

RADIATION PROTECTION FOR INTERVENTIONAL FLUOROSCOPY: RESULTS OF A SURVEY AMONG DUTCH HOSPITALS

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Abstract—A survey was conducted among 20 Dutch hospitals about radiation protection for interventional fluoroscopy. This was a follow-up of a previous study in 2007 that led to several recommendations for radiation protection for interventional fluoroscopy. The results indicate that most recommendations have been followed. However, radiation-induced complications from interventional procedures are still often not recorded in the appropriate register. Furthermore, even though professionals with appropriate training in radiation protection are usually involved in interventional procedures, this often is not the case when these procedures are carried out outside the radiology department. Although this involvement is not required by Dutch law, it is recommended to have radiation protection professionals present more often at interventional procedures. Further improvements in radiation protection for interventional fluoroscopy may come from a comparison of dose-reducing practices among hospitals, the introduction of diagnostic reference levels for interventional procedures, and a more thorough form of screening and follow-up of patients. *Health Phys.* 114(6):627–631; 2018

Key words: interventional fluoroscopy; radiation protection; x rays

INTRODUCTION

RADIATION DOSES from interventional fluoroscopy are among the highest for radiological procedures. As these doses result in a certain risk of adverse effects, radiation protection is especially important in this field. Therefore, a study was conducted in the Netherlands in 2007 to find out what radiation protection measures were taken for patient safety during interventional procedures in Dutch

hospitals (Meeuwssen et al. 2007). This led to three recommendations: (1) modern and specialized equipment should be used for interventional radiology, (2) more attention should be paid to training professionals involved in radiation protection for interventional radiology, and (3) radiation-induced complications should be recorded in a complication register.

Here the authors report a follow-up study of radiation protection for interventional fluoroscopy in the Netherlands, conducted by order of the Dutch Healthcare Inspectorate. For this study a literature review was carried out, and an electronic survey was conducted among 20 Dutch hospitals. The main purpose was to investigate what has been done with the previous recommendations and to find out whether the current interventional fluoroscopy practice is up to date with the state of the art, according to the scientific literature.

MATERIALS AND METHODS

A limited literature review was carried out using the following combinations of keywords (where * denotes a wildcard): “intervention*,” “fluoroscop*,” “radiol*,” “*radiation,” “ionising OR ionizing,” “x-ray,” and “exposure OR dose.” A search was conducted in the literature database PubMed, limited to papers in English published in the last five years. This resulted in 78 hits. Titles and abstracts of these articles were studied, and in several instances, the full papers were retrieved and studied. Several new practices were identified and translated into questions for the survey (see below).

For the survey, 20 general hospitals were randomly selected out of all Dutch hospitals (currently there are approximately 80 conglomerates). An electronic questionnaire was set up in four parts: part 1 consisted of general questions about the respondent; part 2 consisted of general questions about the different departments involved in conducting interventional procedures (number of staff, number of examinations, radiation protection training, etc.); part 3 was about equipment and radiation doses; and part 4 was about screening and follow-up of patients. The questionnaire was sent to both the general management of the hospital and the

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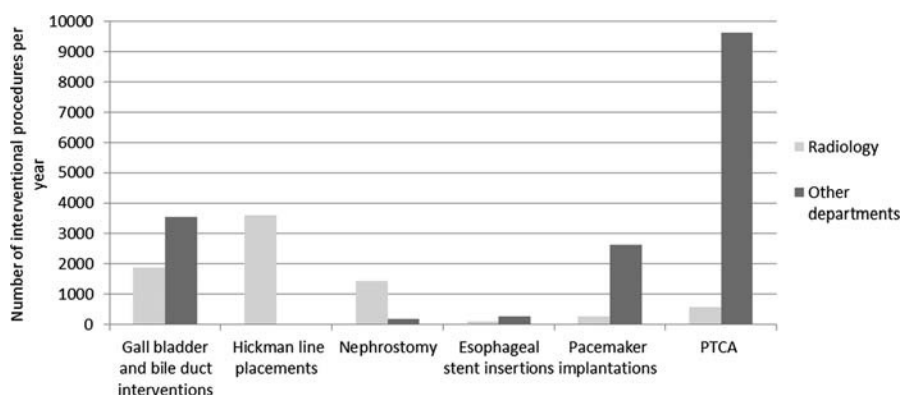


Fig. 1. Overview of a number of different interventional procedures reported by the participating hospitals. Light grey shaded columns refer to procedures carried out in the radiology department; dark grey shaded columns refer to procedures carried out in other departments (such as urology, cardiology, and gastroenterology).

radiology department of the same hospital. In this paper, as well as in the corresponding Dutch report (Bijwaard and Valk 2017), the responses of the hospitals are treated anonymously.

RESULTS

The literature review led to a series of interesting points to be addressed in the questionnaire. Among these were the following facts: (1) in many cases vascular surgeons and radiologists, who have not been trained as interventional radiologists, perform vascular interventions (Reekers 2013); (2) in some cases radiation doses can be reduced when the operator, instead of the radiographer, performs the imaging (Peach et al. 2012); (3) in other cases radiation doses can be kept to a minimum by starting off with very low-dose imaging parameters and gradually increasing these parameters until an adequate image quality is reached (Yamamoto et al. 2013); (4) for heart catheterization procedures, state-of-the-art equipment can reduce radiation doses by 60–90% (Smith et al. 2012); (5) in the transition from conventional imaging to flat-panel detectors, imaging parameters should be optimized in order to avoid an increase in radiation dose (Prieto et al. 2011); (6) in some countries diagnostic reference levels (DRLs) have been introduced for some interventional procedures (Samara et al. 2011; Bleaser et al. 2008); (7) practicing stent placement in a virtual reality simulator leads to more optimized procedures (Willaert et al. 2011); (8) interventional procedures are carried out more and more outside the radiology department where radiation protection supervision is often less stringent and staff members trained in radiation protection are scarce (ICRP 2010); and (9) screening of patients beforehand (for earlier radiation exposures, sensitivity, hereditary conditions, etc.) and follow-up of patients afterwards (for late adverse effects) are good medical practices (Miller et al. 2010; Kato et al. 2010).

Out of the 20 hospitals that were contacted, 18 responded to the survey (90%). In the following, the main findings are presented. The results are described more elaborately in the Dutch report (Bijwaard and Valk 2017). Interventional procedures are performed in the radiology department in 16 of the 18 reporting hospitals. However, among the radiology departments of these 16 hospitals, a difference is seen in the types of interventional procedures that are carried out there: in 13 of the 16 radiology departments, gall bladder and bile duct procedures are performed (5–766 per year); 7 departments do Hickman line placements (1–2,495 per year); 15 place nephrostomy catheters (10–461 per year); 5 insert esophageal stents (3–50 per year); 2 implant pacemakers (120–139 per year); and 2 carry out percutaneous transluminal coronary angioplasty (PTCA) procedures (170–400 per year). In nearly all cases, an interventional radiologist and a radiographer are present when a procedure is carried out in the radiology department. Both have had radiation protection training. One of them usually sets the parameters for the fluoroscopy. In some hospitals, this is always done by the radiographer and in others always by the interventional radiologist, but in most cases (10) it is partly done by both. In six hospitals the parameters are sometimes determined by either another therapist or an assistant. Although the majority of these therapists do have a radiation protection diploma, their assistants usually do not. The equipment that is used in the radiology department is usually less than 10 years of age (18 machines less than 5 years old and 16 machines between 5 and 10 years of age). Only two machines are older than 10 years, and all machines have dose indicators.

Some of the previously mentioned interventional procedures are also carried out in other departments, such as urology, cardiology, and gastroenterology. This is indicated by 14 of the 18 reporting hospitals. In the urology departments of three of these hospitals, placement of nephrostomy catheters takes place (35–117 per year). An interventional

radiologist usually is not present but a radiographer is. In four hospitals it is usually the radiographer setting the imaging parameters and in three it is usually the urologist (the others have not reported this information). Most urologists (seven out of nine) have had radiation protection training. The equipment used is usually less than 10 years of age (seven machines less than 5 years old and nine between 5 and 10 years of age). Only two machines are older than 10 years, and all machines have dose indicators.

The implantation of pacemakers and PTCA procedures are carried out mostly in the cardiology department instead of the radiology department. For the implantation of pacemakers this is the case in 14 hospitals (50–545 per year). PTCA procedures are carried out in the cardiology department in eight hospitals (1.3–2,500 per year). In all cases this is done without an interventional radiologist present, and in only a single case a radiographer is present. In that case, the radiographer sets the fluoroscopy parameters. In two other cases an assistant is responsible for this, but in the remaining cases it is the cardiologist who sets the parameters, and he or she has always had radiation protection training. The equipment used is usually less than 10 years of age (14 machines less than 5 years old and 18 between 5 and 10 years of age). Only three machines are older than 10 years, and all machines have dose indicators.

Interventional procedures involving the gall bladder or bile ducts are performed in the gastroenterology department in nine hospitals (2–1,000 per year). In one hospital, an interventional radiologist is present; in six others a radiographer is present. Esophageal stent placement is done in the gastroenterology department in eight hospitals (1–100 per year). Interventional radiologists are not involved in this procedure, but in half the cases a radiographer is present. In all cases the person responsible for the fluoroscopy setting has taken radiation protection training. The equipment used is usually less than 10 years of age (seven machines less than 5 years old and four between 5 and 10 years of age). Only one machine is older than 10 years, and all machines except for one have dose indicators.

The third part of the questionnaire consisted of specific questions about radiation dose and dose-reducing options. Reported dose-area product (DAP) values ranged from 3 to 288 Gy cm² for gall bladder and bile duct interventions, from 1 to 10 Gy cm² for nephrostomies, from 3 to 13 Gy cm² for esophageal stent placements, from 5 to 30 Gy cm² for pacemaker implantations, from 20 to 146 Gy cm² for PTCA procedures, and for insertion of a Hickman line, from 0 to 1 Gy cm² was reported. All hospitals have equipment that allows for adjustment of tube voltage and current, distances, and field size. Equipment for which radiation filters are available and that allows for pulsed fluoroscopy and last-image hold is available in 14 hospitals. All hospitals have standardized protocols for their equipment. In 14 cases

these protocols have been drafted by the hospitals themselves, and in 4 cases these come from the manufacturer. As reported by the 18 hospitals, options that are best avoided during interventional procedures include electronic zoom (mentioned 10 times), high dose-rate imaging (15 times), noise reduction (9 times), lateral projections (8 times), and craniocaudal projections (8 times). Options that are used to reduce radiation dose include dose spreading (to reduce skin dose, mentioned 4 times), accurate collimation (17 times), use of state-of-the-art catheters (13 times), step-wise adjustment of imaging parameters (11 times), and practicing in virtual reality (3 times). In three hospitals the interventional radiologist keeps track of the total radiation dose delivered during the procedure. In 11 hospitals this task is delegated to a radiographer, and in 3 others this task is not assigned to anyone (1 hospital didn't answer this question). Quality assurance of the equipment in the form of continuity tests is performed every month in 5 hospitals, every six months in 11 hospitals, and once a year in the remaining hospitals. The tests are carried out by a medical physicist (seven times), a radiographer (seven times), or the manufacturer (four times).

The last part of the questionnaire considered screening and follow-up of patients. Sixteen hospitals carry out some form of screening for radiation sensitivity (the others do not). In all cases this includes screening for pregnancy, in 10 cases age was considered, and in 2 cases obesity and previous radiation exposures were taken into account. Comorbidity, medicine use, hereditary factors, and skin color were not mentioned. Seven hospitals indicate that some form of follow-up of their patients is carried out (in some cases this is dose dependent). This usually consists of either a consult with the therapist or through the filling out of a form. Three hospitals reported tissue reactions (deterministic effects) in 22 cases over the last five years. One of the three has reported this to the complication register of the interventional radiology section of the Dutch radiology society.

DISCUSSION

This study is a follow-up of an earlier study (Meeuwse et al. 2007) in which the following recommendations were made: (1) modern and specialized equipment should be used for interventional radiology, (2) more attention should be paid to radiation protection in training professionals involved in interventional radiology, and (3) radiation-induced complications should be recorded in a complication register. The latter recommendation has not been followed: only one out of the three hospitals that report complications sends these to the register. Of the equipment used, overall 45.5% is less than 5 years old and 92% is less than 10 years old. The European Coordination Committee of the Radiological, Electromedical, and Healthcare IT Industry (COCIR)

recommends 60% to be less than 5 years old and 90% to be less than 10 years old (COCIR 2016). The respondents therefore do not fully comply with these recommendations, but in the European comparison charts of COCIR, the Netherlands performs very reasonably. Finally, regarding radiation protection training, nearly all interventional radiologists and radiographers have radiation protection diplomas. However, in many procedures outside the radiology department these professionals are not involved. In some cases, other therapists present have had radiation protection training, but especially in the cardiology department this sometimes is not the case for their assistants. It should be noted also that this currently is not required by Dutch law.

The reported radiation doses differ considerably among hospitals. This may have to do with differences in complexity of the procedures in individual cases and the experience of the therapist involved. However, there also exists a large variability in imaging options that are used (or avoided) to reduce radiation doses. In the Netherlands, no DRLs have been defined for interventional procedures. The International Commission on Radiological Protection (ICRP) does recommend this (ICRP 2017), and several examples do exist in the scientific literature (e.g., Samara et al. 2011; Bleeser et al. 2008). It seems that Dutch hospitals could benefit from these. In Table 1 some statistics of the reported doses are compared to those reported for the United Kingdom (UK) by Hart et al. (2012). Note that DAP values were used instead of cumulative air kerma (which would be more appropriate), because DAP values are commonly recorded and are therefore relatively easy to report for the participating hospitals. If the median values are taken to be the most representative of the Dutch situation (even though the sample size is rather small), these appear to correlate reasonably well with the values from the UK. Except for the procedures that are often performed in the cardiology department (pacemaker implant and PTCA), the DAP values are similar to or below the UK values. The fact that procedures carried out in the cardiology department result in higher doses

raises the question whether doses could be reduced if radiographers or interventional radiologists were present more often at these procedures.

Finally, the results of the survey show that screening and follow-up of patients is common but fairly restricted. Screening for pregnancy is standard practice, but for hereditary conditions, for example, it is rare. Similarly, only 7 (out of 18) hospitals check patients for late tissue reactions, although in 3 hospitals complications are reported. For both screening and follow-up, a more comprehensive approach is recommended in the scientific literature (Miller et al. 2010; Kato et al. 2010).

CONCLUSION

In an earlier study, three recommendations were formulated for Dutch interventional radiology practice. Two of these seem to have resulted in improvements, but the third (regarding registration of complications) currently lacks implementation. This is regrettable considering the fair amount of complications that were reported (voluntarily) by participating hospitals. Apart from this, more attention seems to be paid to radiation protection in the radiology departments. However, interventional procedures are often conducted in other departments. At these procedures radiographers and interventional radiologists often are not present. This is especially true for interventions carried out in the cardiology department (such as PTCA procedures and pacemaker implants). Even though the presence of these professionals is not required by Dutch law, radiation doses might be reduced when a radiographer or radiologist is present. A comparison between Dutch and British dose values seems to indicate that these are usually rather similar, except for the procedures commonly carried out by cardiologists. Further improvements may come from a comparison of dose-reducing practices (which seem to vary considerably among hospitals), the introduction of DRLs for interventional procedures (where they are currently absent), and a more thorough form of screening and follow-up of patients.

Table 1. Summary of reported DAP values for interventional procedures. The values in the last two columns represent the median value reported in this study and the value taken from Hart et al. (2012) for the UK.

Procedure	Hospitals	Min (Gy cm ²)	Max (Gy cm ²)	Mean (Gy cm ²)	Median (Gy cm ²)	UK (Gy cm ²)
Gall bladder	8	3	288	52,9	11,5	32
Hickman line	5	0	1	0,6	1	1
Nephrostomy	8	1	10	5,4	5	5
Esophageal stent	5	3	13	6,8	5	7
Pacemaker	8	5	30	12,5	11	4
PTCA	6	20	146	67,7	51	24

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REFERENCES

- Bijwaard H, Valk D. Interventieradiologie-Inventarisatie van de Nederlandse praktijk met speciale aandacht voor stralingsbescherming van de patiënt. Bilthoven, The Netherlands: RIVM; RIVM report 2017-0025; 2017 (in Dutch).
- Bleeser F, Hoornaert M-T, Smans K, Struelens L, Buis N, Berus D, Clerinx P, Hambach L, Malchair F, Bosmans H. Diagnostic reference levels in angiography and interventional radiology: A Belgian multi-centre study. *Radiat Protect Dosim* 129: 50–55; 2008.
- COCIR. Medical imaging equipment age profile & density: Renewal & replacement now essential & long overdue. Brussels: COCIR; 2016 ed.; 2016.
- Hart D, Hillier MC, Shrimpton PC. Doses to patients from radiographic and fluoroscopic x-ray imaging procedures in the UK—2010 review. Chilton, UK: HPA-CRCE; HPA-CRCE-034; 2012.
- International Commission on Radiological Protection. Radiological protection in fluoroscopically guided procedures performed outside the imaging department. London: SAGE Publications Ltd; ICRP Publication 117; 2010.
- International Commission on Radiological Protection. Diagnostic reference levels in medical imaging. London: SAGE Publications Ltd; ICRP Publication 135; 2017.
- Kato M, Chida K, Sato T, Kadowaki K, Tosa T, Oosaka H, Sasaki M, Sasaki F, Yoshida K. Patient skin injury in cardiac intervention procedures. *Nihon Hoshasen Gijutsu Gakkai Zasshi* 66: 688–689; 2010.
- Meeuwse E, Stoop P, Bijwaard H. Kwaliteitsborging ter optimalisatie van de patientdosis in de interventieradiologie. Bilthoven, The Netherlands: RIVM; RIVM report 300080002; 2007 (in Dutch).
- Miller DL, Balter S, Schueler BA, Wagner LK, Strauss KJ, Vañó E. Clinical radiation management for fluoroscopically guided interventional procedures. *Radiol* 257:321–332; 2010.
- Peach G, Sinha S, Black SA, Morgan RA, Loftus IM, Thompson MM, Hinchliffe RJ. Operator-controlled imaging significantly reduces radiation exposure during EVAR. *Eur J Vasc Endovasc Surg* 44:395–398; 2012.
- Prieto C, Vano E, Fernández JM, Martínez D, Sánchez R. Increases in patient doses need to be avoided when upgrading interventional cardiology systems to flat detectors. *Radiat Protect Dosim* 147:83–85; 2011.
- Reekers J. Lek in systeem bedreigt interventieradiologie, Medisch Contact [online]. 5 June 2013 (in Dutch). Available at <https://www.medischcontact.nl/nieuws/laatste-nieuws/artikel/lek-in-systeem-bedreigt-interventieradiologie.htm>. Accessed 17 March 2018.
- Samara ET, Aroua A, De Palma R, Stauffer JC, Schmidt S, Trueb PR, Stuessi A, Treier R, Bochud F, Verdun FR. An audit of diagnostic reference levels in interventional cardiology and radiology: Are there differences between academic and non-academic centres? *Radiat Protect Dosim* 148:74–82; 2011.
- Smith BG, Tibby SM, Qureshi SA, Rosenthal E, Krasemann T. Quantification of temporal, procedural, and hardware-related factors influencing radiation exposure during pediatric cardiac catheterization. *Catheter Cardiovasc Interv* 80:931–936; 2012.
- Willaert WI, Aggarwal R, Van Herzeele I, O'Donoghue K, Gaines PA, Darzi AW, Vermassen FE, Cheshire NJ. European Virtual Reality Endovascular Research Team EVEResT, patient-specific endovascular simulation influences interventionalists performing carotid artery stenting procedures. *Eur J Vasc Endovasc Surg* 41:492–500; 2011.
- Yamao Y, Yamakado K, Takaki H, Yamada T, Kodama H, Nagasawa N, Nakatsuka A, Uraki J, Takeda K. CT-fluoroscopy in chest interventional radiology: Sliding scale of imaging parameters based on radiation exposure dose and factors increasing radiation exposure dose. *Clin Radiol* 68:162–166; 2013.

