

Commentary

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

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There is a statutory requirement in the UK for all those clinically or physically directing medical radiation exposures to have received adequate training [1]. The radiation protection component of this training is outlined in a schedule to the regulations and includes knowledge of “the ranges of radiation dose that are given to a patient with a particular procedure” [1]. In running training courses to impart this knowledge to clinicians and radiographers, medical physicists often resort to the results of a national survey of doses to patients from diagnostic X-ray examinations which was conducted by the National Radiological Protection Board (NRPB) in the early 1980s [2].

This survey revealed wide ranges in the doses used by different hospitals for the same type of X-ray examination, which in 1992 led the NRPB together with the Institute of Physical Sciences in Medicine, as it then was, and the College of Radiographers to draw up a National Protocol for Patient Dose Measurements in Diagnostic Radiology [3]. The protocol allows X-ray departments to compare their own performance against national norms and to decide whether action is needed to reduce their doses. Implementation of the protocol has been widespread and, in response to a request in the protocol, the results of over 50 000 patient dose measurements made at 375 hospitals throughout the UK had been sent to the NRPB for national collation by the end of 1995 [4]. Consequently, we now have a far more substantial patient dose database than in the past and are able to provide more reliable figures for typical radiation doses to patients from common X-ray procedures. One of the most interesting features of this new database is a reduction by about 30% in the mean doses for common procedures compared with those seen in the survey of 10 years ago.

The national protocol recommends measurement of the entrance dose on the surface of the patient in the middle of the incident X-ray beam for individual radiographs, or the cumulative dose–area product for complete examinations.

Measurements are made on a representative sample of patients for a particular type of radiograph or examination and the mean value is taken as a measure of the typical dose delivered to an average adult patient at that hospital. These directly measured doses can be compared with national reference levels to provide a useful indication of relative performance with respect to patient protection. However, such measurements cannot be readily compared with the radiation doses from other diagnostic procedures such as CT or nuclear medicine which are measured in a different way and result in different dose distributions within the body. Nor can they be directly related to the radiation risk to the patient.

In the context of the regulations [1], the *effective dose* [5] is probably the most relevant quantity in which to express and compare “the dose given to a patient” from different imaging procedures. It takes account of the distribution of dose amongst the radiosensitive organs in the body by summing the individual organ doses, having weighted each one according to the relative sensitivity of the organ to radiation-induced somatic or genetic effects. Knowledge of specific organ or tissue sensitivities to the somatic and genetic effects of radiation is far from precise so, at best, the effective dose provides a way of expressing a complex dose pattern in the body in terms of a single quantity which is roughly proportional to the probability (risk) of harmful radiation effects. However, the risk for a given effective dose decreases with increasing age at exposure since somatic effects, being delayed for many years or even decades after the exposure, will have a reduced opportunity for expression following X-ray examinations on the elderly and genetic effects are of no consequence for patients beyond their reproductive years.

To facilitate the estimation of effective doses, the NRPB has produced a report [6] which provides conversion coefficients to calculate the effective dose to a standard adult patient from entrance surface dose and dose–area product measurements for a wide range of common diagnostic X-ray procedures. The report allows more reliable

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estimates of effective dose to be made than was possible at the time of our earlier survey and also incorporates recent revisions in the definition of effective dose by the International Commission on Radiological Protection [5]. These are two further reasons, in addition to the acquisition of more extensive and recent patient dose measurements, for wishing to revise advice on typical patient doses.

In Table 1 typical effective doses are shown for some common medical X-ray procedures together with an indication of the range in values observed between hospitals for each procedure. The "typical" doses are based on rounded values of the mean effective doses seen in the NRPB-collated national database by the end of 1995 [4]. The X-ray procedures listed in the table are either single radiographs or complete examinations. For the complete examinations the mean numbers of films or spot images are indicated as well as the mean number of seconds of fluoroscopy, where appropriate. The effective dose for an examination consisting of several of the listed radiographs can be estimated simply by adding the contributions of each radiograph. For example, the typical effective dose for a lumbar spine examination comprising all three of the listed lumbar spine radiographs will be 1.3 mSv, whereas if the lumbosacral joint (LSJ) view is omitted, as is becoming increasingly common practice, the effective dose will be 1.0 mSv. These values are considerably lower than those published previously [2, 7] for the lumbar spine examination (2.2 mSv).

A system for patient dosimetry in CT was not

included in the national protocol [3] so the information on common CT examinations is based on a national survey of CT practice conducted by the NRPB in 1989 [8]. Doses for CT examinations are unlikely to have come down since then and might well have increased in view of the ever increasing speed of acquisition of CT images. A survey of all CT scanners in Wales in 1994 [9] showed that typical effective doses for routine CT examinations of the head and chest had remained substantially unchanged, whereas those for the abdomen and pelvis had increased by about 50%. The doses shown in the table for abdominal and pelvic CT reflect these increases. Typical doses for CT examinations quoted in the table are based on the mean values of the distributions seen in widespread surveys which include a proportion of examinations in which a second series of images were taken after the injection of a contrast medium. The proportion of examinations using contrast medium was about one-half which means that the typical dose for CT examinations which include contrast enhanced images will be about one-third higher (*i.e.* $\times 1.33$) than the values shown in the table and for those examinations which do not involve the use of a contrast medium they will be about one-third lower (*i.e.* $\times 0.66$).

An indication of the "ranges of radiation dose given to a patient" has been derived from the distributions in the typical dose delivered to an average adult patient observed over the 375 hospitals included in the NRPB national patient dose database and for the 144 CT scanners included in the NRPB national CT survey. The dose

Table 1. Typical effective doses to standard adult patients in the 1990s

Examination	Typical effective dose (mSv)	Range 5th–95th percentile (mSv)	Ratio 95th/5th percentile
<i>Single radiographs</i>			
Skull AP or PA	0.03	0.012–0.06	5.0
Skull LAT	0.01	0.005–0.02	4.0
Chest PA	0.02	0.008–0.037	4.6
Chest LAT	0.04	0.013–0.08	6.2
Thoracic spine AP	0.4	0.16–1.0	6.3
Thoracic spine LAT	0.3	0.06–0.7	12
Lumbar spine AP	0.7	0.25–1.6	6.4
Lumbar spine LAT	0.3	0.1–0.6	6.0
Lumbar spine LSJ	0.3	0.1–0.7	7.0
Abdomen AP	0.7	0.26–1.4	5.4
Pelvis AP	0.7	0.3–1.3	4.3
<i>Complete examinations</i>			
IVU (6 films)	2.5	0.8–5.6	7.0
Barium swallow (24 spot images, 106 s fluoro.)	1.5	0.7–2.0	3.0
Barium meal (11 spot images, 121 s fluoro.)	3	0.9–4.3	4.8
Barium follow (4 spot images, 78 s fluoro.)	3	1.1–6.5	5.9
Barium enema (10 spot images, 137 s fluoro.)	7	2.6–15	5.8
CT head	2	0.9–3.0	3.3
CT chest	8	2.4–16	6.7
CT abdomen	10	4.0–18	4.5
CT pelvis	10	4.0–18	4.5

distributions are invariably wide, skewed and include a few extreme high-dose outliers. There is frequently some doubt about the reliability of extreme outliers which may not be representative of normal practice at a particular hospital. Consequently, to provide an indication of the range of doses most likely to be met in practice, the range between the 5th and 95th percentile values, encompassing 90% of the sample, is shown in Table 1. The value at the top of this range can be seen to be consistently about twice the typical value. The ratio of the 95th to the 5th percentile value is also shown in the last column and covers factors of between 3 and 12 (average range factor=6).

With such wide ranges in dose evident between different hospitals there is no justification for quoting the typical effective doses to any more than one or two significant figures. For some procedures (chest PA, CT head and CT chest) this results in the revised effective doses being indistinguishable from previously quoted typical values. For most non-CT procedures the new typical doses are between 25% and 60% lower than the old, whereas for abdominal and pelvic CT examinations they are about 35% higher, making them equivalent to about 500 conventional chest X-rays. The information on interhospital dose ranges, however, indicates that some hospitals could be delivering doses up to a factor of two times higher or three times lower than the "typical" values. Whereas this revised dose information provides a welcome indication of a trend towards lower doses for common conventional X-ray procedures, it contains an instructive message for radiology practitioners of a persistent disparity in patient radiation protection practice around the country and of the ever-

increasing importance of CT as a source of population exposure.

References

1. The Ionising Radiation (Protection of Persons Undergoing Medical Examination or Treatment) Regulations 1988. London: HMSO, 1988.
2. Shrimpton PC, Wall BF, Jones DG, Fisher ES, Hillier MC, Kendall GM, et al. A national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals, NRPB-R200. London: HMSO, 1986.
3. IPSM Dosimetry Working Party. National protocol for patient dose measurements in diagnostic radiology, IPSM, NRPB, COR. Chilton: NRPB, 1992.
4. Hart D, Hillier MC, Wall BF, Shrimpton PC, Bungay D. Doses to patients from medical X-ray examinations in the UK—1995 review, NRPB-R289. London: HMSO, 1996.
5. ICRP. 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60. Oxford: Pergamon Press, 1991: Ann. ICRP, 21, Nos 1–3.
6. Hart D, Jones DG, Wall BF. Estimation of effective dose in diagnostic radiology from entrance surface dose and dose-area product measurements, NRPB-R262. London: HMSO, 1994.
7. Shrimpton PC, Wall BF, Croft JR, Webb GAM. Medical Exposure. In: Occupational, Public and Medical Exposure. Guidance on the 1990 Recommendations of ICRP. London: HMSO, 1993: Doc. NRPB 4, No. 2.
8. Shrimpton PC, Jones DG, Hillier MC, Wall BF, LeHeron JC, Faulkner K. Survey of CT practice in the UK. Part 2: Dosimetric aspects, NRPB-R249. HMSO: London, 1991.
9. Hiles PA, Scott SA, Brennen SE, Davies JH. All Wales CT Dose and Technique Survey. Report by the Medical Imaging Sub-committee of the Welsh Scientific Advisory Committee. Cardiff: Welsh Office, 1996.