A systematic review of the efficiency of radiation protection training in raising awareness of medical staff working in catheterisation laboratory

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Abstract

The purpose of this study is to conduct a systematic review of the efficiency of radiation protection (RP) training in minimising the radiation dose to both medical staff and patients. The literature search for the relevant articles was performed using five different databases which included Scopus, ScienceDirect, PubMed, Medline and ProQuest. The search covered English language publications in the period between 2000 and 2014. The search was also limited to peer-reviewed articles on human subjects and reporting patient doses, staff doses or both before and after RP training. The dose reductions were compared using percentage calculations. Ten articles met the inclusion criteria and were included in the study. Seven of these studies showed the value of the RP training by measuring the patient dose and the fluoroscopy time (FT) pre- and post-training , whereas the remaining two of the three studies focused on the occupational doses only and one reported patient and staff doses as well as the FT. After receiving training, a reduction was found in patient doses and FT with a mean and standard deviation of 49% ± 0.15 and 12% ± 0.15, respectively. Additionally, the analysis displayed an occupational dose reduction by a mean and standard deviation of 72% ± 0.14 after receiving training. This review shows the necessity and efficacy of RP training in order to provide a safer environment when utilising the fluoroscopic image-guided machines by medical staff working in the catheterisation laboratory.

Keywords: education, interventional radiology, radiation dose, radiation protection, training

INTRODUCTION

The use of minimally invasive, image-guided procedures in interventional radiology (IR) and cardiology has widely increased due to the benefits demonstrated by these procedures [1]. However, most of these procedures are associated with a high radiation dose to the patient even when performed by trained operators using dose-reducing technology and the latest fluoroscopic equipment [2]. Additionally, regular work with radiation exposure may result in an accumulation of a personnel dose much higher than that received by non-medical staff and patients [3, 4]. Because some incidences of deep skin ulceration and necrosis in patients who underwent coronary interventions were reported, concerns have been raised by regulators and professional bodies such as the US Food and Drug Administration (FDA) and the International Commission on Radiological Protection (ICRP) [5]. The ICRP has also reported that a lack of awareness of potential radiation injuries, their occurrence and how to avoid them unfortunately exist among many interventionalists [6]. This has underlined the importance of involving all medical staff who deal with ionising radiation in radiation protection (RP) training according to their role in the hospital [7, 8].

Training in RP is widely considered to be one of the basic components of medical exposure optimisation programs [9]. Some recent studies have found that cardiologists who received a formal RP training were more likely to be aware of radiation safety than those who did not [10, 11]. However, there is a lack of systematic analysis of the effect of RP training on dose reduction when performing interventional procedures. Thus, the purpose of this review is to explore the value of RP training in minimising the radiation dose to both medical staff (i.e. team members of interventional radiology, cardiology and vascular surgery) and patients, based on a systematic review of the literature.

MATERIALS AND METHODS

The literature search for the relevant articles was performed using five different databases which included Scopus, ScienceDirect, PubMed, Medline and ProQuest. The search covered English- language publications in the period between 2000 and 2014 (the last search was conducted in October 2014). The keywords used for the search were [“Radiation Protection” OR “Radiation Safety” AND “Training” OR “Education” OR “Courses” AND “Interventional Radiology” OR “Cardiology” OR “Vascular Surgery”]. The search was limited to include peer-reviewed articles on human subjects reporting patient doses, staff doses or both before and after RP training. The reference lists of the selected articles were also investigated to identify any additional articles that were not found in the databases. The exclusion criteria included: case study reports, review articles, animal or phantom studies and questionnaire studies.

The following data were extracted from each study: authors, year of publication, number of participants, the type of participants, education type, measurement tool, patient number, mean patient dose before and after training, mean occupational dose before and after training and fluoroscopy time (FT) before and after training. Any missing data were indicated as not applicable (N/A). Data were extracted by two assessors independently, and all disagreements were resolved through consensus.

Due to the differences between studies in the methods and units of measuring the patient and staff doses, all dose reductions were compared using percentage calculations. All means values ± standard deviations were analysed and processed using Microsoft Excel 2010.

RESULTS

The search process and results of selecting articles are presented in Figure 1. Ten articles met the inclusion criteria and were included in the study [12-21]. Seven of these studies showed the value of the RP training by measuring the patient dose and the FT pre- and post-training [13-17, 19, 20], while two of the remaining three studies focused on the occupational dose only [12,21], and the remaining one reported patient and staff doses as well as the FT [18]. Three studies were reported from the same group, but with different outcomes [15-17]. Thus, they were all included in the analysis.

Studies reporting patient dose reduction

Table 1 shows the study characteristics of these 10 articles. As shown in the table, the first eight studies refer to the effectiveness of the radiation safety training delivered to the participants by observing patient doses and FT. All of the participants in these eight articles were interventional cardiologists with the exception of one article [20], whose program covered both interventional radiologists and technologists because the technologists are allowed to control the fluoroscopy pedal in some cases. Dose area product (DAP) and FT readings were collected prior to and after the training (in one study [12], readings of the cumulative skin dose [CSD] instead of the DAP were used). All studies reported no significant differences in patients' size number, their age, gender and body mass index (BMI) pre- and post- the training. Educational events were found to vary from 90 minutes of PowerPoint workshops to 20 hours of basic and advanced theoretical courses and two days of training. A reduction in patient doses and FT after receiving training was shown in all studies by mean and standard deviation of 49% ± 0.16 and 12% ± 0.16, respectively, indicating the effectiveness of implementing RP training. Figure 2 provides the effectiveness of overall reduction in radiation dose and fluoroscopic time among these eight studies.

Studies reporting occupational dose reduction

The last three studies in Table 1 demonstrate the usefulness of the radiation safety training delivered to the participants by observing the differences in the staff doses before and after training. Interventional cardiologists were the targeted sample in all of the three studies. Educational events varied from a radiation protection seminar to continuous RP training and updates in the technical aspects. Because the complexity of the procedure, patient age and BMI may affect readings, all of these aspects were taken into account, and no significant differences were found. The value of the training received in these studies was displayed as a reduction in participants' doses by a mean and standard deviation of 72% ± 0.14 (dose reduction ranges from 58% to 86%).

DISCUSSION

Interventionalists are very attentive to the potential complications related to each interventional procedure and do their best to avoid them. This includes justifying the requested procedure with the referring physician and explaining all benefits and possible risks before acquiring the consent of the patient [1]. However, routine planning usually does not include particular aspects of radiation dose management and protection for patients and staff [22]. The effects of radiation fall into two classifications: stochastic effects, including carcinogenic and genetic effects, and deterministic effects or tissue reactions, which refer to an immediate and predictable changes in the tissue [23]. Linet et al. stated that for a dose of 100 mSv or lower, it is reasonable to assume that the risk of cancer or heritable effects will increase according to the organ or tissue type to be irradiated or even the patient's age [24]. Therefore, paediatric patients and patients with connective tissue disease or diabetes mellitus tend to be more sensitive to radiation than others [2, 25, 26]. In contrast, deterministic effects are considered to be the result of a threshold dose (i.e. cumulative dose dependant), and the severity of the reaction or cell injury will increase as the dose exceeds the threshold [27]. Therefore, it is very important to be aware of the radiation dose and to implement dose reduction strategies during interventional radiology procedures because radiation exposure is a significant concern for interventionalists and patients due to the increasing workloads and increasing complexity of procedures over the last decade [5, 27, 28].

In 2006, IR procedures were estimated to be the third largest source of ionising radiation, representing 14% of all medical exposure in the United States [28]. Thus, to assure optimal patient and personnel safety, it is recommended that each catheterisation laboratory should have their own radiation safety and fluoroscopic training polices based on appropriate sources [29, 30]. Secondly, the institution that provides X-ray fluoroscopic services should employ a credentialing process to give authority before operating the equipment. This includes a compulsory knowledge threshold that is required to fulfil the role of physicians performing fluoroscopically guided procedures [29]. Recommendations on the curriculum can be provided by some international organisations such as ICRP, European Commission (EC) and the World Health Organisation (WHO) [8]. A range between two and 20 training hours is suggested by authorities such as the EC and the Joint Commission on the Accreditation of Healthcare Organisation (JCAHO). The education style could involve didactic courses, computer-based instrcution or self-study, and the aquired knowledge should be tested with by a certifying exam [29, 30]. This review further supports the idea that significant dose reduction was achieved after receiving radiation protection training.

There are some limitations in this analysis. First, studies included in the analysis were from 2000 and onwards because we focused on the RP training practice over the last 15 years, although there were early publications emphasising the importance of RP training. The low number of eligible references was another limitation, especially those focusing on staff doses. Additionally, missing or unreported values in some articles minimised the characteristics of the extracted data. Some of the included studies have a small number of participants, adding another limitation to the study. Moreover, this analysis only looked at the over all dose reduction due to receiving the training programme and did not assess how these doses were measured. This review was also limited to studies published in the English language which may have contributed to a biased opinion in the study findings. Finally, all references were found to focus on the main operator rather than those of the entire team including technicians and nurses. Consequently, the need to generalise these findings to the entire group of catheterisation laboratory workers presents a limitation. Therefore, it may be desirable to include technicians and nurses in future studies because they are also exposed to the potential radiation hazards.

In conclusion, this systematic review shows that radiation protection training leads to a significant reduction in dose to medical staff and patients. Regulatory and healthcare authorities should play an important role in maintaining safety and implementing radiation protection training to medical staff when the interventional radiology procedures need to be utilised.

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Figure and figure legends

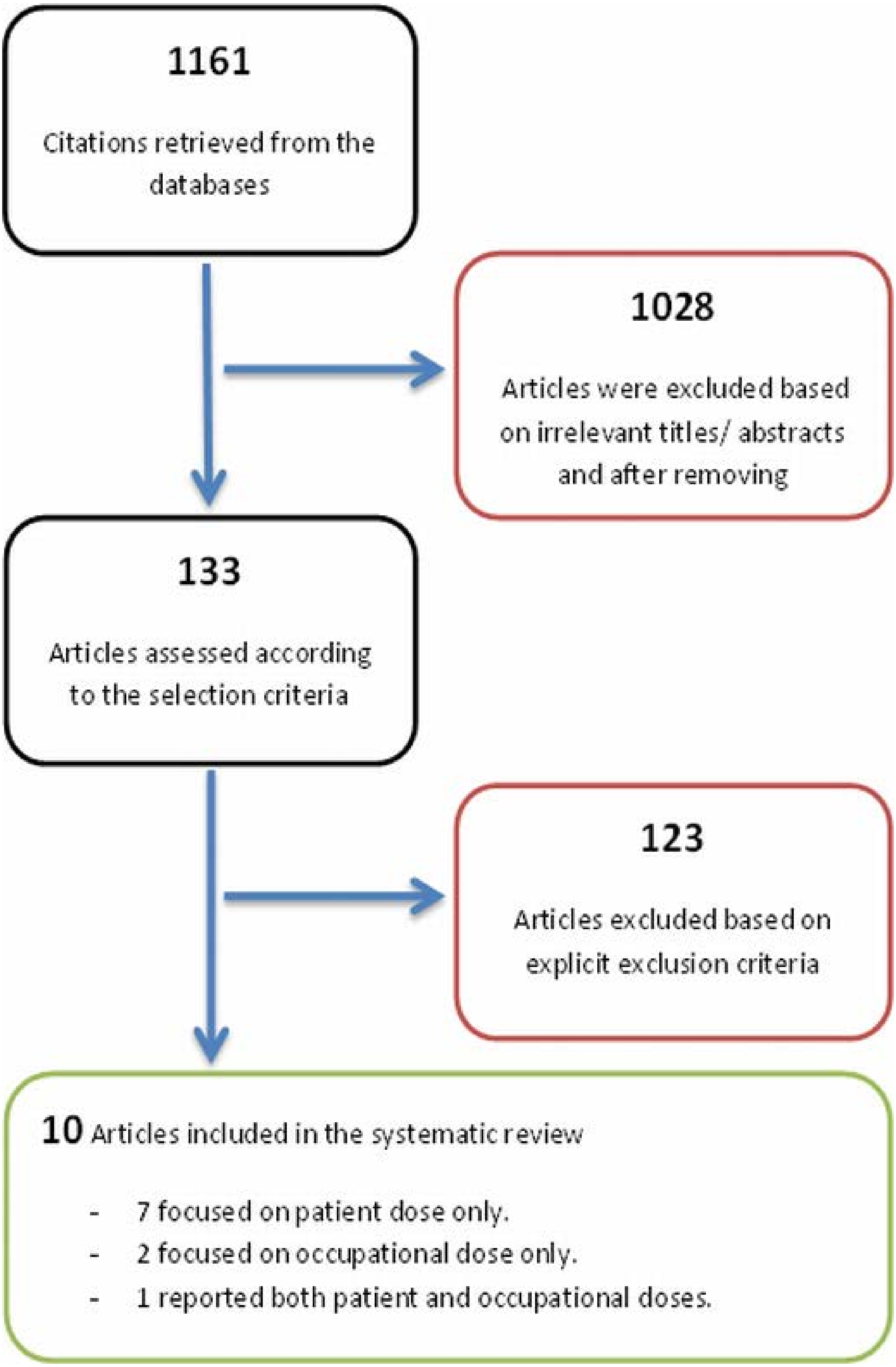
1161
Citations retrieved from the databases
1028
Articles were excluded based on irrelevant titles/ abstracts and after removing
133
Articles assessed according to the selection criteria
123
Articles excluded based on explicit exclusion criteria
10 Articles included in the systematic review
- 7 focused on patient dose only.
- 2 focused on occupational dose only.
- 1 reported both patient and occupational doses.

Figure 1. Flow chart showing the search strategy to identify eligible references.

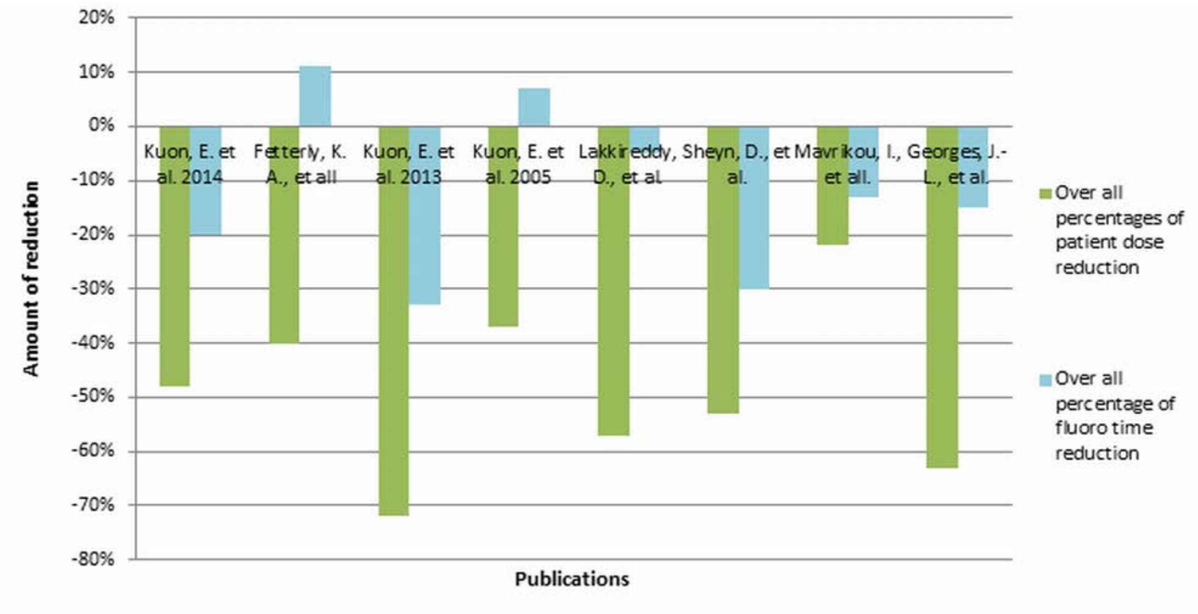

Figure 2. Effectiveness of dose reduction and fluoroscopic time reduction in eight studies.

Table 1. Study characteristics of these eligible studies.

Authors	Year of publication	No. and type of participants	Education type	Measurement tool	Before attending radiation protection training				After attending radiation protection training			
					No. of patients	DAP	FT	Occupational dose	No. of patients	DAP	FT	Occupational dose
Kuon et al [17]	2014	154 Interventional cardiologists	20-h basic and advanced theoretical courses	Recording DAP, FT and number of radiographic frames and runs for CA patients before and after mini-course	1540	26.5 Gy × cm^2	159s	N/A	1540	13.7 Gy × cm^2 (48.4% reduction)	126 s (20.8% reduction)	N/A
Kuon et al [16]	2013	7 Interventional cardiologists	90 Minute PowerPoint workshop	Recording DAP, FT and number of radiographic frames and runs for CA patients befor and after 2 years from the 90 min course	70	31.4 Gy × cm^2	180	N/A	70	8.5 Gy × cm^2 (reduce 72%)	120 (33% reduction)	N/A
Fetterly et al [13]	2012	27 Interventional Cardiologists and 65 fellows	Training including practical examination + x-ray system technical changes	Reporting the CSD for all procedures and compare between the first and last study quarters	1580	969 mGy× cm^2	7.2 min	N/A	1475	568 mGy (reduce 40%)	8.0 min 11.4% increase)	N/A
Georges et al [14]	2009	5 Interventional cardiologists	2 days training course in radio-protection and implementing of technical recommendations.	DAP, FT and Number of runs were assessed for CA and PCI patients before and after the training program.	1072	178 Gy × cm^2	19.4 min	N/A	1128	65 Gy × cm^2 (reduce 63%)	16.4 min (15% reduction)	N/A
Sheyn et al [20]	2008	11 Interventional Radiology staff	A detailed lecture and article were given to	Recording the total FT, cumulative DAP and the use of shielding	432	16.1 ± 2 Gy × cm^2	220.1 ± 28.4 s	N/A	616	7.5 ± 1.7 Gy × cm^2 (reduce	157.2 ± 16.6 s (30% reduction)	N/A

		(physicians and technologists)	participants.	equipments 4 months before and after the educational program						53%)		
Mavrikou et al [19]	2008	7 Interventional Cardiologists	Training programme on specific issues of radiation protection	DAP, FT, number of images and cumulative dose were obtained from the system for CA and PTCA procedures 6 months before and after the program.	982	224.3 Gy × cm^2	29.1 min	N/A	720	174 Gy × cm^2 (22% reduction)	25.1 min (13% reduction)	N/A
Kuon et al [15]	2005	7 Interventional Cardiologists	90 Minute PowerPoint workshop	Recording DAP, FT and number of radiographic frames and runs for CA patients before and after mini-course	70	30.8 Gy × cm^2	245 s	N/A	70	19.2 Gy × cm^2 (37% reduction)	266 (7% increase)	N/A
Lakkireddy et al [18]	2009	3 Interventional Cardiologists	Implementing a comprehensive radiation safety program	Exposure doses were assessed before and after the program	21	548 ± 363 Gy × cm^2	74 ± 24 min	0.036 ± 0.009 mGy	20	234 ± 120 Gy cm^2 (57% reduction)	70 ± 20 min (5% reduction)	0.015 ± 0.003 mGy (58% reduction)
Abatzoglou et al [12]	2013	3 Interventional Cardiologists	Radiation protection seminar	Levels of cardiologist exposure 7 months before and 9 months after the seminar were analysed and compared.	70	N/A	N/A	N/A	70	N/A	N/A	71.6 % reduction in staff dose)
Vano et al [21]	2006	17 Interventional Cardiologists	Continuous training for staff and fellows + continuous updating in the technical aspects.	A 15-year follow-up of personal dosimetry records (over and under their lead aprons).	Over 5000 cases per year	N/A	N/A	Real mean effective dose = 8.5 mSv year	Over 5000 cases per year	N/A	N/A	Real mean effective dose= 1.2 mSv year (86% reduction)

DAP-dose area product, FT-fluoroscopy time.