Radiation protection for surgeons and anesthetists: practices and knowledge before and after training

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Abstract

The use of radiological activity in the operating room (OR) and a regulatory decrease of the eye lens dose warrant an assessment of how medical staff are protected from radiation. This study aims to evaluate practices and knowledge in radiation protection (RP) for OR doctors before and after training. A descriptive study of surgeons and anesthetists in a French public hospital center was conducted in 2016. An ad hoc questionnaire concerning occupational practices and knowledge about RP was distributed before and one month after RP training. Among 103 doctors attending the training, 90 answered the questionnaire before the training. Results showed a lack of knowledge and good practice in RP. Most of the participants (86.7%) had never been trained in RP and recognized insufficient knowledge. Most of them (92.2%) wore a lead apron, 50.0% a thyroid-shield, 5.6% lead glasses, 53.3% a passive dosimeter and 17.8% an electronic dosimeter. None of them benefitted from collective protective equipment such as a ceiling suspended screen. The questionnaire following the training was completed by only 35 doctors. A comparison before and after training results showed an improvement in knowledge (scores of correct responses: 5.5/16 before and 9.5/16 after training) but not in RP good practices (scores of correct responses: 3.2/7 before and 3.3/7 after training). One training session appears to be insufficient to improve the application of the safety rules when x-rays are used.

Communication needs to be improved regarding RP among anesthetists and surgeons, such as training renewal, workstation analysis in OR related to x-ray use and occupational medical follow-up. Otherwise, radiological risks in OR need to be given better consideration, such as radio-induced cataract risk. It is necessary to encourage the use of dosimeters and protective equipment and to strengthen access to lead glasses and collective protective equipment, such as ceiling suspended screens. All these recommendations ensure the received dose is reduced to as low as is reasonably achievable.

Keywords: ionizing radiation, operating room, occupational practices, awareness, medical staff

1. Introduction

The medical use of ionizing radiation is constantly increasing. The European directives Euratom are based on publications of the International Commission on Radiological Protection (ICRP) whose objective is to assess the state of knowledge on the effects of radiation to identify implications for protection rules to be adopted. This concerns medical professionals who expose not only patients to diagnostic or therapeutic ionizing radiation, but also themselves. These professionals must be trained in radiation protection (RP) for patients [1]. However, only a minority of doctors performing radiological examinations inform their patients about any health risk after exposure [2, 3]. Surgical procedures with intraoperative ionizing radiation are on the rise and it is relevant to implement compliance and best practice rules for RP practice in this environment. As regards the European directive Euratom, professionals exposed to ionizing radiation, such as operating room (OR) doctors, must be trained in RP [4]. Not only is training beneficial for optimizing the use of x-ray machines [5], but it promotes awareness of ionizing radiation hazards among staff. Moreover, analysis of workstations (evaluation of the projected dosimetry of workers which determines occupational categorization) and the use of dosimeters (passive and electronic) in areas exposed to ionizing radiation are mandatory and require coordination between the Occupational Health Department, RP technical advisors and employers. Otherwise, doctors in OR must have a reinforced medical follow-up. Several surgical specialties, such as vascular [6], urological [7] or neurosurgery [8], are particularly exposed to ionizing radiation. Although the whole-body doses received by OR medical staff are clearly lower than the regulatory dose limit [9–11], radiological exposure is likely to be high to the hands [12] and the eye lens. Despite radiological exposure in OR, RP devices are not adequately considered [13], resulting in a lack of the use of protective clothing and dosimeters [14] among staff. The degree of involvement in RP varies per surgical specialty [15], level of experience and occupational status. Indeed, team leaders' recognition of RP rules [5] is a determinant factor. In addition to occupational practices, studies have shown that knowledge in RP is not well known by OR staff [16–18] and is even lower amongst radiologists [19]. Many OR professionals request be trained in RP [14, 19] and they are aware [20] of radiological hazards, especially radiation-induced cataracts. One study showed that interventional cardiologists have a four times greater risk of developing a radio-induced cataract [21] than an unexposed population. In this context, in 2011, the ICRP issued recommendations to decrease the current annual regulatory limit from 150 mSv to 20 mSv for the eye lens [22], and this was integrated into the European Directive 2013/59 Euratom. Access to lead glasses and the installation of collective protective

Table 1. Items of the questionnaire before and after training, proposals of response and points for calculating the score of correct responses.

Questionnaire before or after training	Items	Proposed responses
		Occupational practices
Before	How often are you exposed to ionizing radiation?	Several times: a day/a week/a month/never
Before and after	Which protective equipment do you use?	Lead apron (1 point)/thyroid-shield (1 point)/lead glasses (1 point)/collective protective equipment
	Which dosimeter(s) do you use?	passive (1 point)/electronic (1 point)/dosimetric ring (1 point)
	Where do you position your dosimeters?	Under (1 point)/on the apron/it is variable
	Do you think you are at risk of a radio-induced cataract?	Yes/no
		Knowledge
Before and after	Self-assessment of knowledge level about RP	Excellent/good/sufficient/insufficient
	What is the annual limit dose for exposed workers (category A and B)?	50 mSv, **20 mSv** (1 point for category A), **6 mSv** (1 point for category B), 1 mSv/do not know
	What is the annual limit dose for the public?	50 mSv, 20 mSv, 6 mSv, **1 mSv** (1 point)/do not know
	What is the annual limit dose for pregnant women?	6 mSv, **1 mSv** (1 point), 0 mSv/do not know
	What is the ALARA principle? (open question)	**As low as reasonably achievable** (1 point)
	If the dose rate is 20 mGy h^{-1} within 1 meter of the ionizing source, what is the dose rate within 3 meters of this source?	20 mGy h^{-1}, 10 mGy h^{-1}, **5 mGy h^{-1}** (1 point)/do not know
	Which pathology(ies) result from the stochastic effect?	**Leukemia** (1 point)/cataract/alopecia/radiodermatitis/do not know
	What is the renewal frequency of your passive dosimeter (PD)?	**1 month** (1 point for category A), **3 months** (1 point for category B), 6 months, 12 months, do not know
	Upon which category of ionizing radiation occupational exposure do you depend?	Category A[a] (1 point): theoretical annual effective dose or annual equivalent dose > 3/10e of annual limit dose Category B[a] (1 point): theoretical annual effective dose or annual equivalent dose between 1/10e and 3/10e of annual limit dose Do not know
	I do not need to use an electronic dosimeter (ED) if I already use a PD	Yes/**no** (1 point)
	An ED has an overdose alarm system	**Yes** (1 point)/no

Table 1. (Continued.)

Questionnaire before or after training	Items	Proposed responses
	An ED measures real-time dose	**Yes** (1 point)/no
	Before using an ED, it needs to be identified on a terminal	**Yes** (1 point)/no
Before	Have you already attended your occupational medical visit?	Yes/no
	Have you already attended RP training for workers or patients?	Yes/no
After	Have you changed your occupational practices after training?	Yes/no
	When the x-ray tube is horizontal, you position yourself:	**On the side of the image intensifier**/ on the side of the x-ray tube

[a] Category A and B professionals must have a medical visit every year and every two years respectively. Correct answers regarding knowledge appear in bold type.

equipment, such as ceiling suspended screens [23], significantly reduce radiology exposure to the eye lens [24], and the notion of a stochastic mechanism for radiation-induced cataracts [25] validates the use of RP devices to minimize, as much as reasonably possible, received doses according to the as low as reasonably achievable (ALARA) principle. Bibliographic data on the decreasing lens dose, significant radiological exposure in OR and lack of RP awareness among OR doctors justify evaluating occupational practices and knowledge in RP in this population and relevance of regulatory RP training. To our knowledge, no paper has conducted research on this topic with both surgeons and anesthetists regarding RP before and after training. This study evaluates occupational practices and knowledge in RP among OR surgeons and anesthetists before and after training.

2. Materials and methods

2.1. Study population and RP training

This study surveyed all the surgeons and anesthetists from a public hospital center in the South of France receiving one-day masterly training on RP for patients and workers in 2016. Invitation to the training was organized by the leaders from surgical and anesthesia departments as well as RP advisors. The participants of the training were informed of the study's objective and invited to answer the questionnaire at the beginning of the training. Participation was voluntary and each doctor was free to fill out the questionnaire or not. Privacy of the collected data was guaranteed and an explanatory note was appended to the questionnaire. Six training sessions were conducted in April and May 2016 and focused on the regulations of the use of fluoroscopy, annual limit doses for workers and the public, radiological hazards (stochastic and deterministic effects) and optimized good practices using ionizing radiation.

2.2. Questionnaire

Lacking any validated questionnaires for RP, an ad hoc questionnaire was developed based on several bibliographic sources [15, 16, 19, 26–28] and distributed before and after training. The questionnaire was nominative to compare pre/post training responses and included gender, age, occupational status and medical or surgical specialty. A hand-written questionnaire was distributed a few minutes before the beginning of the training. This method of completion was privileged to increase the probability of responses, as opposed to an electronic questionnaire which could have been distributed several days before training and whose response rates would have been lower. Conversely, an electronic version was used for post-training evaluation one month after training. This post training questionnaire was sent by email to the occupational mailbox of the respondents to the first questionnaire with one-month availability. A score of correct responses among 23 items mentioned in both versions of the questionnaire (table 1) was defined; 1 point per correct answer out of a total of 23 points was awarded with 7 points for practices and 16 points for knowledge.

2.3. Data analysis

Responses were analyzed using SPSS Version 20. Results were compared with the Chi square test according to the following subgroups: gender, age ($\leqslant$ or $>$40 years-old), medical specialty (surgeon or anesthetist), surgical specialty (surgeons treating adults or pediatric surgeons), and the respondent group, i.e. those that only responded to the questionnaire before training (the before respondent population) versus those that responded to both the pre and post-training questionnaire (the before/after respondent population). The Student's t-test was used to compare the mean age between the before respondent population and the before/after respondent population. The participants who did not specify their specialty were excluded from the subgroup analysis. In the before/after respondent population, a comparison of the pre/post training responses regarding occupational practices and knowledge was conducted using the Mac-Nemar statistical test which applies to matched groups. A comparison of the scores of correct answers before and after training was analyzed using the Student's t-test for matched groups. The significance level p was set at 0.05.

3. Results

3.1. Characteristics of the participants

Of the 103 physicians in the training sessions, 90 (87.4%) responded to the questionnaire before training. There were 35 (38.9% of the before respondent population) who completed the questionnaire after training. The before/after respondent population was significantly older than the before respondent population. Their demographics appear in table 2.

3.2. Occupational practices in the before respondent population

The mean score of good practices in RP among the before respondent population is 2.9/7. Details are cited in table 3. The results show that 13 participants had already attended their occupational medical visit and only 12 had already attended RP training.

3.2.1. Ionizing radiation exposure. Sixty OR doctors (66.7%) reported being exposed to radiation at least several times per week, and among those, 21 (23.3%) indicated exposure occurring several times a day. More anesthetists (82.9%) than surgeons (52.0%) ($p = 0.003$) and more surgeons treating adults (62.9%) than pediatric surgeons (26.7%) ($p = 0.019$) claimed to be exposed several times a week or a day to radiation (figure 1).

Table 2. Demographics (gender, age, specialty and status) of the respondents to the pre-training questionnaire (the before respondent population, $n = 90$) and the respondents to both pre and post-training questionnaires (the before/after respondent population, $n = 35$).

	The before respondent population $n = 90$	The before/after respondent population $n = 35$	p
Gender			0.069
Men: n (%)	51 (56.7)	24 (68.5)	
Women: n (%)	39 (43.3)	11 (31.5)	
Age			
Mean ±standard deviation	43.8 ± 11.7	48.5 ± 10.8	<0.001
[Min-max]	[24–64]	[30–63]	
⩽40 years old: n (%)	42 (47.2)	11 (31.5)	0.013
>40 years old: n (%)	47 (52.8)	24 (68.5)	
No answer: n (%)	1 (2.9)	0 (0)	
Specialty			
Anesthetist: n (%)	35 (39.3)	11 (31.4)	0.242
Surgeon total: n (%)	50 (55.6)	22 (62.9)	
Surgeon treating adults: n (%)	35 (39.3)	14 (40.0)	0.384
Pediatric surgeon: n (%)	15 (16.9)	8 (22.9)	
No answer: n (%)	5 (5.6)	2 (5.7)	
Status			0.687
Hospital practitioner: n (%)	45 (50.0)	19 (57.6)	
University practitioner: n (%)	15 (16.7)	11 (33.3)	
Assistant[a]: n (%)	14 (15.6)	2 (6.1)	
Resident: n (%)	8 (8.9)	1 (2.9)	
No answer: n (%)	8 (8.9)	2 (6.1)	

[a] A doctor who has just finished his medical studies. He practices in the hospital most often for two years, supervises and teaches students.

3.2.2. The use of protective equipment and dosimeters. Eighty-three individuals make use of a lead apron (92.2%) while 47 (52.2%) wear a thyroid shield. More surgeons treating adults (94.3%) than pediatric surgeons (73.3%) use a lead apron ($p = 0.037$) and more anesthetists (62.9%) than surgeons (40.0%) ($p = 0.038$) use a thyroid-shield (figure 2 and table 3). Otherwise, five individuals use lead glasses and none of the participants benefit from collective protective equipment. We note that 48 individuals (53.3%) regularly use a passive dosimeter (PD) and 16 (17.8%) an electronic dosimeter (ED). More surgeons treating adults (31.4%) than pediatric surgeons (0%) use an ED ($p = 0.014$) (figure 2). According to table 3, half of the participants correctly position their dosimeter under a lead apron. We note that 46.7% of the participants feel they are at risk of a radio-induced cataract. The younger participants (58.1% versus 36.2% of >40 years-old participants) have a better awareness of this risk ($p = 0.037$).

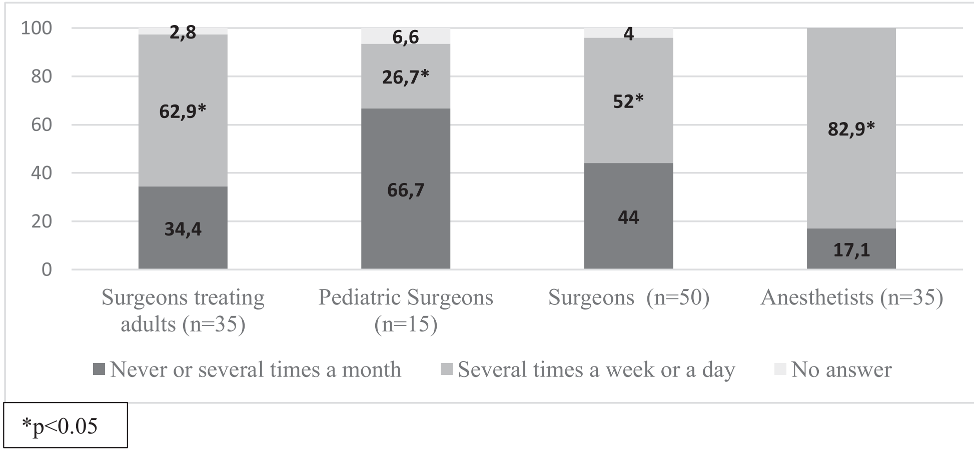

Figure 1. Distribution (%) of x-ray exposure frequency (never or several times a month, several times a week or a day, no answer) according to specialty.

Table 3. RP occupational practices: evaluation before training among the before respondent population with a comparison between anesthetists and surgeons.

	The before respondent population $n = 90$ N (%)	Anesthetists $n = 35$ N (%)	Surgeons $n = 50$ N (%)	*P*
Use a lead apron	83 (92.2)	34 (97.1)	44 (88.0)	0.131
Use a thyroid-shield	47 (52.2)	22 (62.9)	20 (40.0)	0.038
Use lead glasses	5 (5.6)	0 (0.0)	2 (4.0)	0.231
Use collective protective equipment	0 (0.0)	0 (0.0)	0 (0.0)	1.000
Use a PD	48 (53.3)	16 (45.7)	27 (54.0)	0.452
Use an ED	16 (17.8)	3 (8.6)	11 (22.0)	0.100
Use a dosimetric ring	13 (14.4)	1 (2.9)	7 (14.0)	0.083
Feel at risk of a cataract	42 (46.7)	15 (42.9)	22 (44.0)	0.917
Dosimeter under a lead apron	45 (50.0)	12 (34.3)	28 (56.0)	0.048

3.3. Knowledge in the before respondent population

The mean score of correct responses regarding RP knowledge among the before respondent population is 5.6/16. Responses related to RP knowledge before training are cited in table 4. According to workstation analysis in OR carried out previously by RP technical advisors from the hospital center, the vascular surgeons are classified as category A and the remaining population is classified as category B. According to table 4, 35.6% of the participants know their category for ionizing radiation exposure. Despite the low use of ED, most of the participants (93.3%) know that the use of PD does not dispense of the use of ED. Less than 10% of the participants know the annual limit dose for exposed workers, the public and pregnant women (table 4). The younger participants (⩽40 years-old) have a better response accuracy concerning regulatory dose limits, especially for the public (correct response rate of 28.0% versus no correct response among the over 40 year-old respondents, $p < 0.001$). We

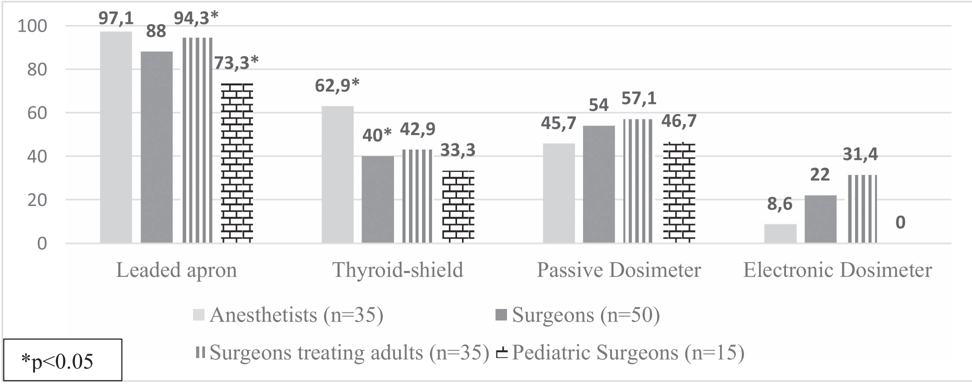

Figure 2. Distribution (%) of the use of a lead apron, a thyroid-shield, a passive dosimeter and an electronic dosimeter according to specialty.

Table 4. RP knowledge: evaluation before training among the before respondent population.

	The before respondent population $n = 90$ N (%)
Know and explain the ALARA principle	4 (4.4)
Correct response regarding distance: 5 mGy h^{-1}	35 (38.9)
Know the category for ionizing radiation exposure	32 (35.6)
Evaluation: excellent, good or sufficient	11 (12.2)
Leukemia: stochastic effect	53 (58.9)
Alopecia: not stochastic effect	62 (68.9)
Radiodermatitis: not stochastic effect	42 (46.7)
Cataract: not stochastic effect	42 (46.7)
I do not need to use an ED if I already use a PD: NO	84 (93.3)
ED measures real-time dose rate: YES	38 (42.2)
ED has alarm overdose system: YES	21 (23.3)
Identifiers need to be entered on a terminal before using an ED: YES	49 (54.4)
Renewal frequency of a PD: 1 or 3 months	25 (27.8)
Annual dose limit (category A): 20 mSv	12 (13.3)
Annual dose limit (category B): 6 mSv	8 (8.9)
Annual dose limit for the public: 1 mSv	12 (13.3)
Dose limit for pregnant women: 1 mSv	13 (14.4)

note that the global score of correct responses regarding RP knowledge and occupational practices among the before respondent population is 8.5/23.

3.4. Comparison between pre/post training

After training, 35 individuals (38.9% of the before respondent population) responded to the pre- and post-training questionnaire. Their demographics appear in table 2 and their answers in table 5. Those over 40 years were more likely to respond ($p = 0.013$). Half of the

Table 5. RP occupational practices: evaluation among the before/after respondent population ($n = 35$) before and after training.

	Before training N (%)	After training N (%)	*P*
Use a lead apron	31 (88.6)	30 (85.7)	1.000
Use a thyroid-shield	17 (48.6)	16 (45.7)	1.000
Use lead glasses	2 (5.7)	3 (8.6)	1.000
Use collective protective equipment	0 (0.0)	0 (0.0)	1.000
Use a PD	22 (62.9)	24 (68.9)	0.375
Use an ED	9 (25.7)	9 (25.7)	1.000
Use a dosimetric ring	6 (17.1)	5 (14.3)	1.000
Feel at risk of a cataract	15 (42.9)	18 (51.4)	0.289
Dosimeter under a lead apron	22 (62.9)	25 (71.4)	0.375
Change practices after training	—	26 (74.3)	—
Position on the side of the image intensifier	—	18 (51.4)	—

Table 6. RP knowledge: evaluation among the before/after respondent population ($n = 35$) before and after training.

	Before training N (%)	After training N (%)	*P*
Know and explain the ALARA principle	2 (5.7)	15 (42.9)	<0.001
Correct response regarding distance: 5 mGy h^{-1}	15 (42.9)	25 (71.4)	<0.001
Know category for ionizing radiation exposure	12 (34.3)	28 (80.0)	<0.001
Evaluation: excellent, good or sufficient	7 (20.0)	21 (60.0)	0.001
Leukemia: stochastic effect	15 (42.9)	26 (74.3)	0.013
Alopecia: not stochastic effect	27 (77.1)	30 (85.7)	0.754
Radiodermatitis: not stochastic effect	18 (51.4)	20 (57.1)	1.000
Cataract: not stochastic effect	20 (57.1)	22 (62.9)	1.000
I do not need to use an ED if I already use a PD: NO	34 (97.1)	32 (91.4)	—
ED measures real-time dose rate: YES	16 (45.7)	26 (74.3)	0.003
ED has alarm overdose system: YES	11 (31.4)	17 (48.9)	0.092
Identifiers need to be entered on a terminal before using an ED: YES	21 (60.0)	29 (82.9)	0.035
Renewal frequency of PD: 1 or 3 months	12 (34.3)	17 (48.6)	0.070
Annual dose limit (category A): 20 mSv	6 (17.1)	21(60.0)	0.001
Annual dose limit (category B): 6 mSv	3 (8.6)	17 (48.6)	0.001
Annual dose limit for the public: 1 mSv	5 (14.3)	18 (54.1)	0.001
Dose limit for pregnant women: 1 mSv	5 (14.3)	12 (34.3)	0.001

participants (51.4%) are correctly positioned on the side of the image intensifier when the x-ray tube is horizontal. We note that 74.3% report a change in RP occupational practices after training (table 5). However, comparison of the good practice scores before and after training in table 5 show that the participants have not changed their occupational practices, such as using protective equipment and dosimeters. Conversely, a comparison of the score of correct responses regarding RP knowledge before and after training ($p < 0.001$) in table 6

Table 7. Mean scores of correct responses (total score, occupational practices and knowledge in RP) among the before/after respondent population and comparison before and after training.

	Before training	After training	*P*
Total score (/23)	8.7	12.8	<0.001
Occupational practices (/7)	3.2	3.3	0.666
Knowledge (/16)	5.5	9.5	<0.001

shows that training has had a significant impact. The total scores of correct responses were 8.7/23 (3.2/7 regarding occupational practices and 5.5/16 about knowledge) and 12.8/23 (3.3/7 about occupational practices and 9.5/16 about knowledge) before and after training respectively (table 7). Otherwise, the scores of the correct responses among the 55 participants who responded to the pre-training questionnaire were only 2.7/7 regarding occupational practices and 5.6/16 regarding knowledge. There was no difference between the before/after respondent population ($p = 0.172$ and $p = 0.855$ for occupational practices and knowledge, respectively).

4. Discussion

4.1. Strengths and limitations

This study aimed at evaluating practices and knowledge in RP before and after training among surgeons and anesthetists. Other OR professionals, such as nurses, are concerned by radiation exposure and must be trained in RP, but we have focused exclusively on doctors because the six training sessions were organized for this population. Moreover, doctors represent a specific population, especially by the lack of hierarchical control over dosimetric and medical follow-up unlike the nursing population. To our knowledge, there is no study conducted with both surgeons and anesthetists which evaluates practices and knowledge in RP, and a comparison of the responses before and after training is interesting, though we have to consider the sample of only 35 practitioners after training. The response rate for the questionnaire before training was very high (87.3%), in contrast to the response rate for the questionnaire after training (38.9%). These rates could be explained by the hand-delivered distribution of the questionnaire before the beginning of the training. The before/after respondent population was significantly older than the before respondent population. The youngest practitioners may have been encouraged by their team-leaders (older) to attend training and therefore respond to the questionnaire before training. This may not be the case for the electronic post-training questionnaire. The main weakness in the comparison of responses before and after training is the two separate methods for completing the questionnaire: hand-written just before training, and on a computer after training. This latter method does not effectively assess knowledge since the participants could research answers before submission. The results are based on declarative information and it was impossible to check the use of RP devices at workstations. However, Kim *et al* [29] demonstrate the reliability of self-reported information on professional practices in RP. The period between the pre/post training evaluation was short; indeed the questionnaire after training was sent just before summer, hoping to maximize the response rate. It would be relevant to re-evaluate after a longer time period.

4.2. Occupational practices and knowledge before training

The low level of knowledge regarding RP (mean score of correct responses 5.6/16) among the before respondent population could be explained by the lack of training among almost 90% of them. Radiation exposure in OR is significant since half of the surgeons are exposed at least once per week. Pediatric surgeons report less exposure, possibly due to the limited use of fluoroscopy on children because this population is most vulnerable to radiation hazards [30], but also because highly irradiating procedures, such as endovascular procedures [31], are less common on children. Anesthetists are more often exposed to ionizing radiation since they are also exposed to ionizing radiation outside OR (interventional radiology and resuscitation departments). This study highlights the low score of good practices in RP (mean score of 2.9/7 among the before respondent population). Indeed, we note the low use of dosimeters since a PD is used by half of the participants. This result is consistent with that of Jentzsch *et al* [15] where a dosimeter was used (usage $\geqslant$50% of the time) by 44% of the participants from a trauma center and a children's hospital. In our study, an ED is only used by 18.0% of the participants. Moreover, self-reported information concerning the use of dosimeters is probably not completely reflective of actual practices [29]. Most of the operators (92.2%) use a lead apron and 52.2% use a thyroid-shield. This is consistent with the study conducted by Jentzsch *et al* [15] where the rates of the use of a lead apron and a thyroid-shield are slightly lower (84.0% and 33.0%). However, this study was concerned with usage $\geqslant$50% of the time and our study did not ask the participants to specify the frequency of wearing protective equipment. Our study shows that pediatric surgeons are less likely to wear a lead apron than surgeons treating adults, which is, once again, consistent with the study of Jentzsch *et al* [15], where the participants from a trauma center wore a dosimeter and thyroid-shield more often than participants from a children's hospital. Anesthetists are more likely to use individual protective devices. Their orthostatic and immobile position is minimized and therefore they are better able to support the weight of a lead apron. Very few OR doctors wear lead glasses, although almost half of them are aware of the risk of radio-induced cataracts. The need to adapt the glasses to operators' individual visual correction and the high cost makes access to lead glasses difficult. The younger participants have better knowledge of the annual limit doses, possibly because the RP principle is taught during medical university studies. This is consistent with a study conducted with radiologists and emergency doctors which revealed an inversely proportional relationship between the level of experience and knowledge of medical staff regarding radiological risks [32]. Another study conducted with physicians [18] found no relationship between RP knowledge and years of exposure to radiation. Moreover, Jentzsch *et al* [15] showed in their study that most of the participants (89.0%) correctly responded that doubling the distance reduces radiation exposure by a factor of four, although in our study the correct response rate regarding the distance in RP was only 38.9%.

4.3. Knowledge and professional practices after training

After training, the participants perceived an improvement of their knowledge. Indeed, the mean score of correct responses regarding RP knowledge before and after training was significantly improved (5.5/16 and 9.5/16 respectively, $p < 0.001$) though we must consider the limitation of the content of the questions relating to knowledge. However, training does not have a beneficial effect regarding compliance with RP practices since the mean scores are respectively 3.2/7 and 3.3/7 before and after training among the before and after respondent population ($p = 0.666$). Otherwise, after training, only 51.4% of the before and after respondent population are correctly positioned on the side of the image intensifier when the x-ray tube is horizontal. This result is, once again, consistent with Jentzsch *et al* [15] which showed a correct response rate of 49.0%, but this population did not receive recent training as opposed to our study. Our study shows that most of the participants had never received RP training, and one training session is not sufficient to improve the application of the safety rules of radiation. A short-term change of occupational practices after training is complex given physical and organizational requirements, especially with staff not always aware of risks. In addition, wearing a heavy lead apron can be ergonomically unappealing. There is a need to strengthen RP awareness in medical staff. This mostly concerns the attitude of team leaders who serve as role models for their staff [5]. The study results show the need to modify the training strategy regarding RP: regular and more easily accessible computer training with a self-assessment questionnaire, promoting access to lead glasses and installation of collective protective equipment in OR. Moreover, OR doctors should be aware of the obligation of a medical follow-up.

5. Conclusion

This study's objective was to assess RP knowledge and practices before and after training among anesthetists and surgeons. Despite significant x-ray exposure in this population, our assessment revealed a lack of RP knowledge and a low utilization of dosimeters and protective equipment such as lead glasses. This study shows a short-term improvement of knowledge after training, although we have to consider the low sample size of the respondents after training. However, there was no improvement in occupational practices in RP after training. This observation reveals the need to modify training strategies and to promote awareness of radiological risks and RP safety rules among OR doctors. Finally, in the context of the decrease of the eye lens dose, it is necessary to develop access to lead glasses and collective protective equipment in OR.

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