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**X-ray management in electrophysiology: a survey of the Italian Association of Arrhythmology and Cardiac Pacing (AIAC)**

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1 **X-ray management in electrophysiology: a survey of the Italian Association**  
2 **of Arrhythmology and Cardiac Pacing (AIAC)**

3

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10

1 **Abstract**

2 Aims. Radiation use in medicine has significantly increased over the last decade, and  
3 Cardiologists are among the specialists most responsible for X-ray exposure. The present  
4 study investigates a broad range of aspects, from specific European Union directives to  
5 general practical principles, related to radiation management among a National cohort of  
6 Cardiologists.

7 Methods and results. A voluntary 31 questions survey was run on the Italian Arrhythmology  
8 and Pacing Society (AIAC) website. From June 2019 to January 2020, 125 cardiologists,  
9 routinely performing interventional electrophysiology, participated at the survey. Eighty-  
10 seven (70.2%) participants are aware of the recent European Directive (Euratom 2013/59),  
11 however only 35 (28.2%) declare to have read the document in details. Ninety-six (77.4%)  
12 participants register the dose delivered to the patient in each procedure, in 66.1% of the cases  
13 both as fluoroscopy time and dose area product. Years of exposition ( $p=0.009$ ) and working in  
14 a center performing pediatric procedures ( $p=0.021$ ) related to greater degree of X-ray  
15 equipment optimization. The majority of participants (72, 58.1%) did not recently attend  
16 radioprotection courses. The latter related to increased awareness of techniques to reduce  
17 radiation exposure (96% vs 81%,  $p=0.022$ ), registration of the delivered dose in each  
18 procedure (92% vs 67%,  $p=0.009$ ), and X-ray equipment optimization (50% vs 36%,  
19  $p=0.006$ ).

20 Conclusion. Italian interventional cardiologists show an acceptable level of radiation  
21 awareness and knowledge of updated European directives. However, there is clear space for  
22 improvement. Comparison to other health professionals, both at National and International  
23 levels, is needed to pursue proper X-ray management and protect public health.

1 *Keywords: Survey; radiation risk; radioprotection; cardiac electrophysiology.*

## 1 **Introduction**

2 X-rays are classified as class I carcinogens [1], and the mechanisms explaining their effects  
3 are well known. As carcinogenesis due to radiation exposure is a stochastic process, a safety  
4 threshold does not exist, being even low doses of X-rays possible cause of malignancies [2].

5 In addition, radiation exposure induces detrimental effects on several organs, as the  
6 crystallinus, brain and endocrine/reproductive system, provoking cataract, reproductive  
7 disorders and neurodegenerative effects [3–6].

8 Radiation use in medicine has significantly increased over the last decade, and, excluding  
9 Radiotherapists, Cardiologists are the specialists responsible for the majority of X-ray  
10 exposure (about 40%) [7].

11 In the attempt to optimize radiological hazard management, driven by the European Council's  
12 Regulation update (Euratom 2013/59), cardiological societies have issued guidelines and  
13 recommendations. Overall, the principles of exposure optimization and justification emerge as  
14 guiding, highlighting the central role of the "3 A's": Audit, Awareness, and Appropriateness  
15 [8–11].

16 The present study describes the results of a web-based survey proposed to Italian  
17 interventional electrophysiologists by a Working Group of the Italian Association of  
18 Arrhythmology and Cardiac Pacing Society (Associazione Italiana di Aritmologia e  
19 Cardiostimolazione, AIAC) to investigate a broad range of aspects, from specific European  
20 Union directives to general practical principles, related to radiation management.

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1 **Methods**

2 A voluntary survey including 31 questions and open or multiple-choice answers was run on  
3 the AIAC website ([www.AIAC.it](http://www.AIAC.it)). Requirements to participate in the survey were registration  
4 to National Society's website and approval of the specific privacy data policy (according to  
5 article 13, 196/2003 of the Italian Regulation and 13, 679/2016 of the European Union  
6 normative).

7 The questionnaire was designed by MA and MDG, on behalf of the "Area Raggi Zero", an  
8 official AIAC's Working Group ([https://aiac.it/attivita/aree-task-force/aree-aiac/area-raggi-  
9 zero/](https://aiac.it/attivita/aree-task-force/aree-aiac/area-raggi-zero/)), to investigate global perception of X-ray exposure hazard, knowledge of and  
10 adherence to current normative prescriptions among interventional electrophysiologists  
11 members of the Society.

12 The complete list of questions is detailed in the Appendix Table S1. The survey was online  
13 from June 2019 to January 2020.

14

15 *Statistical analysis*

16 Continuous variables are reported as mean and standard deviation (SD), whereas categorical  
17 variables as number of cases and percentage ( $\pm$  the 95% margin of error). For stratification in  
18 categorical variables, age, years of exposition and number of procedures as first practitioner,  
19 were classified into median and quartiles (IQR). Categorical variables were compared by  
20 contingency tables and chi-square test. Continuous variables were compared within strata by  
21 ANOVA analysis or t-test. All tests of significance were two tailed and a  $p < 0.05$  was  
22 considered statistically significant. Analysis was performed using R V.4.0.0 (R Foundation  
23 for Statistical Computing, Vienna, Austria).

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## 1 **Results**

2 Across 15 Italian regions, 125 Cardiologists, specialized in interventional electrophysiology,  
3 participated at the survey (Figure 1). The response rate to the survey, according to the 2017  
4 AIAC census [12], was 14% (125 cardiologist out of the 910 included in this census),  
5 representative of 37% (64 out of the 174) of the Italian centers performing interventional  
6 electrophysiology. Participants demographic characteristics are reported in Table 1: 47  
7 (37.9±8.5%) are employed in centers where 100-200 electrophysiological procedures are  
8 performed each year, 52 (41.9 ± 8.7%) in centers performing also pediatric procedures.  
9 Complete details on answers to the 31 questions of the survey are reported in Table S1 in the  
10 Appendix.

11 Concerning background knowledge on the topic, 20 (18.5 ±7.3%) of the participants state to  
12 not recognize any of the proposed international literature on X-rays clinical hazards, and 16  
13 (12.9 ± 5.9%) declare not to be aware of available techniques to minimize radiation use in the  
14 electrophysiological laboratory.

15 Eighty-seven (70.2 ± 8.1%) participants are aware of the recent European Directive (Euratom  
16 2013/59), however only 35 (28.2 ± 7.9%) have read it in details. The majority of participants  
17 (72, 58.1 ± 8.7%) did not recently attend radioprotection courses, in 46.8 ± 8.8% of the cases  
18 due to lack of proposals by their institution.

19 Three out of four participants (96, 77.4 ± 7.4%) register the delivered dose to the patient in  
20 each procedure, in 66.1 ± 8.3% of the cases both as fluoroscopy time and dose area product  
21 (DAP); a similar quote of participants is aware of his own exposition dose during the previous  
22 year (94, 75.8 ± 7.5%).

23 The first operator is commonly (109, 87.9 ± 5.7%) in charge of controlling X-rays delivery; a  
24 radiology technician is always available for 50 (40.3 ± 8.6%) participants.



1 X-ray equipment is regularly optimized for  $41.9 \pm 8.7\%$  of the participants (for  $21.8 \pm 7.3\%$  on  
2 a case-by-case basis); for  $11.3 \pm 5.6\%$  the equipment is never optimized.

3 Among the interviewed electrophysiologists, only 14 ( $11.3 \pm 5.6\%$ ) do not have an  
4 electroanatomical mapping system available. When available, the majority uses them for  
5 ablation procedures of a comprehensive set of arrhythmias: as an example,  $85.8 \pm 6.4\%$  of the  
6 participants perform more than 50% atrial fibrillation (AF) ablations with electroanatomical  
7 mapping systems (full details in Figure S1, Appendix). The economic burden is the most  
8 common reason ( $35, 34.0 \pm 9.1\%$ ) for not routinely using these systems.

9 Participant's age, gender, years of exposition, number of procedures per year and involvement  
10 in pediatric procedures were tested at univariate analysis in search of inference with the given  
11 answers (Table S2, Appendix).

12 Participant's age (median 43, IQR 36-51) relates to an increased awareness of the previous  
13 year's exposure ( $p=0.023$ ). Years of exposition (median 10, IQR 5-20), and working in a  
14 center performing pediatric procedures are associated with a greater degree of X-ray  
15 equipment optimization, at least periodically ( $56\%$  if  $> 20$  years of exposition vs  $23\%$  if  $\leq 5$   
16 years of exposition,  $p=0.009$ , and  $52\%$  vs  $35\%$ ,  $p=0.021$ , in centers performing or not  
17 pediatric procedures respectively; Figure 2). The presence of a radiology technician did not  
18 influence the rate of equipment optimization ( $p=0.246$ ) or the recording of the dose delivered  
19 to the patient ( $p=0.992$ ). Working in a center performing pediatric procedures relates to  
20 availability of electroanatomical mapping systems ( $0\%$  vs  $19\%$  with no mapping systems,  
21  $p<0.001$ ), and their differential use among the different procedures ( $p=0.014$ ): participants  
22 working in centers performing pediatric procedures, more commonly use mapping systems  
23 for all procedures, including device implantations ( $25\%$  vs  $7\%$ ); conversely, none of them  
24 perform biventricular pacing implantations exclusively ( $0\%$  vs  $13\%$ ).

1 Similarly, number of procedures as first practitioner in the previous year is associated with  
2 periodical X-ray equipment optimization (53% if > 125 procedures per year vs 38% if ≤ 50  
3 procedures per year, p=0.017), and the differential use of mapping systems among the  
4 different procedures: practitioners performing a higher number of procedures per year (≥ 126,  
5 81-125, 51-80) more frequently use mapping systems in high percentage of procedures (76-  
6 100%) for AF and atypical atrial flutter (88% vs 85% vs 79% vs 52%, p=0.049), for AT (88%  
7 vs 92% vs 79% vs 48%, p=0.010), and for VT (92% vs 93% vs 75% vs 48%, p=0.002);  
8 compared to their colleagues performing ≤ 50 procedures per year, respectively (Figure 3). In  
9 addition, center's volume influences operator's knowledge of techniques to minimize  
10 radiation use: the respondents who declare not to be aware of any technique decreased with  
11 the increase of procedures per year (50 and 0% for <50, and >500 procedures per center per  
12 year, respectively; p = 0.009; Figure S2, Appendix).

13 Finally, attendance of radioprotection courses, related to increased awareness of techniques to  
14 reduce radiation exposure (96% vs 81%, p=0.022), registration of the delivered dose in each  
15 procedure (92% vs 67%, p=0.009), and X-ray equipment optimization (50% vs 36%,  
16 p=0.006; Figure 4).

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## 1 **Discussion**

2 The extensive X-ray use by Cardiologists is a matter of fact, to increase knowledge on  
3 radiological hazard management is the community's responsibility. The present study,  
4 performed among Italian Cardiologists routinely performing interventional electrophysiology,  
5 highlights the strong motivation of AIAC to fulfil the audit, awareness, and appropriateness  
6 principles, with the final aim to achieve proper X-ray management and improve social health.  
7 The response rate of this survey, albeit lower than the average reported by surveys performed  
8 among healthcare professionals [13], is in line with that of voluntary web-based surveys  
9 performed among physicians [14]. In addition, participants to the survey are representative of  
10 more than one third of the Italian centers performing interventional electrophysiology.  
11 The survey inquired a broad range of aspects, from specific European Union directives (e.g.  
12 participation to radioprotection courses, as prescribed in article 14 of the Euratom 2013/59  
13 normative), to general principles related to practical radiation management (e.g. frequency of  
14 X-ray equipment optimization).

15 Several encouraging features emerge from the survey. The majority of participants (77%)  
16 register the delivered dose in all procedures, commonly (66%) both as fluoroscopy time, than  
17 as DAP, a more precise parameter of radiation delivery, better correlating to the scattered  
18 radiation received by the personnel in the lab. Proficient dose registration is a known factor  
19 increasing radiation awareness in all the staff [15].

20 Similarly, Italian interventional electrophysiologists declare adequate knowledge of available  
21 radiation reduction techniques and relative literature. Of note, three papers [16–18] inspired  
22 about 40% of participants. More than half of the participants of the survey reported that they  
23 optimize the X-ray equipment periodically or on a case-by-case basis, another highly relevant  
24 strategy to decrease X-ray exposure [15]. Eventually, availability of electroanatomical

1 mapping systems to guide non-fluoroscopic catheter manipulation, a highly effective  
2 approach to minimize X-ray exposure [16,18–22], is wide.

3 On the other hand, there surely is space for improvement. Radioprotection courses appear  
4 largely unavailable (46.8%), and about one third of the participants are unaware of the latest  
5 update of the European radioprotection regulations. The positive effect of radioprotection  
6 courses on radiation awareness [23] is confirmed by the present study. Participants who  
7 recently participated to radioprotection classes declared superior knowledge of radiation  
8 reduction techniques, higher compliance in recording delivered dose in each procedure and  
9 more frequent X-ray equipment optimization (Figure 4). Electroanatomic mapping systems,  
10 albeit having demonstrated to be effective in reducing radiation delivery [24], do not  
11 automatically translate into a reduction of X-ray exposure or in the increase of radiation  
12 awareness and knowledge. Their use, in any case, needs to be accompanied with radiation use  
13 mitigation [15], the cornerstone of improved radiation management.

14 Of note, the presence of a radiology technician, known to influence radiation delivery (e.g. by  
15 optimizing collimation and view projections) [15,25] was lacking for nearly half (46%) of the  
16 participants. In any case, based on the present survey, this did not seem to influence the rate  
17 of equipment optimization, nor the recording of the dose delivered to the patient.

18 Altogether, the results emerging from the survey indicate that interventional  
19 electrophysiologists performing pediatric procedures, most likely due to the higher  
20 detrimental effects in this subgroup [8], are more sensitive to radiation harm and more  
21 commonly optimize X-ray equipment or use electroanatomical mapping systems.

22

### 23 *Limitations*

24 This work presents some limitations. First, the number of participants is limited; this may

1 have entailed statistical under-powering and must be taken into account for data  
2 interpretation. Another limitation stems from the design of the study: as participation to the  
3 web-based survey was voluntary, a selection bias may be present, with the most radiation-  
4 sensitive practitioners more represented. Finally, the aim of the survey was to investigate the  
5 overall awareness of the European and Societies' guidelines among a National cohort of  
6 Cardiologists routinely performing interventional electrophysiology. Direct queries assessing  
7 if recommendations are actually followed, that inevitably would directly or indirectly involve  
8 other subjects or institutions than those participating to the survey, were, in fact, expressly  
9 avoided. Information on whether specific indications are followed (e.g. correct indication of  
10 supervised or appropriate workplace radiological surveillance) do, therefore, not emerge from  
11 the survey. Eventually, although European Council Regulation, guidelines and  
12 recommendations are shared with other European countries, the study is representative of the  
13 Italian situation, and, transposition may widely diverge.

14

## 15 **Conclusion**

16 Italian interventional electrophysiologist show an acceptable level of radiation awareness and  
17 knowledge of updated European directives. However, there is clear space for improvement, as  
18 a significant percentage of participants, for example, did not recently attend radioprotection  
19 courses. Comparison to other health professionals (e.g. Radiologists, Radiotherapists) both at  
20 National and International levels is needed to fulfil the audit, awareness, and appropriateness  
21 principles, and pursue proper X-ray management to protect public health.

22

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1 **Data availability statement**

2 The data underlying this article will be shared on reasonable request to the corresponding  
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4



1 **Conflict of interest**

2 None declared.

3

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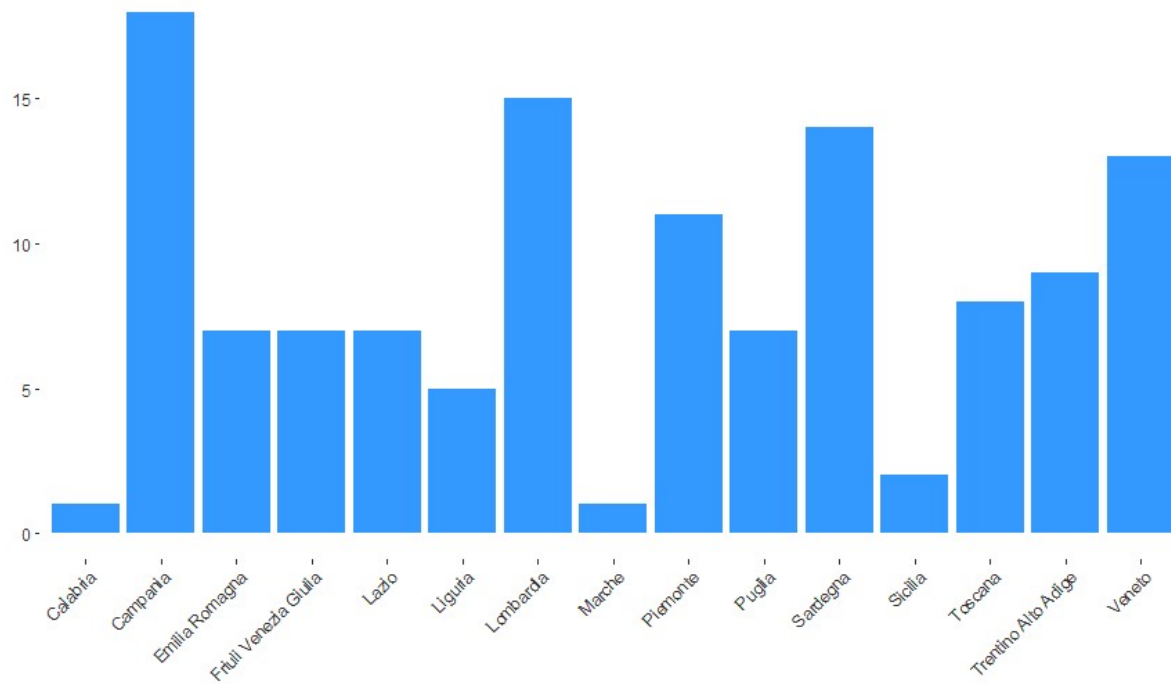
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21

1 **Figures**

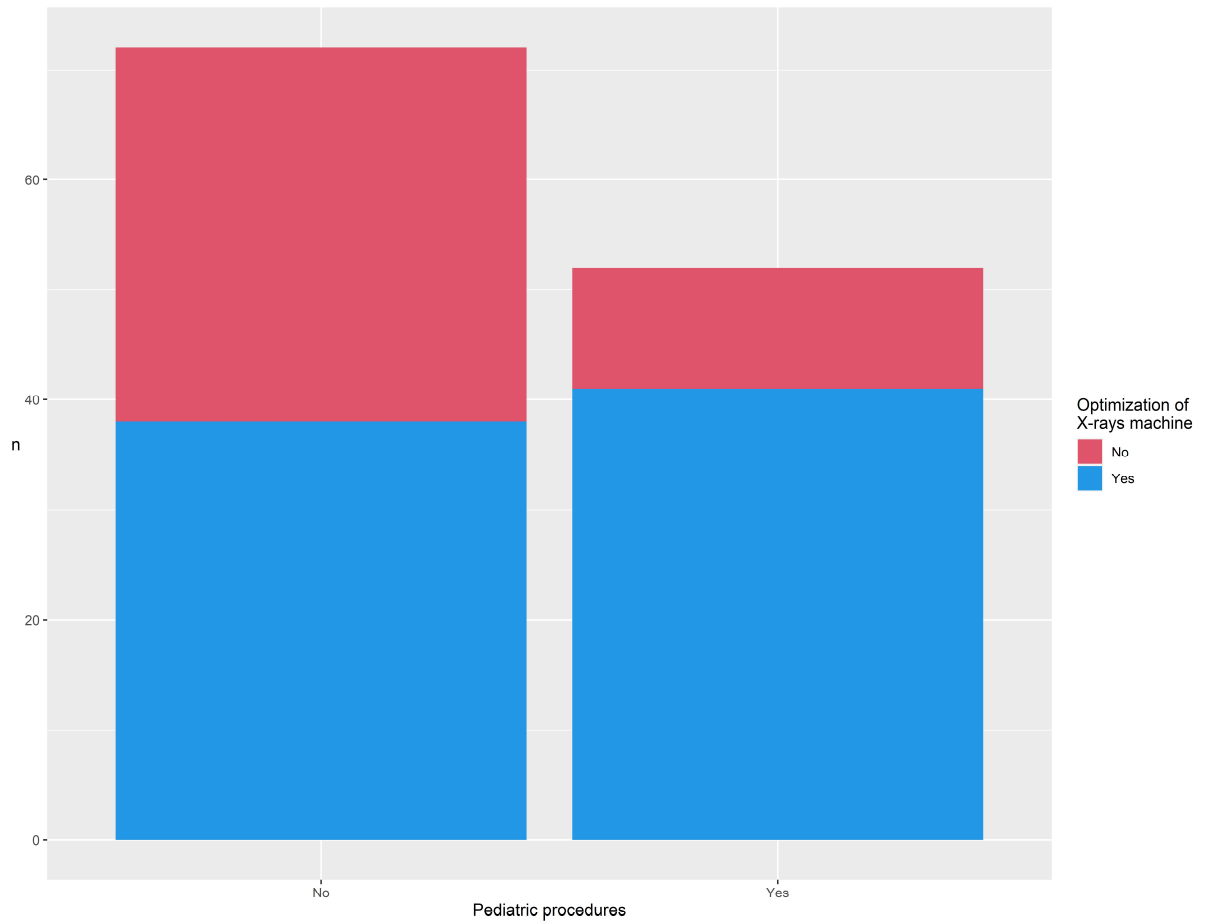
2 **Figure 1.** Italian interventional electrophysiologists participating to the web-based survey  
3 stratified by Region.

4



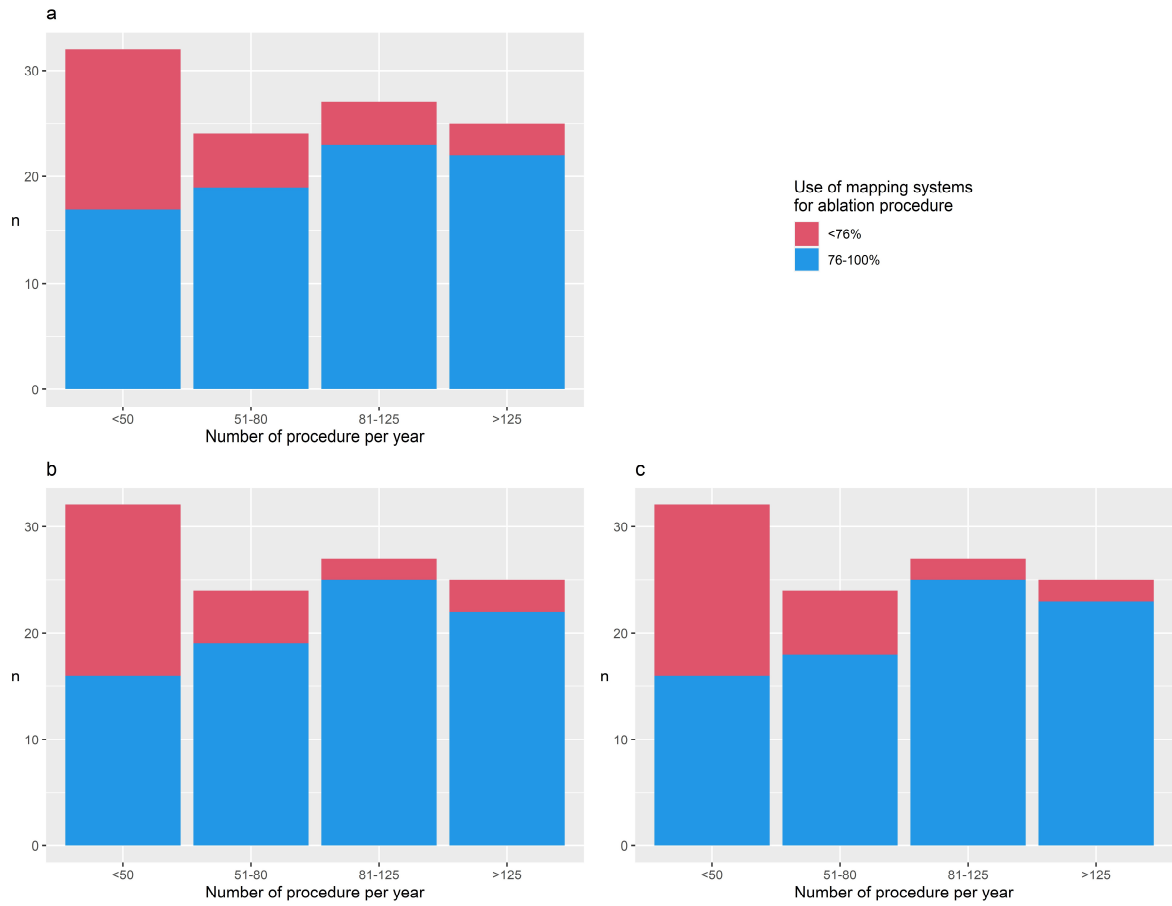
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1 **Figure 2.** Participants working in centers performing (n=52) or not (n=72) pediatric procedures  
2 and X-ray equipment optimization (for the purpose of the figure the answers “Yes, case by case”  
3 and “Yes, periodically” have been merged in “Yes”; the answers “No” and “I do not know”  
4 have been merged in “No”).

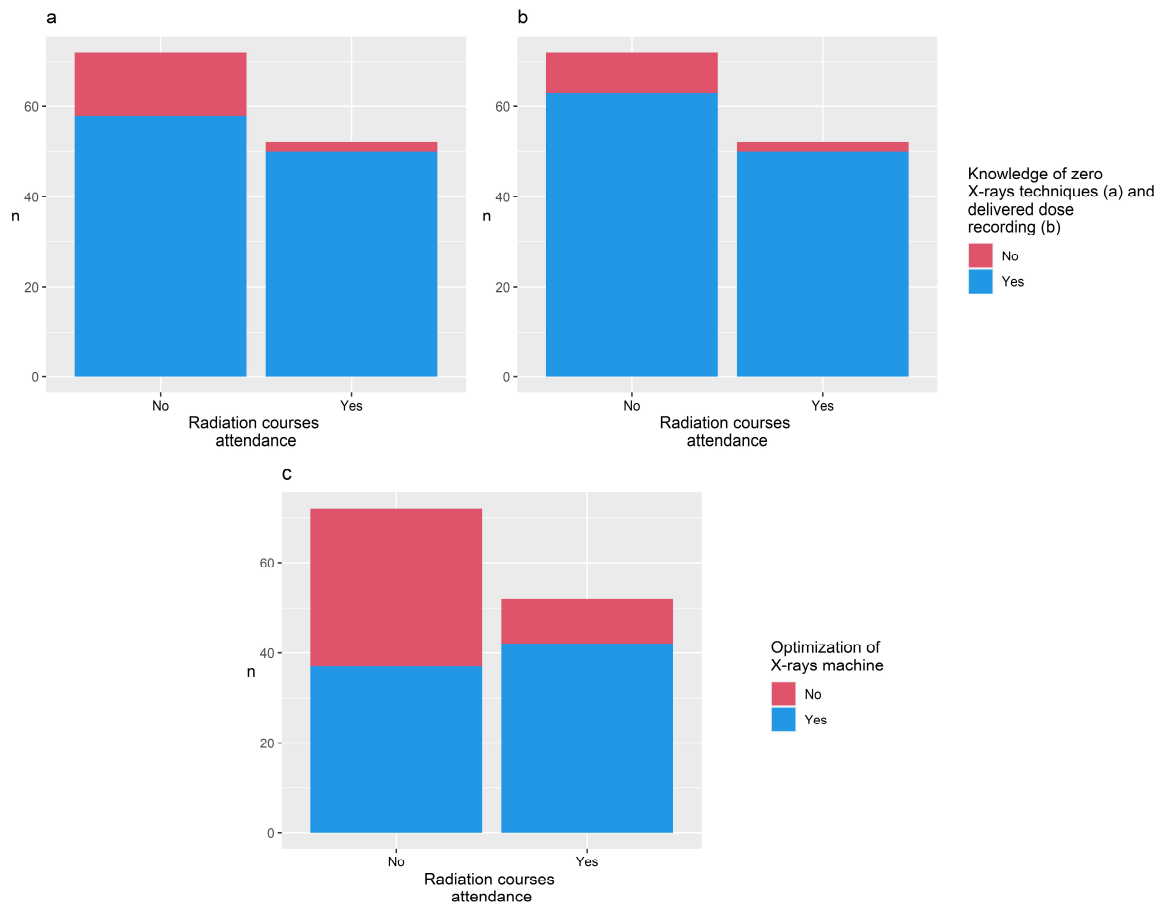




- 1 **Figure 3.** Number of procedures performed as first operator and use of mapping systems for at
- 2 least 75% of AF (a), atrial tachycardia (b) and ventricular tachycardia (c) ablation procedures.



1 **Figure 4.** Radioprotection courses attendance (Yes=52, No=72) stratified by awareness of  
 2 techniques to reduce radiation exposure (a), recording of delivered radiation dose in each  
 3 procedure (b), and regular X-ray equipment optimization (c). For the purpose of the figure, in  
 4 panel “b”, the answers “Yes”, “Yes, not in every patient” and “Yes, but it is not stored” have  
 5 been merged in “Yes”; in panel “c”, the answers “Yes, case by case” and “Yes, periodically”  
 6 have been merged in “Yes”; the answers “No” and “I do not know” have been merged in “No”.  
 7



1 **Tables**

2 **Table 1.** Principal participant's demographics characteristics (mean  $\pm$ SD, or count and  
3 percentage).

4

<b>Variable</b>	
Gender, male	94 (75.2%)
Age (years)	44.1 ( $\pm$ 9.59)
Total years of X-ray exposure	14.1 ( $\pm$ 15.96)
Number of procedures as first operator per year	106.0 ( $\pm$ 89.09)

5