IAEA-CN-85-64

PATIENT DOSES IN DIGITAL CARDIAC IMAGING.

XA0101650

W. Huda[1], K. Phadke[2], K.M Ogden[1], M.L Roskopf[1]
Departments of Radiology[1] and Medicine,[2] SUNY Upstate Medical University, New York, United States of America

Abstract

In this pilot study, we obtained estimates of entrance skin doses and the corresponding effective doses to patients undergoing *digital* cardiac imaging procedures on a GE Advantx LC/LP Plus system. Data were obtained for six patients undergoing diagnostic examinations and six patients who had interventional procedures. For each patient examination, radiographic techniques for fluoroscopic and digital cine imaging were recorded, together with the irradiation geometry. The projection with the *highest* exposure resulted in an average skin dose of 0.64 ± 0.41 Gy (maximum of 1.6 Gy). The average patient skin doses taking into account overlapping projections was 1.1 ± 0.8 Gy (maximum of 3.0 Gy). The exposure area product (EAP) incident on the patient was converted into the energy imparted to the patient and the corresponding effective dose. The average patient effective dose was 28 ± 14 mSv (maximum 62 mSv), with the resultant average fatal cancer risk estimated to be of the order of 8 x 10^{-3}. Average doses for interventional procedures in cardiac imaging are higher than those associated with diagnostic examinations by approximately 50%.

1. Introduction

Cardiac imaging is recognized as a procedure that results in relatively high patient doses [1]. Cine film is currently being replaced by *digital* x-ray imaging equipment, and the resultant images are increasingly being viewed using (soft copy) display stations. It is therefore of interest to obtain doses to patients who undergo *digital* cardiac imaging procedures, and to produce quantitative estimates of the corresponding patient radiation risks.

In this pilot study, we quantified the entrance skin doses that predict the possibility of inducing a deterministic effect to the skin, as well as patient effective doses that quantify the stochastic risk of inducing cancer and genetic effects. Cardiac imaging may be performed for obtaining a diagnostic information (i.e., diagnostic) or during procedures that attempt to treat the patient (i.e., interventional), and data were obtained for both types of examination.

2. Method

1. Cardiac imaging workload

Each year, about 860 diagnostic examinations and 160 angioplasty examinations are performed in the catheterization suite at University Hospital, Upstate Medical University, Syracuse NY. The imaging is performed on a GE Advantx LC/LP Plus[1] system that was installed in 1999. In this pilot study, data was collected on twelve randomly selected patients undergoing digital cardiac imaging. Six patients underwent diagnostic examinations and the other six patients underwent interventional procedures (e.g., angioplasty).

X-ray beam characteristics were measured at the x-ray tube potential used clinically. The x-ray output was determined in terms of air kerma (μGy) per unit mAs, where an exposure of 1 R (2.58 x 10^{-4} C kg^{-1}) corresponds to an air kerma of 8.73 mGy. For the frontal plane operated at 80 kVp, the measured output at 60 cm was 130 μGy/mAs at a distance of 60 cm, and the corresponding Half Value Layer was 3.4 mm Al.

[1] General Electric Medical Systems, Milwaukee WI, United States of America.

2. Skin doses

In fluoroscopy, information was recorded for the selected x-ray tube potential (i.e., kVp), tube current (mA) and total fluoroscopy time. In digital imaging, information was recorded for the average x-ray tube potential (kVp), tube current (mA), exposure time per frame (s), and the total number of image frames acquired.

The source to patient skin distance was determined from the source to image receptor distance (SID), together with the air gap between the patient and the image intensifier. Patients were modeled as elliptical cylinders with dimensions of 27 cm (Anterior-Posterior) and 40 cm (Lateral).

Data were recorded for each separate projection. For any patient, the projection with the maximum skin dose was termed projection 1, the second highest skin dose was projection 2 and so forth. Since it is inappropriate to arithmetically sum all entrance skin doses [2], we explicitly estimated the *maximum* skin dose by taking into account any overlap of the x-ray projections used for each patient [3].

3. Effective doses

Data on the image receptor size and x-ray tube output permitted the exposure-area product (EAP) incident on the patient to be determined. The EAP was converted into the corresponding value of energy imparted taking into account both the x-ray beam quality (HVL) and the patient thickness [4], with the effective density in the cardiac region taken to be 800 kg m^{-3}. Values of energy imparted were converted into effective doses using a conversion factor of 19 mSv J^{-1}, which is a representative value of the effective dose per unit energy imparted in cardiac imaging [5].

3. Results & discussion

1. Skin doses.

Table 1 summarizes the entrance skin doses for the twelve patients included in this study. Data in Table 1 show that the entrance skin doses falls off rapidly with projection number. For example, the mean dose for the fifth projection was <20% of the value of the average dose for projection 1.

Table 1. Entrance skin dose (Gy) summary for twelve patients, when *no* account is taken of any overlap of different projections

Projection	# of patients	Mean ± σ	Minimum	Maximum
1	12	0.64 ± 0.41	0.28	1.6
2	12	0.48 ± 0.35	0.12	1.4
3	12	0.23 ± 0.11	0.07	0.47
4	7	0.21 ± 0.14	0.03	0.44
5	5	0.11 ± 0.08	0.02	0.21

For most patients, there was some overlap of entrance skin doses between adjacent projections (e.g., PA & RAO 45° or LAO 45° & LAO 25°). Taking into account projection overlap, the average *maximum* skin doses was 1.1 ± 0.8 Gy. The highest *maximum* skin dose was 3.0 Gy, and the lowest *maximum* skin dose was 0.38 Gy.

2. Effective doses.
The average effective dose for digital cardiac imaging was 28 ± 14 mSv. The minimum patient effective dose was 7.8 mSv and the maximum patient effective dose was 62 mSv. The nominal radiation risk coefficient for an adult working population is taken to be 4% per Sv[6]. Taking into account the demographic data for patients undergoing medical examinations would likely reduce the radiation risk. In this study, we used a risk reduction factor of ~0.34 as a representative value for a population undergoing x-ray studies [7]. The average stochastic risk of inducing fatal cancer for patients undergoing digital cardiac imaging is therefore of the order of 8×10^{-3}.

3 Diagnostic examinations vs Interventional procedures.
The data in Table 2 show average dose parameters for patients undergoing diagnostic examinations and interventional procedures. Average doses for interventional procedures are higher than those associated with diagnostic examinations by approximately 50%. It is also notable that the variability in patient doses is considerably higher for interventional procedures than for diagnostic procedures.

Table 2. Comparison of patient doses between diagnostic and interventional procedures

Dose parameter	Diagnostic procedures	Interventional procedures
Effective dose	23 ± 4 mSv	33 ± 19 mSv
Projection 1 skin dose	0.54 ± 0.20 Gy	0.74 ± 0.56 Gy
Maximum skin dose	0.84 ± 0.20 Gy	1.3 ±1.0 Gy

4. Conclusions

Digital cardiac imaging results in relatively high skin doses and effective doses. The highest skin doses observed in this study are comparable to threshold doses for the induction of deterministic effects such as skin erythema [8]. Effective doses in cardiac imaging are much higher than those encountered in most areas of diagnostic radiology and nuclear medicine [1, 9].

Acknowledgements

The authors gratefully acknowledge the financial and technical support of General Electric. Maryana Kushnir RT provided valuable assistance in helping to collect radiation technique data on patients undergoing cardiac catheterization.

References

[1] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION (UNSCEAR), 1993 Report to the General Assembly, (United Nations, NY) 1993.

[2] CUSMA, J.T., BELL, M.R., WONDROW, M.A., TAUBEL, J.P., HOLMES, D.R., Real-time measurements of radiation exposure to patients during diagnostic coronary angiography and percutaneous interventional procedures, Journal of the American College of Cardiology **33** (1999) 427-435.

[3] STERN, S.H., ROSENSTEIN, M., RENAUD, L., ZANKL, M., Handbook of selected tissue doses for fluoroscopic and cineangiographic examination of the coronary arteries, HHS Publication FDA 95-8289, September 1995.

[4] [GKANATSIOS, N.A., HUDA, W., Computation of energy imparted in diagnostic radiology, Med. Phys. **24** (1997) 571-579.

[5] HUDA, W., GKANATSIOS, N.A., Effective dose and energy imparted in diagnostic radiology, Med. Phys. **24** (1997) 1311-1316.

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP), 1990 Recommendations of the ICRP. Pergamon Press (Oxford), 1991.

[7] HUDA, W., BEWS, J., Population irradiation factors (PIFs) in diagnostic medical dosimetry, Health Physics **59** (1990) 345-347.

[8] WAGNER, L.K., ELFEL, P.J., GEISE, R.A., Potential biological effects following high x-ray dose interventional procedures, JCIR **5** (1994) 71-84.

[9] HUDA, W. Radiation dosimetry in diagnostic radiology, AJR **169** (1997) 1487-1488.