

APPENDIX D: Additional resources and supporting documents *cont*

MEDICAL RADIATION

Medical radiation is one of the largest sources of radiation exposure to humans outside natural background radiation. The main diagnostic sources of radiation are CT (computed tomography) and X-rays. Magnetic Resonance Imaging does not involve ionising radiation.

Advances in CT image quality and test speed have revolutionised radiology by providing high diagnostic yield for clinicians. However, the associated radiation doses are larger than the conventional X-ray, and its use has steadily increased in frequency since the early 1970s. The number of CT examinations rose in the USA nearly seven times from 1981 to 1995, from 2.8 million to 20 million scans¹ or up to 11% of radiographic examinations, accounting for 67% of the radiation exposure.² Similarly, the volume of CT scans in the UK in 1998 represented 4% of all radiological procedures and accounted for 40% of the collective dose to the population.^{2,3} Various reports from the USA claim that 4 to 11.2 % of CT procedures are administered to children under the age of 15 years.^{1,4}

National dose surveys in the UK and elsewhere show significant variations in individual-dose for the same CT examination, by factors of 10 to 40, due to differences in scanner design and institutional-specific examination techniques.^{3,5} Therefore, regardless of the diagnostic benefits of CT procedures, there is some effort to standardise methodologies and protect people from unnecessary exposure via reduced dosage without reduction in image quality.^{6,7}

1. RADIATION DOSES

1.2 Doses from Head Computed Tomography

Specific techniques of dosimetry have been developed for measuring the person's exposure to radiation. Doses can be expressed in two ways.

1. Organ or tissue dose, usually expressed in milligray (mGy), which reflects the energy deposited by X-rays per gram of irradiated body tissue, averaged over the particular organ or tissue.
2. Effective dose, usually expressed in millisieverts (mSv) which is a calculated weighted sum of organ doses that takes into account organ differences in radio-sensitivity and is a useful index to compare the relative radiation risks from varying radiological procedures.

Generally, the literature shows that effective doses from head CT scanning in adults range from 1.3 mSv to 2.3 mSv.^{1,2,4,5,7-10} In comparison to conventional X-ray examinations of the skull with a range of effective doses from 0.07 mSv to 0.2 mSv, CT examinations involve 5 to 32 times more radiation exposure.^{2,10} The eyes, thyroid and breasts typically receive doses of about 50 mGy, 2 mGy and 0.03 mGy, respectively, from a head CT scan.

Recent studies have shown that doses to infants and children from head CT examinations can be considerably higher than those for adults. For example, Huda et al reported that the effective doses estimated for head CT examinations showed mean values of 7.6 mSv and 1.3 mSv in new-borns and adults respectively in a study of 46 people in a hospital in the USA in 1997/98.⁷ Lowering the dose people receive is possible with adjustments of scan technique, tube current and filtration factors, alterations in pitch, and image reconstruction parameters.^{6,10}

For comparison, the average natural background radiation level in the UK gives rise to an annual effective dose of 2.2 mSv, with regional averages ranging from 1.5 mSv to 7.5 mSv per year. Average natural background radiation level in New Zealand is relatively low at about 0.15 mSv per year, although there is considerable regional variation, and variation due to other factors, such as whether one lives in a wooden brick house (1998).

1.3 (UK) National Radiological Protection Board (NRPB) Estimate Summary

A summary of estimates of the effective doses received by adults, children and infants from CT and X-ray examinations of the head and cervical spine are detailed in Table 1 below.¹¹ These estimates are based on an NRPB survey^{12*} and use published paediatric enhancement factors.¹³ These estimates assume that the same CT technique factors are used for children and adults (which has been common practice until recently). The estimates for radiographic exams are based on typical effective doses for adults in a further NRPB survey.¹⁴ Effective X-ray doses for children are normally assumed to be the same as those for adults.¹⁵

* Since this article was written new information has become available, which modifies the numbers used. Refer to: <http://bjr.birjournals.org/cgi/content/abstract/79/948/968>

Table 1: Effective radiation doses for different imaging techniques, by age group.

Person's Age (y)	Effective dose (mSv)	
	Head	
	Radiographs*	CT
0	0.06	4.1
1	0.06	3.6
5	0.06	2.7
10	0.06	2.2
Adult	0.06	1.8

* assumes 1 PA + 1 AP + 1 lateral radiograph per examination

2. CANCER RISKS

The risk of radiation-induced malignancies from a single CT exposure is difficult to assess. There have been no published prospective studies measuring incidence of cancer among CT exposed people; however, hypothetical cancer induction rates have been calculated from the long-term follow up of populations exposed to large doses of radiation. The International Commission on Radiological Protection reports a nominal probability coefficient of 5% per Sv effective dose for the lifetime risk of fatal cancer in a population of all ages and both sexes exposed to radiation at the relatively low doses used in CT examinations.¹⁰ Diederich et al use the same risk coefficient (suggesting that there will be 5 fatal cancers in every 100,000 individuals exposed to 1 mSv) and reports that risks for infants and children would be higher than the risk for adults.¹⁶

On that basis, and using the dose per CT given in Table 1 above, an approximation of the Numbers Needed to Harm (NNHs) per CT scan by age can be calculated. These are shown in Table 2.

Table 2: Radiation doses and resultant increased risk of lifetime fatal cancer by age group

Person's Age (y)	Head CT Effective dose (mSv)	Resulting risk of lifetime fatal cancer (per CT scan)	NNH	95% interval
0	4.1	0.000205	4,878	3,404–8,601
1	3.6	0.00018	5,556	3,800–10,325
5	2.7	0.000135	7,407	4,831–15,876
10	2.2	0.00011	9,091	5,714–22,223
Adult	1.8	0.00009	1,1111	6,721–32,049

CT scans may also often be repeated, so if the person receives two CT scans, the risk is as outlined in Table 3.

Table 3: Radiation doses from two CT scans and resultant increased risk of lifetime fatal cancer by age group

Person's Age (y)	2 x Head CT Effective dose (mSv)	Resulting risk of lifetime fatal cancer (per 2 CT scans)	NNH	95% interval
0	8.2	0.00041	2,439	1,867–3,515
1	7.2	0.00036	2,778	2,094–4,125
5	5.4	0.00027	3,704	2,689–5,946
10	2.2	0.00022	4,545	3,206–7,808
Adult	3.6	0.00018	5,556	3,800–10,325

Thus approximately one in every 5000 infants who receive a CT scan will die of cancer at some point in their life as a result of the scan.

More specifically, Brenner et al estimate that the lifetime cancer mortality risks from CT examinations on a one-year-old child are approximately an order of magnitude higher than the risks for CT-scanned adults.¹ While this paper calculates a projected 500 additional cancer deaths per year in the USA from currently performed paediatric CT examinations, these estimates should be considered with caution, as they are based on extrapolations from mortality data of Japanese atomic bomb survivors exposed to predominantly higher radiation doses than people who have a CT scan.

The risks drop dramatically at ages above 60 years due to the reduced lifetime available in which these delayed effects of radiation can occur.[†]

Thus the best available evidence suggests that paediatric CT will result in increased lifetime risks of cancer compared with adult CT due to both the higher radiation doses currently delivered to children and their increased sensitivity to radiation-induced cancer over a longer life span.^{1,10}

3. MANAGEMENT OF RADIATION EXPOSURE

In line with good radiation-exposure practice, every effort should be made to minimise radiation dose during imaging of the head, while ensuring that image quality and coverage is sufficient to achieve an adequate diagnostic study.

In spite of the potential risks of increased radiation exposure as a result of these guidelines, this is justified by the increased effectiveness in identifying and managing people with significant brain injuries.

[†] NNHs and confidence intervals calculated using the on-line *UBC Clinical Significance Calculator* at <http://www.healthcare.ubc.ca/calc/clinsig.html>

References

1. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risks of radiation-induced fatal cancer from pediatric CT. *Am J Roentgenol* 2001;176(2):289–96.
2. Mettler FA, Wiest PW, Locken JA, Kelsey CA. CT scanning: Patterns of use and dose. *J Radiol Prot* 2000;20:353–9.
3. Shrimpton PC, Edyvean S. CT scanner dosimetry. *Br J Radiol* 1998;71(841):1–3.
4. Hart D, Wall BF. Radiation exposure of the UK population from medical & dental X-ray examinations. National Radiological Protection Board, NPRB-W4; August 2001.
5. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly: Sources and effects of ionizing radiation, Annex D: Medical Radiation Exposures. United Nations Sales Publication, 2000.
6. Chan C, Wong YC, Chau LF, Yu SK, Lau PC. Radiation dose reduction in paediatric cranial CT. *Pediatric Radiology*. 1999;29(10):770–5.
7. Huda W, Chamberlain CC, Rosenbaum AE, Garrisi W. Radiation doses to infants and adults undergoing head CT examinations. *Med Phys* 2001;28(3):393–9.
8. American Academy of Pediatrics. Risk of ionizing radiation exposure to children: a subject review. *Pediatrics* April 1998;101(4 Pt 1):717–9.
9. Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. National Radiological Protection Board. *Br J Radiol* 1997;70(833):437–9
10. International Commission on Radiological Protection. Managing patient dose in computed tomography. A report of the International Commission on Radiological Protection. *Ann ICRP*. 2000;30(4):7–45.
11. Wall BF. Personal communication from the National Radiological Protection Board 2002.
12. Shrimpton PC, Jones DG, Hillier MC, Wall BF, Le Heron J.C, Faulkner K. Survey of CT practice in the UK. Part 2: Dosimetric aspects. NRPB-R249. Chilton: National Radiological Protection Board, 1991.
13. Khursheed A, Hillier MC, Shrimpton PC, Wall BF. Influence of patient age on normalized effective doses calculated for CT examinations. *Br J Radiol*. 2002;75(898):819–30.
14. Hart D, Wall BF. Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations. NRPB-W4 edition. National Radiological Protection Board: Didcot, 2002.

15. Hart D, Jones DG, Wall BF. Coefficients for estimating effective doses from paediatric x-ray examinations. NRPB-R279. Chilton, Oxon: National Radiological Protection Board, 1996.
16. Diederich S, Lenzen H. Radiation exposure associated with imaging of the chest: comparison of different radiographic and computed tomography techniques. *Cancer* 2000; 89(11 Suppl): 2457–60.
17. National Radiation Laboratory. Sources, effects and risks of ionising radiation. Information Sheet 5. Christchurch, NZ: 1998.