has reported 234 confirmed cases of seizures of radioactive sources between 1993 and 1998 (IAEA, 1999). The illicit trafficking of radioactive sources and the once difficult to imagine crime of orphaned sources being used for malevolent purposes are of considerable concern to regulatory authorities such as the NRL (refer to the article on emergency response planning in this issue of *The Source*). In particular, improvements in the security of radioactive sources are nationally and internationally seen as key areas for improvement.

For a thorough discussion of major radiation accidents and associated issues, readers are directed to the excellent series of articles in the publication referenced below.

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Reference: IAEA, 1999. IAEA Bulletin, Vol 41 No. 3. 1999.

Resources

Newly available on the NRL website (www.nrl.moh.govt.nz):

- Information on Core of Knowledge course modules
  (Follow the links: Legislation & Licensing – Non-medical licensee training – Core of Knowledge.)
- Incident reporting forms (non-medical and medical)
  (Follow the links: Legislation & Licensing – Incident reporting forms.)
- The dental pamphlet (Radiation protection for dentists and assistants) is now available as a PDF file.
  (www.nrl.moh.govt.nz/Publications.html#Dental pamphlet)
- Results of ELF and RF surveys
  (Follow the links: FAQs & Advice - Radiation in the environment – ELF and RF Surveys.)
- A form for determination of gamma nuclides in water samples, soil, sediments and solids
  (Follow the links: Services & Products - Environmental – Soil, sediment & solids.)
- *Code of safe practice for the use of sealed radioactive materials for brachytherapy*, NRL C14 has been published and can be purchased for $25 + GST In New Zealand or NZ$50 overseas

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NRL
National Radiation Laboratory

The Source

Issue 15
May 2004

Radiation emergency response planning: meeting of key agencies

The Ministry of Health through the National Radiation Laboratory hosted a round-table meeting on 4 February 2004 for key agencies who have a role in emergency preparedness for incidents involving ionising radiation.

The meeting was attended by senior representatives from the following organisations: Fire Service, Police, Ambulance, Defence Force, Customs, Department of Prime Minister, Ministry of Civil Defence and Emergency Management, District Health Boards, Public Health and Ministry of Health.

At the meeting participants were briefed on the following topics:

- ionising radiation risks
- uses of radiation in New Zealand
- radiation protection principles and legislation
- radiological monitoring instrumentation
- the existing radiation incident response plan
- reported and potential incidents.

There were also some practical exercises dealing with the full range of potential radiation incidents from a transport accident involving radioactive material to the detonation of a dirty bomb in an urban area.

In addition, considerable time was devoted to round-table discussions aimed at clarifying the roles of the individual key agencies, identifying gaps that currently exist in planning and identifying resources that can be made available between the key agencies.

The meeting was concluded with the development of a provisional multi-agency action plan which identified a number of key actions related to training, exercises, public information, equipment and development of additional protocols and guidelines.

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Review of licence conditions

All licences issued under the *Radiation Protection Act 1965* contain conditions specifying particular requirements that must be complied with in addition to the requirements of the Act and its regulations. Typically, current conditions on licences have invoked compliance with an NRL Code of Safe Practice, where one exists and is applicable, together with some restrictions on scope of use (for example, with respect to equipment and or facility). The National Radiation Laboratory has recently completed a review of the licence conditions that are in current use and, as a result, has developed a new set of conditions that have improved clarity, cover perceived weaknesses in previous conditions or lack of conditions, and that will be auditable via the NRL compliance monitoring programme.

The conditions placed on a given licence will depend on the purpose of the radiation use, the type of facility, and on the qualifications, training and experience of the licensee. The biggest change from the review is where an appropriate Code of Safe Practice does not exist. For these licences there will now be a condition requiring the particular use of radiation to be in accordance with a specified Radiation Safety Plan.

Another area of change will be the requirement for continuing education in radiation safety for licensees. For non-medical uses of radiation, assessment of compliance with respective continuing education conditions will be performed during NRL compliance monitoring visits. For licensees associated with medical uses of radiation, it is envisaged that continuing education in radiation safety will be part of the larger continuing medical education requirement of the *Health Practitioners Competence Assurance Act 2003* and the mechanisms for this are yet to be developed.

Most of the other changes are relatively minor, primarily with changes in the wording to improve clarity.

The implementation of the new licence conditions will commence mid year with all new applications, and licence renewals as they arise. The transition to the new system of conditions will take one year to complete. All licensees will need to read their new conditions, after renewal, to ensure that they are aware of any changes.

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Can x-rays 'fry' the brain?

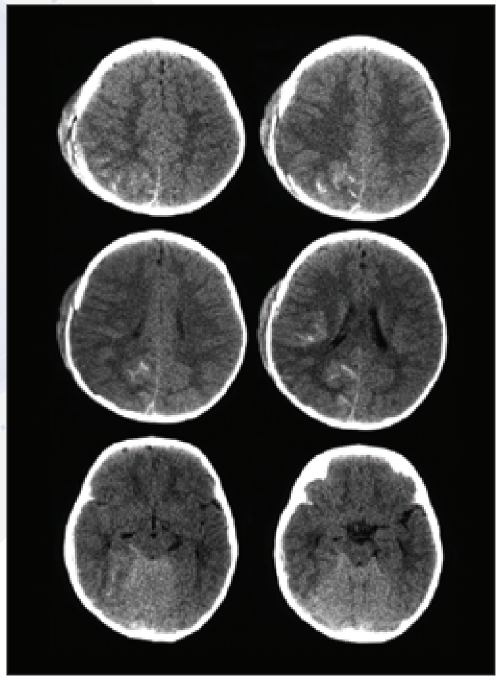
A recent article in the British Medical Journal *(Effect of low doses of ionising radiation in infancy on cognitive function in adulthood: Swedish population based cohort study.* P Hall, H-O Adami, D Trichopoulos, et al. BMJ 2004; 328: 19) has generated considerable reaction in the medical literature.

In their article, Hall and colleagues concluded that low doses of ionising radiation to the brain in infancy influence cognitive abilities in adulthood. How did they come to this conclusion and does this new information have implications for the current practice of radiology?

The retrospective Swedish study looked at about 3000 males who had received radiation before the age of 18 months as treatment for cutaneous haemangioma. The method of treatment was radiotherapy either using applicators containing radium-226 or using contact therapy with soft x-ray beams ($\leq$ 60 kVp, with an HVL $\leq$ 1 mm Al). The estimates of the doses received by the brain, as a result of the treatment, were as high as 2.8 Gy, with an overall average brain dose of 52 mGy. About 600 patients received brain doses in excess of 100 mGy.

Assessment of intellectual capacity was determined by whether the patient subsequently attended high school (having gained an average grade or better) and how well the patient (at age 18 or 19 years) performed certain standardised cognitive tests.

The researchers found a significant decrease in the probability of attending high school as the radiation dose increased, and this significance was maintained when adjustments were made for potential confounders, such as father's socio-economic status. They also found a significant trend of decreasing cognitive test results (general instructions, concept discrimination and technical comprehension) with increasing dose. And for both measures, the association was strongest for those that had received the highest doses.



Much of the debate over the article has arisen because the authors then concluded that irradiation of the infant brain at levels of dose similar to those resulting from CT scans of the head may adversely affect intellectual development, and hence the risk and benefits of performing CT scans on children with minor head trauma needs re-evaluating.

Not surprisingly the article has provoked a range of reactions. The effects of larger doses to the developing brain are well known, for example the in utero exposures at Hiroshima and Nagasaki, with brain doses of 1 Gy or greater being strongly associated with severe mental retardation. However, effects at lower doses are not well established, nor has the issue of whether there is a threshold dose for such effects.

The article has also confused many readers. The "dose" normally associated with a CT head examination of an adult is 2 mSv – this number being significantly lower than the 100 mGy used in the article as indicative of the brain dose in a CT examination of an infant's head. Both numbers are broadly correct, with the caveat that each is protocol dependent. The 2 mSv is an effective dose – the equivalent uniform whole body dose that would have the same effect (in terms of cancers and hereditary effects) as the actual doses received by the various organs in the patient. The 100 mGy is the dose that could be received by the brain for a CT scan of an infant's head using a protocol that was not well optimised – eg, using an adult protocol. But even for an optimised protocol the brain dose could easily be in the range of doses implicated in the study.

Another objection raised by readers was that the radiation used in the therapy was different to that used in a CT examination – ie, gammas, betas and soft x-rays versus diagnostic x-rays. All are, however, examples of low LET (linear energy transfer) radiation and, as such, all have a radiation weighting factor (for equivalence of biological effects) equal to unity. Thus the doses in grays and milligrays in the article could easily have been reported as equivalent doses in sieverts and millisieverts, with the same numerical values.

Are there other confounding issues? Because the assessment of intellectual performance was performed solely within the cohort of haemangioma patients (as a function of dose) the only means of confounding would be if there were some additional effect that affected both the intellectual performance and the size of the brain dose. Such a possibility has been postulated by one respondent – namely that cortical haemangiomas can occur in conjunction with cutaneous haemangiomas, and that the sizes of these two types of haemangiomas are often correlated. Hence a larger dose for a larger cutaneous haemangioma being correlated with a larger cortical haemangioma, which in turn results in poorer intellectual performance.

So what are we to conclude?

As mentioned above, the article called for re-evaluation of protocols for assessing children with minor head injuries, with the implication that CT should not be used. However, existing published protocols already state such a position – CT head scans are not appropriate for minor head injuries. But a reminder to apply the first International Commission on Radiological Protection principle of justification to all exposures is always timely.

But probably the key message is further reinforcement of the ALARA principle – keeping doses as low as is reasonably achievable, consistent with the required image quality – and in particular that CT examinations of children must be tailored appropriately. The simple expediency of using adult settings (eg, adult values of mAs per rotation) is simply not acceptable.

The jury may still be out on whether there are health effects from brain irradiations at doses similar to those that can be delivered in CT head examinations, but simple application of the above radiation protection principles will minimise the impact if indeed such effects do occur.

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For more information contact John Le Heron (John_Le_Heron@nrl.moh.govt.nz).

New reports on radiofrequency fields

Three new reports reviewing research on the effects of radiofrequency (RF) fields on health have found no cause to change current exposure guidelines. The reports, published by the Swedish Radiation Protection Authority (SSI), the Health Council of the Netherlands and the British Advisory Group on Non-ionising Radiation (AGNIR), find no good evidence of adverse effects at exposures which comply with guideline levels, but highlight the need for further studies in order to definitively state whether such exposures are safe or not.

Areas in which most research effort is focused include studies into possible effects of RF fields on cancer (especially brain tumours in cellphone users), the blood-brain barrier and cognitive effects. Potential cognitive effects (for example, on reaction speed) were highlighted in 2000 by the UK Independent Expert Group on Mobile Phones (IEGMP). Research published since then, however, has provided inconsistent results, and it is still not clear whether there are effects or not. Research findings into effects on cancer have been clearer: experimental studies on animals and epidemiological studies have both provided no persuasive evidence of an effect. Nevertheless, the reviews caution that the epidemiological evidence is limited due to the short follow-up periods involved (short in comparison to the length of time for a tumour to develop). Investigations into potential effects on the blood-brain barrier have been carried out over several decades, with a recent resurgence of interest due to the publication of apparently positive results from some research groups. All three reviews warn that these studies have problems which limit their usefulness: overall, the SSI report comments that "a careful analysis of the available data does not indicate the existence of a health risk", and there are similar comments in the other two reports.

On the basis of the AGNIR report, the British National Radiological Protection Board has recommended adoption of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure guidelines in the UK. (These guidelines form the basis of the New Zealand RF field exposure Standard NZS 2772.1:1999.)

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References:

- SSI report can be downloaded from www.ssi.se/english/EMF_exp_Eng_2003.pdf
- Health Council of the Netherlands report can be downloaded from www.healthcouncil.nl/pdf.php?ID=886
- AGNIR report can be downloaded from: www.nrpb.org/publications/documents_of_nrpb/pdfs/doc_14_2.pdf
- New NRPB recommendations can be downloaded from: www.nrpb.org/publications/documents_of_nrpb/pdfs/doc_15_2.pdf