SCIENTIFIC LETTER

Cardiac catheterisation: radiation doses and lifetime risk of malignancy

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Cardiac catheterisation and angiography uses ionising radiation and therefore produces a radiation dose to the patient and to the operating staff. The dose to the patient can be measured using thermoluminescent dosimeters placed on the skin or by using a large-area detector attached to the x ray tube to measure the dose–area product (DAP) for the incident x ray beam (DAP meter). The DAP is particularly useful for assessing and comparing the radiation dose from screening procedures. It provides a more useful indication of the overall patient exposure than measurement of surface dose at particular locations. The dose measurement is used either as a surrogate for radiation risk or as a step in actually estimating the risk. Published factors allow conversion of the DAP to effective dose, a derived quantity in which doses to different organs or tissues are weighted according to their radiosensitivity and summed to give a risk-related dose quantity.^{1–5}

UK legislation does not give dose limits for patients undergoing medical diagnostic exposures, but requires adherence to the “as low as reasonably practicable” principle, and comparison of doses with diagnostic reference levels for common procedures. Published data for patient exposure, absorbed dose, effective dose and risk of malignancy from the different specific diagnostic cardiac catheterisation procedures are incomplete, and there are no national diagnostic reference levels for individual procedures.

We undertook this study with the aim of establishing local patient doses for six different diagnostic cardiac catheterisation procedures by looking at screening times and DAP results, and then establishing the effective dose. From these values, we estimated the patient risk in each specific procedure group.

METHOD

We prospectively collected data on 4398 diagnostic cardiac examinations carried out in a regional cardiac catheter laboratory over a period of 3 years. We did not include patients who had coronary angiography and went on to have revascularisation. The patients’ demographic details and the examination details were recorded (including screening time, number of acquisitions and number of cine frames).

The x ray equipment used was a digital Philips Polydiagnost C2 single-plane image-intensifier system (installed in 1992), which has an automatic control of x ray exposure parameters. The average tube potential was 80 kVp (kilovoltage peak) and the total filtration was 4 mm aluminium (equivalent thickness of aluminium). The tube potential and the filtration were kept constant throughout all procedures. A diamentor (PTW-Physikalische Technische Werkstaetten, Freiberg) was used to measure the DAP. The recorded DAP values were corrected to a standard patient size. Effective dose measured in millisieverts was calculated from the DAP reading using conversion factors for the various projections corresponding to a filtration of 4 mm aluminium and a mean tube kilovoltage of 80 kV as described

previously.^{1–5} The proportion of total DAP assigned to each projection was estimated for each of the six diagnostic groups in the study, to derive a conversion factor for each examination group (0.23 mSv/Gy cm² for right anterior oblique views and 0.205 mSv/Gy cm² for left anterior oblique views).

We estimated the risk of malignancy for each specific examination from the effective dose values. Published reports indicate an estimate of 2.5% per Sievert (2.5×10^{-2} /Sv or 1 in 40 000/mSv) additional lifetime risk of fatal cancer for a population between the ages of 40 and 60 years, and this figure has been used for comparative purposes here. Additional details and the methods of statistical analysis are available in a supplementary report at <http://heart.bmj.com/supplemental>.

RESULTS

The descriptions of the projections used, conversion factors and demographic details of the patients studied are available in the supplementary report. Table 1 summarises the screening time, DAP, effective dose and estimated risk of malignancy for the different groups. Diagnostic group 1 had the lowest values of DAP and effective dose compared with the other diagnostic groups, with the lowest additional lifetime risk (0.011%) of malignancy (LROM). The sequential increase in LROM from one group to another was statistically significant except for groups 3 and 4, which had equivalent risk.

DISCUSSION

The potential harmful effects of radiation are documented along with permitted recommended safe dose limits to staff (International Commission on Radiological Protection). Two types of radiation effects may occur: deterministic (skin erythema and ulceration) and stochastic effects. The risk of long-term stochastic effects (eg, cancer, leukaemia) is usually assessed by effective dose, which makes some allowance for the properties of the radiation concerned and for non-uniform distribution of radiation over the body. We did not observe any deterministic effect in the current patient population. We did not perform long-term follow-up of these patients to evaluate the appearance of stochastic effects; the estimated frequency of malignancy would require a long-term follow-up of a cohort larger than ours to prospectively validate our estimates.

The DAP measurements have been widely used in previous studies either as a means of comparison of radiation dose or as a step for estimation of risk. Our results on the DAP measurements and effective dose are comparable to previous studies. However, this is the first study to describe in detail the hypothetical additional LROM in patients undergoing different radiological cardiac diagnostic procedures. This study also provides diagnostic reference levels as recommended by the

Abbreviations: DAP, dose–area product; LROM, lifetime risk of malignancy

Table 1 Screening time (s), dose–area product (Gy cm²), effective dose (mSv) and estimated risk (%) of malignancy for diagnostic cardiac imaging

Groups	Number	Screening time	DAP (Gy cm ²)	ED (mSv)	Risk (%)	Additional risk of cancer
A.COR	464	240.7 (333.9, 114)	20.1 (17.7, 15.6)	4.4	0.011	1 in 9000
A.LVC	3288	199 (242, 120)	21.7 (11.9, 19.1)	4.8	0.012	1 in 8000
RHLVC	207	529.9 (398, 420)	32.1 (20.3, 27.4)	7.0	0.018	1 in 6000
A.LAC	194	414.6 (412, 279)	33 (18, 29.4)	7.4	0.018	1 in 6000
A.CAB	175	697 (486, 558)	40.3 (18, 37.7)	8.9	0.022	1 in 5000
A.CAC	70	815.3 (487.5, 732)	51.4 (22.6, 46.8)	11.5	0.029	1 in 3000

A.CAB, ventriculography, coronaries and graft studies; A.CAC, aortogram, coronaries and graft study; A.COR, coronaries only; A.LAC, aortogram and coronaries; A.LVC, left ventriculography (LV) and coronaries; DAP, dose–area product; ED, effective dose; RHLVC, right heart catheterisation with A.LVC. Values are expressed as mean (SD, median).

International Commission on Radiation Protection (ICRP 60), as directed in Europe by Council Directive 97/43/Euratom and as implemented in the UK by the Ionising Radiation (Medical Exposure) Regulations 2000.

In a previous report, the mortality associated with cardiac catheterisation and coronary angiography was 0.11%. The incidence of total major complications was 1.7%. Living in Cornwall (UK) has an additional radiation of 7 mSv/year and a flight to the US has an additional radiation dose of 40–50 µSv. The typical effective dose for a chest x ray (PA) is 0.02 mSv and for angiography is 10 mSv. Magnetic resonance coronary angiography does not involve radiation, and nuclear medicine involves 8–20 mSv of radiation.

The risks associated with coronary heart disease itself and the procedure of coronary angiography are relatively high compared with the hypothetical additional lifetime risk of malignancy in patients undergoing different radiological cardiac diagnostic procedures. Nevertheless, the additional LROM should not be ignored, particularly for younger patients, especially given the high numbers of cardiac procedures performed worldwide. In addition, the information provided allows informed consent for asymptomatic patients undergoing repeat coronary catheterisation as part of a clinical trial rather than for a specific clinical indication.

The radiation dose to the patient can be minimised by opening the iris on the television camera, allowing a lower increase in beam intensity and also by using flat panel detectors which have more sophisticated controls. To minimise scatter, an air gap between the patient and the detector can be used. In addition, the need for left ventriculography can be questioned if the relevant information can be acquired by non-invasive means.

More complex cardiac radiological procedures are associated with higher radiation doses, thereby greatly increasing the lifetime risk of malignancy. Every additional procedure must always be justified by a positive balance of benefit over risk for

each patient. Stochastic risks of radiation by and large should not greatly affect this judgement, given that non-radiation risks are an order of magnitude higher.

Additional details and statistical analysis methods are available at <http://heart.bmj.com/supplemental>

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REFERENCES

- Hart D, Jones D, Wall B. Estimation of effective dose in diagnostic radiology from the entrance surface dose and dose-area product measurements. *Radiat Prot Board NRPB* 1994;**R262**:1–57.
- Broadhead D, Chapple C, Faulkner K, et al. The impact of cardiology on the collective effective dose in the North of England. *Br J Radiol* 1997;**70**:492–7.
- Rassow S. From the entrance dose to the calculation of organ doses. *Radiat Prot Dosim* 1998;**80**:327–9.
- Le Heron J. Estimation of effective dose to the patient during medical x-ray estimations from measurements of the dose-area product. *Phys Med Biol* 1992;**37**:2117–26.
- Leung K, Martin C. Effective dose for coronary angiography. *Br J Radiol* 1996;**69**:426–31.