

## Occupational Health Risks in Cardiac Catheterization Laboratory Workers

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**Background**—Orthopedic strain and radiation exposure are recognized risk factors in personnel staff performing fluoroscopically guided cardiovascular procedures. However, the potential occupational health effects are still unclear. The purpose of this study was to examine the prevalence of health problems among personnel staff working in interventional cardiology/cardiac electrophysiology and correlate them with the length of occupational radiation exposure.

**Methods and Results**—We used a self-administered questionnaire to collect demographic information, work-related information, lifestyle-confounding factors, all current medications, and health status. A total number of 746 questionnaires were properly filled comprising 466 exposed staff (281 males; 44±9 years) and 280 unexposed subjects (179 males; 43±7 years). Exposed personnel included 218 interventional cardiologists and electrophysiologists (168 males; 46±9 years); 191 nurses (76 males; 42±7 years), and 57 technicians (37 males; 40±12 years) working for a median of 10 years (quartiles: 5–24 years). Skin lesions ( $P=0.002$ ), orthopedic illness ( $P<0.001$ ), cataract ( $P=0.003$ ), hypertension ( $P=0.02$ ), and hypercholesterolemia ( $P<0.001$ ) were all significantly higher in exposed versus nonexposed group, with a clear gradient unfavorable for physicians over technicians and nurses and for longer history of work (>16 years). In highly exposed physicians, adjusted odds ratio ranged from 1.7 for hypertension (95% confidence interval: 1–3;  $P=0.05$ ), 2.9 for hypercholesterolemia (95% confidence interval: 1–5;  $P=0.004$ ), 4.5 for cancer (95% confidence interval: 0.9–25;  $P=0.06$ ), to 9 for cataract (95% confidence interval: 2–41;  $P=0.004$ ).

**Conclusions**—Health problems are more frequently observed in workers performing fluoroscopically guided cardiovascular procedures than in unexposed controls, raising the need to spread the culture of safety in the cath laboratory. (*Circ Cardiovasc Interv.* 2016;9:e003273. DOI: 10.1161/CIRCINTERVENTIONS.115.003273.)

**Key Words:** cancer ■ cardiac catheterization ■ cataract ■ fluoroscopy  
■ ionizing radiation ■ radiation risk ■ safety

Complex catheter-based procedures confer distinct occupational health risks to cardiologists and paramedical staff in catheterization and electrophysiology laboratory.<sup>1,2</sup> Previous studies have documented orthopedic injuries and musculoskeletal pain as a likely consequence of wearing heavy-leaded aprons mandatory to reduce radiation risk.<sup>3–6</sup> A state of high arousal inherent in the procedural performance for continued periods may also have long-term psychological consequences, leading to stress and anxiety.<sup>7</sup> However, long-term radiation exposure remains the main occupational hazard. Cardiologists and staff accumulate significant lifetime radiation exposure in the range of 50 to 200 mSv,<sup>8,9</sup> corresponding to a whole body dose equivalent of 2500 to 10000 chest x-rays with a projected professional lifetime attributable excess cancer risk of 1 in 100.<sup>10</sup> Chronic occupational radiation exposure may, over time, be associated with an increased prevalence of cataracts and

cancers,<sup>2,8</sup> and possibly other diseases, including early vascular and neurocognitive aging.<sup>11,12</sup> The purpose of this study was to describe the health status of personnel staff performing fluoroscopically guided cardiovascular procedures and compare it with that of unexposed subjects.

### See Editorial by Klein and Bazavan

In addition, we explored whether the prevalence of major health conditions in exposed workers is associated with length of occupational radiation exposure.

### Methods

#### Study Population

The study was conducted on workers at Italian interventional cardiology and electrophysiology laboratories and compared with

Received September 1, 2015; accepted February 24, 2016.

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\*A list of all Healthy Cath Lab Study Group participants is given in the Appendix.

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*Circ Cardiovasc Interv* is available at <http://circinterventions.ahajournals.org>

DOI: 10.1161/CIRCINTERVENTIONS.115.003273

### WHAT IS KNOWN

- Orthopedic strain and chronic radiation exposure from fluoroscopy are recognized risk factors for cardiologists and paramedical staff in catheterization and electrophysiology laboratory. However, the distinct occupational health risks still need to be investigated.

### WHAT THE STUDY ADDS

- The survey shows that several health problems are more frequently observed in workers performing fluoroscopically guided cardiovascular procedures than in unexposed controls.
- The primary risks mostly related to work activity and radiation exposure included orthopedic illnesses, cataract, skin lesions, and cancers, particularly in workers with longer duration of occupational work.
- The secondary findings showed an increased prevalence of anxiety/depression, hypertension, and hypercholesterolemia, supporting the recent evidence of other radiogenic noncancer effects.
- These findings can contribute to spread the culture of safety in the cardiac catheterization laboratory.

unexposed subjects. Cardiologists and paramedical staff attending the Annual Scientific meetings of the Italian Society of interventional cardiologists (SICI-GISE meeting 2011 and 2012) and Italian Society of cardiac electrophysiologists (AIAC 2014) were invited to fill out a structured questionnaire on a voluntary basis. Unexposed subjects were randomly selected and did never experience occupational exposure to ionizing radiation. They included physicians (mostly cardiologists), other professional researchers (biologists, computer scientists, engineers, and so on), biomedical industry employees, nurses, and technical and administrative staff working in the CNR Research Campus in Pisa or attending the scientific meetings when recruitment was performed. This study was conducted with informed consent of every participant subject and was approved by the institutional Ethical Research Committee.

### Data Collection

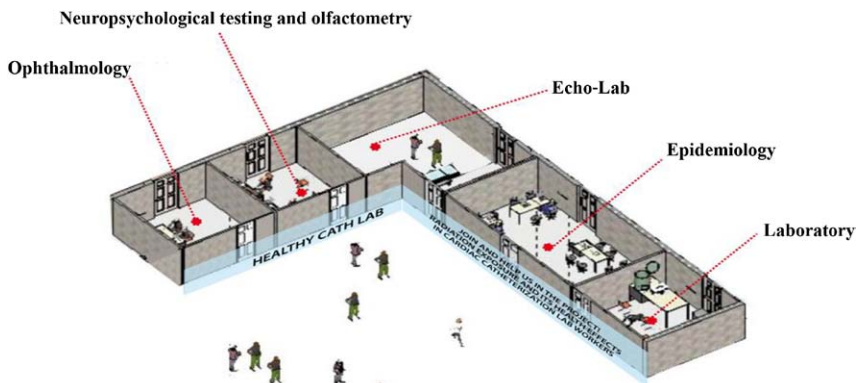
A self-administered questionnaire was used to collect demographic information, work-related information (radiological workload and years of employment), variables about lifestyle (smoking habits and consumption of alcohol), and information on all current medications

and health status. Before the congress, all 3200 potential participants were polled through email disseminated through the mailing list of the scientific society, briefly explaining aims, methods, and location of the Healthy cath laboratory suite during the meeting (Figure 1). The actual participation took place during the meeting, with specialized personnel hosting participants and tutoring them with a help desk during the self-filled questionnaire. Nine hundred and fifty-three subjects filled the questionnaires, but 207 responses were incomplete and of poor quality, with missing responses (none of the multiple choice boxes ticked for that item) and multiple responses (>1 box ticked for an item requiring a single response), and were not further considered. Some participants also underwent on-site specialized testing for imaging, such as carotid scan or blood sampling, for subsequent analysis of molecular biomarkers, such as telomeres, as previously described.<sup>11</sup>

The questionnaire included items concerning the present and past medical history of the subject by a list of health problems (eg, orthopedic illness, skin lesions, cataract, diabetes mellitus, thyroid function, anxiety/depression, hypertension, hypercholesterolemia, strokes, ischemic heart disease, and cancer). In particular, orthopedic illness included cervical, hip/knee, and lumbar injuries. Skin lesions comprised transient erythema, dermatitis, dry desquamation, and temporary epilation. Stress and depressive symptoms were defined by the presence of frequent feelings of nervousness or anxiety, hopelessness, pessimism, fatigue, and insomnia. Furthermore, participants were asked about the diagnosis of tumor site and laterality. The medication history was also used to obtain a valid and reliable measure of health status. Duration of occupational work was categorized into 3 categories of years:  $\leq 5$  years; 6–15 years, and  $\geq 16$  years. Additionally, an occupational radiological risk score (ORRS) was constructed by combining length of employment, individual caseload, and proximity to the radiation source. ORRS was estimated in each subject for first operator (working in proximity to the source of radiation) by multiplying years of cath laboratory work times the number of procedures per year ( $>200=3$ ;  $100-200=2$ ;  $<100=1$ ). Obtained scores were multiplied by 0.5 (ie, reduced by 50%) in case of second operator, nurse, or technician because they typically stand at a further distance from the source of radiation and would, thus, be expected to receive a lower dose.<sup>11</sup> We considered as smoker individuals who smoked at least 3 cigarettes per day; ex-smokers as those who stopped smoking at least 6 months before study inclusion; and nonsmokers as those who never smoked. The consumption frequency of alcoholic beverages (beer, wine, and liquor) was classified in drinkers who drank  $\geq 3$  alcoholic drinks per day (beer, wine, and liquor) and nondrinkers who drank  $<3$  drinks per day.

### Statistical Analysis

Statistical analyses were performed with the Statview statistical package, version 5.0.1 (Abacus Concepts, Berkeley, CA). Data are expressed as mean $\pm$ SD if normally distributed or as median (quartiles) if skewed. Differences between the means of 2 continuous variables were evaluated by unpaired Student's *t* test or Whitney test as appropriate. Two types of statistical models were used. First, differences



**Figure 1.** Schematic representation of Healthy cath laboratory suite.

in frequencies and percentages were tested by  $\chi^2$  analysis. All cath laboratory workers were grouped together and compared with the reference. Comparison analysis was also used to investigate difference for job position and years of occupation. In the next step, unconditional logistic regression analysis was used to estimate odds ratios (ORs) and 95% confidence interval (CI) for the association between specific disease and occupational radiation exposure. To predict the odds of disease with the years of exposure and career caseload, we performed the regression analysis by stratifying according to the tertiles of occupation and ORRS. The crude odds ratio of reported medical conditions had been adjusted for possible confounding by age, sex, and smoking. A 2-tailed *P* value <0.05 was chosen as the level of significance.

## Results

A total number of 746 questionnaires were properly filled comprising 466 exposed staff (281 males; 44±9 years) and 280 unexposed subjects (179 males; 43±7 years). Exposed personnel included 218 interventional cardiologists/electrophysiologists (168 males; 46±9 years); 191 nurses (76 males; 42±7 years), and 57 technicians (37 males; 40±12 years) working for a median of 10 years (quartiles: 5–24 years). We obtained a reliable reconstruction of the lifetime cumulative professional exposure for 73 workers (45 interventional cardiologists/electrophysiologists and 28 nurses). Median lifetime effective doses were 21 mSv (quartiles: 12–71 mSv) and 7 mSv (quartiles: 2–21 mSv) for interventional cardiologists and nurses, respectively. The reported annual interventional caseload was <100 in 27%, between 100 and 200 in 31%, and >200 in 42% of operators. The estimated median ORRS resulted 23 (quartiles: 10–63), 8 (quartiles: 3–28), and 7 (quartiles: 3–23) for interventional cardiologists, nurses, and technicians, respectively. The demographic characteristics of the 2 study groups are presented in Table 1. There was no difference in terms of age, sex, and education

**Table 1. The Sociodemographic Characteristics of the Study Subjects**

	Staff in Interventional Cardiology (n=466)	Unexposed Group (n=280)	<i>P</i> Value
Age, y±SD	44±9	43±7	0.11
Men, n (%)	281 (60.3%)	179 (63.9%)	0.32
Year of exposure work, median (quartiles)	10 y (5–24)	...	...
Years of education, y±SD	18±3	18±4	0.87
Lifetime effective doses, median (quartiles)		...	
Physicians (n=45)	21 mSv (12–71)		
Nurses (n=28)	7 mSv (2–21)		
BMI, kg/m <sup>2</sup>	24.1±1.8	23.9±1.7	0.23
Current smoking, n (%)	125 (26.8)	64 (22.8)	0.001
Heavy drinking (yes), n (%)	8 (1.7)	6 (2.1)	0.67

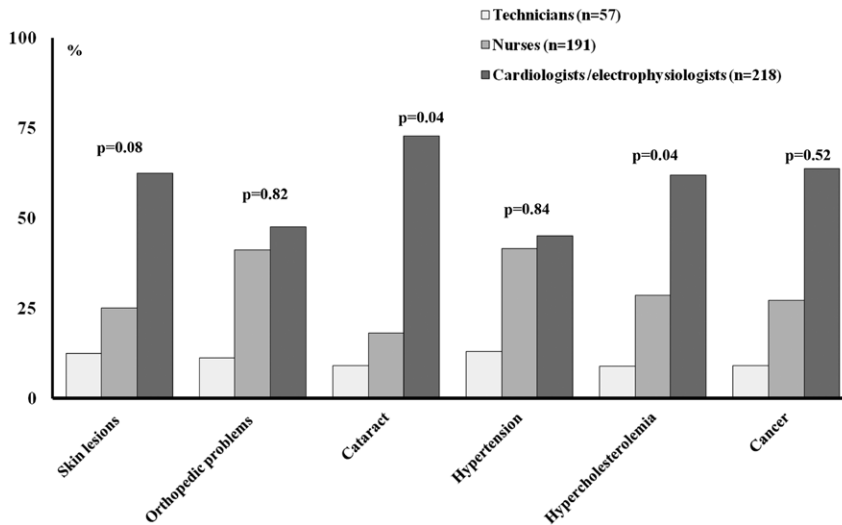
BMI indicates body mass index.

between exposed and unexposed subjects. Compared with unexposed subjects, personnel staff performing fluoroscopically guided cardiovascular procedures had a higher proportion of smokers (*P*=0.001). Exposed workers had a significantly higher prevalence of skin lesions (*P*=0.002), orthopedic problems (*P*<0.001), cataract (*P*=0.003), anxiety/depression (*P*<0.001), and thyroid disease (*P*=0.03) when compared with unexposed subjects (Table 2). There was no significant difference between participants in the rate of cardiovascular events (stroke and heart attacks), in spite of a higher prevalence of hypertension (*P*=0.02) and hypercholesterolemia (*P*<0.001) was found in exposed subjects when compared with unexposed subjects (Table 2). The prevalence of health problems was generally higher in the order physicians>nurses>technicians, as shown in Figure 2. A composite end point which included disease potentially associated with occupational exposure to radiation (cataract and cancer) showed statistical difference between 3 staff groups with the highest prevalence reported by interventional cardiologists/electrophysiologists followed by nurses and technicians (69% versus 22% and 9%, respectively; *P*=0.03). In the multiple logistic regression analysis, adjustment for potential confounders did not attenuate the association between occupational radiation exposure and skin lesions (OR, 2.8; *P*=0.01), orthopedic illness (OR, 7.1; *P*<0.001), cataract (OR, 6.3; *P*=0.01), and hypercholesterolemia (OR, 3.1; *P*=0.001) compared with unexposed subjects, as shown in Table 3. The effect of the years of work on the prevalence of health problems was evaluated after stratification by occupational exposure duration. By univariate analysis, there was a significant trend of increased rate of skin lesions (*P*=0.005), orthopedic illness (*P*<0.001), cataract (*P*<0.001), hypertension (*P*<0.001), hypercholesterolemia (*P*<0.001), and cancer (*P*<0.001) across the years of work (Figure 3).

The distribution of cancers by age, sex, smoking, years of occupational work, and side are shown in Table 4. Tumors occurred in 7 physicians (5 interventional cardiologists and 2 electrophysiologists), 3 nurses, and 1 technician. All subjects had worked for prolonged periods (18±8.2 years)

**Table 2. Medical Conditions in Questionnaire Participants**

	Staff in Interventional Cardiology (n=466)	Unexposed Group (n=280)	<i>P</i> Value
Skin lesion	40 (8.6)	8 (2.0)	0.002
Orthopaedic illness	141 (30.2)	15 (5.4)	<0.001
Cataract, n (%)	22 (4.7)	2 (0.7)	0.003
Thyroid disease, n (%)	35 (7.5)	10 (3.6)	0.03
Anxiety/depression, n (%)	58 (12.4)	6 (2.1)	<0.001
Cardiovascular events, n (%)	1 (0.2)	2 (0.7)	0.29
Hypertension, n (%)	60 (12.9%)	21 (7.5%)	0.02
Hypercholesterolemia, n (%)	56 (12.0%)	11 (4.0%)	<0.001
Diabetes mellitus, n (%)	7 (1.5%)	3 (1.1%)	0.62
Cancer, n (%)	11 (2.6)	2 (0.7)	0.09



**Figure 2.** Prevalence of health problems among personnel staff performing fluoroscopically guided cardiovascular procedures stratified by job position.

in interventional practice with exposure to ionizing radiation. Compared with those who were unexposed, workers in the 2 highest categories of occupational exposure years had a higher risk of cataract (6–15 years: OR, 6.3; 95% CI, 1.3–30;  $P=0.002$ ;  $\geq 16$  years: OR, 10.6; 95% CI, 2.1–52;  $P=0.004$ ) in the adjusted models, whereas there was no significant association for workers in the first category ( $\leq 5$  years: OR, 1.3; 95% CI, 0.1–15;  $P=0.81$ ). A higher risk of cancer was only observed for workers with  $\geq 16$  years (OR, 8.7; 95% CI, 1.4–52;  $P=0.02$ ) after adjusting for age, sex, and smoking.

Similar results were obtained when the data were analyzed on the basis of categories of ORRS.

In highly exposed physicians, adjusted OR with respect to unexposed subjects remained increased for hypertension (OR, 1.7; 95% CI, 1.0–3;  $P=0.05$ ), hypercholesterolemia (OR, 2.9; 95% CI, 1–5;  $P=0.004$ ), cancer (OR, 4.5; 95% CI, 0.9–25;  $P=0.06$ ), and cataract (OR, 9.0; 95% CI, 2–41;  $P=0.004$ ; Table 5).

## Discussion

The present survey shows that workers performing fluoroscopically guided cardiovascular procedures have significantly higher risk of several health problems compared with unexposed subjects.

The primary risks mostly related to work activity and radiation exposure included orthopedic illnesses, cataract, skin lesions, and cancers, particularly in workers with longer duration of occupational work.

The secondary or indirect findings showed an increased prevalence of anxiety/depression, hypertension and hypercholesterolemia, supporting the recent evidence of other radiogenic noncancer effects.<sup>11–14</sup>

For primary risks, our findings support previous observations concerning an increased rate of orthopedic illness related to long hours of standing and heavy lead aprons.<sup>3–7</sup>

Among eye tissues, the lens is the most radiosensitive, and thus, cataract formation may be the primary ocular complication associated with ionizing radiation exposure. Recent studies of interventional cardiologists also identified high rates of

lens opacities, which can be observed in one third of staff after 30 years of work.<sup>15</sup>

Radiation-induced cancer remains the most alarming and serious long-term occupational risks for interventional cardiologists, despite the limited data validating these growing concerns.<sup>2,7,8</sup>

Recent reports found an increased number of tumors on the left side of the brain, the region of the head known to be more exposed to radiation and least protected by traditional shielding.<sup>16,17</sup>

Although the evidence supporting an increase in radiation-induced cancer among interventional cardiologists remains inconclusive, molecular studies showed that interventional cardiologists have a 2-fold increase of chromosomal damage (surrogate biomarkers of cancer risk) in circulating lymphocytes than clinical cardiologists.<sup>18</sup>

Notably, recent findings on International Nuclear Workers cohort provided strong evidence of a positive association between radiation exposure and leukemia even for low-dose exposure.<sup>19</sup>

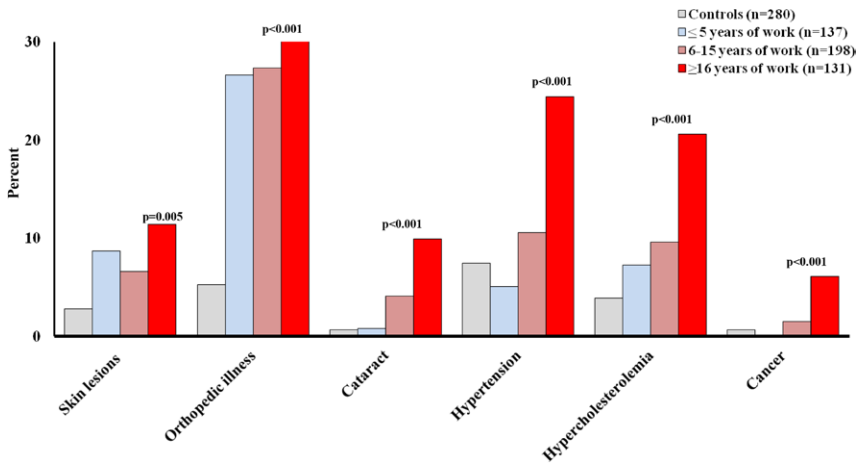
Moreover, the cohort of US radiological technologists suggested that protracted occupational exposure to radiation before the implementation of more stringent radiation

**Table 3.** ORs and 95% CIs per Medical Conditions Among Staff Working in Interventional Cardiology/Cardiac Electrophysiology Compared With Unexposed Subjects

Condition	Unadjusted OR (95% CI)	P Value	Adjusted OR (95% CI)*	P Value
Skin lesion	3.2 (1.5–6.9)	0.003	2.8 (1.3–6.1)	0.01
Orthopedic problems (back/neck/knee), n (%)	7.7 (4.4–13.3)	<0.001	7.1 (4.0–12.4)	<0.001
Cataract, n (%)	6.9 (1.6–29.5)	0.001	6.3 (1.5–27.6)	0.01
Hypertension, n (%)	1.8 (1.1–3.1)	0.02	1.5 (0.9–2.6)	0.1
Hypercholesterolemia, n (%)	3.3 (1.7–6.5)	<0.001	3.1 (1.5–6.2)	0.001
Cancer, n (%)	3.4 (0.7–15.3)	0.1	3.0 (0.6–13.7)	0.2

CI indicates confidence interval; and OR, odds ratio.

\*Adjusted for age, sex, and smoking.



**Figure 3.** Rate of health problems by years of occupational work.

protection measures in the late 1950s may be linked with mortality from specific cancers and circulatory system diseases.<sup>20</sup>

In fact, evidence has now emerged for increased risks of other radiogenic noncancer effects, especially an excess risk for stroke and myocardial infarction.<sup>21</sup> Although the underlying biological mechanisms are not well defined, experimental evidence supported low-dose ionizing radiation exposure causes a significant long-term alterations in lipid metabolisms and endothelial function.<sup>22</sup> Our study did not demonstrate a statistically significant increase in the prevalence of cardiovascular events; however, there was a higher prevalence of vascular risk factors, such as hypertension and hypercholesterolemia.

Dose-related increases in the incidence or prevalence of hypertension<sup>23</sup> and elevated serum cholesterol concentrations<sup>24</sup> have also been found among atomic-bomb survivors, who

received with an average dose of <200 mSv, with >50% of exposed individuals having doses <50 mSv,<sup>25</sup> that is, less than the effective dose received by interventional cardiology/cardiac electrophysiology workers from occupational radiation exposure over their lifetime. Further support is demonstrated by recent findings showing that chronic low-dose radiation exposure is associated with early signs of vascular aging and subclinical atherosclerosis after correction for potential confounders.<sup>11</sup> It is also noteworthy that a significantly increased left-sided carotid atherosclerosis was also found in our recent article,<sup>11</sup> providing further support for a causal connection between occupational radiation exposure and early signs of vascular damage.

Notably, chronic low-dose rate ionizing radiation triggers changes in the endothelial cell biology that induce the onset of premature senescence, and these alterations may in part be responsible for the increased risk of chronic low-dose radiation-associated cardiovascular disease.<sup>26</sup> Furthermore, the most significant molecular alterations induced by exposure to radiation affected lipid metabolism in exposed mice by using a multiplatform mass spectrometry-based strategy.<sup>27</sup>

Finally, we observed a 6× higher rate of self-described anxiety/depression in the exposed staff. This might represent an occupational illness because of high stress and psychological strain posed by the work of the interventionalist and also possibly for a direct effect of radiation, which is especially relevant ( $\leq 1-2$  Sv on the left hemisphere after a lifetime exposure) on the unprotected head of the first operator and at chronic low doses may impact detrimentally on hippocampal neurogenesis and neuronal plasticity, with possible negative effects on mood stability and psychiatric morbidity.<sup>13,14</sup>

### Comparison With Previous Studies

Recent studies addressed the subject of safety of healthcare workers who participate in invasive procedures requiring radiation. Orme et al collected data with an electronic survey on 1042 employees exposed to radiation (compared with a group of 499 unexposed workers).<sup>5</sup> They showed a prevalence of musculoskeletal pain in exposed workers, with similar values of cancer, cataract, and hypothyroidism compared with nonexposed subjects. Klein et al surveyed by email 314 members of the Society for Cardiovascular Angiography and Interventions and reported that  $\approx 1$  out of 2 operators reported at least one

**Table 4.** Distribution of Cancers by Age, Sex, Smoking, Years of Occupational Work, and Side

Subject	Age	Sex	Years of Work	Smoking	Cancer	Side
Interventional cardiologist	54	M	20	Ex	Melanoma	Left
Interventional cardiologist	56	M	29	No	Skin basal cell carcinoma	NA
Interventional cardiologist	35	M	7	Yes	Seminoma	NA
Interventional cardiologist	64	M	18	Ex	Prostate adenocarcinoma	NA
Interventional cardiologist	60	M	25	No	Skin basal cell carcinoma	Left
Electrophysiologist	50	M	18	Yes	Bladder urothelial carcinoma	NA
Electrophysiologist	32	M	2	No	Melanoma	Right
Nurse	47	F	12	No	Skin liposarcoma	Left
Nurse	41	F	21	Ex	Uterus	NA
Nurse	47	F	27	Ex	Breast	Right
Technician	47	F	19	Yes	Breast	Right

F indicates female; M, Male; and NA, not applicable or not available.

**Table 5. Medical Conditions, ORs and 95% CIs According to ORRS Categories**

	Unexposed Subjects (n=280)	ORRS ≤5 (n=124)	ORRS 6–12 (n=115)	ORRS ≥13 (n=227)	OR (95% CI)*	P Value
Cataract, n (%)	2 (1)	2 (2)	2 (2)	19 (8)	9.0 (2–41)	0.004
Hypertension, n (%)	21 (7)	8 (6)	6 (5)	46 (20)	1.7 (1.0–3)	0.05
Hypercholesterolemia, n (%)	11 (4)	10 (8)	7 (6)	39 (17)	2.9 (1–5)	0.004
Cancer, n (%)	2 (1)	0	2 (2)	9 (4)	4.5 (0.9–25)	0.06

CI indicates confidence interval; OR, odds ratio; and ORRS, occupational radiological risk score.

\*OR for the highly exposed group (ORRS ≥13) compared with unexposed subjects after adjustment for age, sex, and smoking.

orthopedic injury, with a small but substantial prevalence of cancer.<sup>6</sup> However, some peculiar aspects of the different studies should be considered. Orme et al evaluated workers of a single, multisite institution (Mayo Clinic), whereas Klein et al evaluated a multicenter population through a scientific society, but without a control group.<sup>5,6</sup> The responders who took the survey by Orme et al were on average less exposed (only 15% physicians) than those recruited in the present survey (218 physicians out of 466 participants in the exposed group, ie, 47%). This may have to do with the way the survey was conducted. We made an electronic poll through the scientific societies' mailing lists, but also a direct head-to-head interview with dedicated personnel during 3 annual meetings of scientific societies in an ad hoc space in the congress exhibition. In this way, more experienced and more exposed members of the professional community were more likely to be involved, following the example of senior opinion leaders who promoted the survey and explained the scientific rationale through dedicated advertising material and focused sessions in prime time of the meeting. Whatever the underlying reason, our surveyed population consisted of a relative majority of cardiologists (47% of the overall population) with long-standing exposure as first operators (40% with >15 years in current position). These epidemiological differences may be important because both cancer and noncancer effects are related to cumulative effects of aging and cumulative radiation exposure over the years. They can only be detectable at a more advanced age, after longer periods of exposure.

### Study Limitations

In our study, we used the survey method integrated by personal interview during scientific meetings, with a response rate of 30%. The response rate was comparable to that obtained by other studies using a similar approach and ranging from 42% to 57%.<sup>5,6</sup> The response rate dropped around 10% if we include not only workers who opened the mail but also those who received solicitations.<sup>6</sup> Although at the end our response rate was adequate, in this as in similar studies, the presence of a potential selection bias exists, with a possible disproportionate contribution of respondents with existing health issues, who may reasonably think that their complaints are occupationally related, whereas those without medical issues may be less inclined to participate. In addition, no direct assessment of radiation dose was possible in most participants, and dose exposures were only indirectly estimated through self-assessed volumes of procedures. This was unavoidable because it was—and still it is in some environments—standard practice not to wear regularly dosimeters. A

diligent radioprotection habit may affect negatively the working potential of workers, which are now essentially punished for wearing dosimeters because they can be stopped from working for overexposure.<sup>28</sup> Also our unexposed group can be biased because we had more cardiovascular risk factors in the radiation workers than in the exposed group, and now it is accepted that the same risk factors for cardiovascular disease may also facilitate cancer occurrence.<sup>29</sup> Nevertheless, our data provide valuable information in showing that in the contemporary Italian interventional cardiologists and cardiac electrophysiologist community, we observed a higher rate of serious orthopedic illness, cataracts, and cancer. When laterality of cancer was applicable, we did observe a higher trend to leftward distribution of cancer in exposed physicians because the 67% of cases occurring in physicians showed left sidedness, whereas the malignancy was left sided in 33% of cancers occurring in nurses and technicians. Although numbers are too small to allow any conclusion, the data may be considered consistent with a greater left-sided exposure in physicians, which stay closer to patients with their left side during intervention. In fact, the major source of radiation to the operator is the scatter radiation originating from the patient's body targeted by the primary radiation beam. Independently of the access site, cardiology procedures are mostly performed from the right side of the patient, and this determines the greater irradiation to the left side compared with the right one, which is less exposed because of the inverse square law and the local shielding because of left-sided structures.<sup>30,31</sup> Our findings are to be considered with caution, and further larger studies are certainly needed at this point, and at least one is ongoing. The Multi-Specialty Occupational Health Group (MSOHG) undertook a cohort mortality study comparing cancer and other serious disease outcomes (including cardiovascular diseases and cataracts) in 44 000 physicians performing fluoroscopically guided procedures (including interventional cardiologists, radiologists, neuroradiologists, and others) and in 12 000 noninterventional radiologists with risks in 101 000 physicians who are unlikely to be occupationally exposed to radiation (eg, family physicians or psychiatrists).<sup>2</sup> The MSOHG is collaborating with experts in occupational health, epidemiology, and radiation effects from the United States Navy and the Radiation Epidemiology Branch of the National Cancer Institute to perform epidemiological studies addressing the fundamental questions important to all those working in such an environment. This study is a part of the larger One Million Workers Study, which includes a population of US radiation workers with lifetime dosimetry, including medical and nonmedical, such as nuclear power plant workers and

atomic veterans.<sup>32</sup> It may take some time before the data of this study are available. In the meantime, every effort should be made to raise the radiation awareness in the professional communities of interventional cardiologists and cardiac electrophysiologists, promoting justification of the examination, optimization of the dose, and maximal protection of the radiation workers.<sup>33–35</sup> This is in the best interest of patients and workers, so that risks intrinsic with the use of these life-saving techniques can be minimized and unnecessary disabilities and lost manpower can be prevented.<sup>36</sup> The results of the present study confirm and emphasize this message and will hopefully contribute to spread the culture of safety in the cardiac catheterization laboratory.

## Appendix

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## Acknowledgments

First and foremost, special thanks go to the cardiologists and nurses and all participating subjects who participated in the Healthy Cath Laboratory study. We also thank the following colleagues for their help and support to developing and fielding the survey: Loredana Fortunato, Gabriele Trivellini, and Sabrina Molinaro.

## Disclosures

None.

## References

- Dehmer GJ. Occupational hazards for interventional cardiologists. *Catheter Cardiovasc Interv.* 2006;68:974–976. doi: 10.1002/ccd.21004.
- Klein LW, Miller DL, Balter S, Laskey W, Haines D, Norbash A, Mauro MA, Goldstein JA; Joint Inter-Society Task Force on Occupational Hazards in the Interventional Laboratory. Occupational health hazards in the interventional laboratory: time for a safer environment. *J Vasc Interv Radiol.* 2009;20(7 suppl):S278–S283. doi: 10.1016/j.jvir.2009.04.027.
- Goldstein JA, Balter S, Cowley M, Hodgson J, Klein LW; Interventional Committee of the Society of Cardiovascular Interventions. Occupational hazards of interventional cardiologists: prevalence of orthopedic health problems in contemporary practice. *Catheter Cardiovasc Interv.* 2004;63:407–411. doi: 10.1002/ccd.20201.
- Orme NM, Rihal CS, Gulati R, Holmes DR Jr, Lennon RJ, Lewis BR, McPhail IR, Thielen KR, Pislaru SV, Sandhu GS, Singh M. Occupational health hazards of working in the interventional laboratory: a multisite case control study of physicians and allied staff. *J Am Coll Cardiol.* 2015;65:820–826. doi: 10.1016/j.jacc.2014.11.056.
- Klein LW, Tra Y, Garratt KN, Powell W, Lopez-Cruz G, Chambers C, Goldstein JA; Society for Cardiovascular Angiography and Interventions. Occupational health hazards of interventional cardiologists in the current decade: Results of the 2014 SCAI membership survey. *Catheter Cardiovasc Interv.* 2015;86:913–924. doi: 10.1002/ccd.25927.
- Goldstein JA. Orthopedic afflictions in the interventional laboratory: tales from the working wounded. *J Am Coll Cardiol.* 2015;65:827–829. doi: 10.1016/j.jacc.2014.12.020.
- Detling N, Smith A, Nishimura R, Keller S, Martinez M, Young W, Holmes D. Psychophysiologic responses of invasive cardiologists in an academic catheterization laboratory. *Am Heart J.* 2006;151:522–528. doi: 10.1016/j.ahj.2005.03.044.
- Picano E, Vano E. Radiation exposure as an occupational hazard. *EuroIntervention.* 2012;8:649–653. doi: 10.4244/EIJV8I6A101.
- Vaño E, Gonzalez L, Fernandez JM, Alfonso F, Macaya C. Occupational radiation doses in interventional cardiology: a 15-year follow-up. *Br J Radiol.* 2006;79:383–388. doi: 10.1259/bjr/26829723.
- Venneri L, Rossi F, Botto N, Andreassi MG, Salcone N, Emad A, Lazzeri M, Gori C, Vano E, Picano E. Cancer risk from professional exposure in staff working in cardiac catheterization laboratory: insights from the National Research Council's Biological Effects of Ionizing Radiation VII Report. *Am Heart J.* 2009;157:118–124. doi: 10.1016/j.ahj.2008.08.009.
- Andreassi MG, Piccaluga E, Gargani L, Sabatino L, Borghini A, Fata F, Bruno RM, Padovani R, Guagliumi G, Picano E. Subclinical carotid atherosclerosis and early vascular aging from long-term low-dose ionizing radiation exposure: a genetic, telomere, and vascular ultrasound study in cardiac catheterization laboratory staff. *JACC Cardiovasc Interv.* 2015;8:616–627. doi: 10.1016/j.jcin.2014.12.233.
- Tonacci A, Baldus G, Corda D, Piccaluga E, Andreassi M, Cremonesi A, Guagliumi G, Picano E. Olfactory non-cancer effects of exposure to ionizing radiation in staff working in the cardiac catheterization laboratory. *Int J Cardiol.* 2014;171:461–463. doi: 10.1016/j.ijcard.2013.12.223.
- Picano E, Vano E, Domenici L, Bottai M, Thierry-Chef I. Cancer and non-cancer brain and eye effects of chronic low-dose ionizing radiation exposure. *BMC Cancer.* 2012;12:157. doi: 10.1186/1471-2407-12-157.
- Marazziti D, Tomaiuolo F, Dell'Osso L, Demi V, Campana S, Piccaluga E, Guagliumi G, Conversano C, Baroni S, Andreassi MG, Picano E. Neuropsychological testing in interventional cardiology staff after long-term exposure to ionizing radiation. *J Int Neuropsychol Soc.* 2015;21:670–676.
- Vano E, Kleiman NJ, Duran A, Rehani MM, Echeverri D, Cabrera M. Radiation cataract risk in interventional cardiology personnel. *Radiat Res.* 2010;174:490–495. doi: 10.1667/RR2207.1.
- Filkelstein MM. Is brain cancer an occupational disease of cardiologists? *Can J Cardiol.* 1998;14:1385–1328.
- Roguin A, Goldstein J, Bar O. Brain tumours among interventional cardiologists: a cause for alarm? Report of four new cases from two cities and a review of the literature. *EuroIntervention.* 2012;7:1081–1086. doi: 10.4244/EIJV7I9A172.
- Andreassi MG, Cioppa A, Botto N, Joksic G, Manfredi S, Federici C, Ostojic M, Rubino P, Picano E. Somatic DNA damage in interventional cardiologists: a case-control study. *FASEB J.* 2005;19:998–999. doi: 10.1096/fj.04-3287fje.
- Leuraud K, Richardson DB, Cardis E, Daniels RD, Gillies M, O'Hagan JA, Hamra GB, Haylock R, Laurier D, Moissonnier M, Schubauer-Berigan MK, Thierry-Chef I, Kesminiene A. Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study. *Lancet Haematol.* 2015;2:e276–e281. doi: 10.1016/S2352-3026(15)00094-0.
- Liu JJ, Freedman DM, Little MP, Doody MM, Alexander BH, Kitahara CM, Lee T, Rajaraman P, Miller JS, Kampa DM, Simon SL, Preston DL, Linet MS. Work history and mortality risks in 90,268 US radiological technologists. *Occup Environ Med.* 2014;71:819–835. doi: 10.1136/oemed-2013-101859.
- Little MP, Azizova TV, Bazyka D, Bouffler SD, Cardis E, Chekin S, Chumak VV, Cucinotta FA, de Vathaire F, Hall P, Harrison JD, Hildebrandt G, Ivanov V, Kashcheev VV, Klymenko SV, Kreuzer M, Laurent O, Ozasa K, Schneider T, Tapio S, Taylor AM, Tzoulaki I, Vandoolaeghe WL, Wakeford R, Zablotska LB, Zhang W, Lipshultz SE. Systematic review and meta-analysis of circulatory disease from exposure to low-level ionizing radiation and estimates of potential population mortality risks. *Environ Health Perspect.* 2012;120:1503–1511. doi: 10.1289/ehp.1204982.
- Borghini A, Gianicolo EA, Picano E, Andreassi MG. Ionizing radiation and atherosclerosis: current knowledge and future challenges. *Atherosclerosis.* 2013;230:40–47. doi: 10.1016/j.atherosclerosis.2013.06.010.
- Sasaki H, Wong FL, Yamada M, Kodama K. The effects of aging and radiation exposure on blood pressure levels of atomic bomb survivors. *J Clin Epidemiol.* 2002;55:974–981.

24. Wong FL, Yamada M, Sasaki H, Kodama K, Hosoda Y. Effects of radiation on the longitudinal trends of total serum cholesterol levels in the atomic bomb survivors. *Radiat Res.* 1999;151:736–746.
25. Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. *Radiat Res.* 2000;154:178–186.
26. Yentrapalli R, Azimzadeh O, Barjaktarovic Z, Sarioglu H, Wojcik A, Harms-Ringdahl M, Atkinson MJ, Haghdoost S, Tapio S. Quantitative proteomic analysis reveals induction of premature senescence in human umbilical vein endothelial cells exposed to chronic low-dose rate gamma radiation. *Proteomics.* 2013;13:1096–1107. doi: 10.1002/pmic.201200463.
27. Laiakis EC, Strassburg K, Bogumil R, Lai S, Vreeken RJ, Hankemeier T, Langridge J, Plumb RS, Fornace AJ Jr, Astarita G. Metabolic phenotyping reveals a lipid mediator response to ionizing radiation. *J Proteome Res.* 2014;13:4143–4154. doi: 10.1021/pr5005295.
28. Klein LW. Cautionary measures. In: *Cover Study. The Cost of Living. Occupational Hazards for Cath Lab Operators Pose Health Risks in the Long-Term. Cardiology Today's Intervention.* May–June 2012.
29. Rasmussen-Torvik LJ, Shay CM, Abramson JG, Friedrich CA, Nettleton JA, Prizment AE, Folsom AR. Ideal cardiovascular health is inversely associated with incident cancer: the Atherosclerosis Risk In Communities study. *Circulation.* 2013;127:1270–1275. doi: 10.1161/CIRCULATIONAHA.112.001183.
30. Vañó E, González L, Guibelalde E, Fernández JM, Ten JJ. Radiation exposure to medical staff in interventional and cardiac radiology. *Br J Radiol.* 1998;71:954–960. doi: 10.1259/bjr.71.849.10195011.
31. Reeves RR, Ang L, Bahadorani J, Naghi J, Dominguez A, Palakodeti V, Tsimikas S, Patel MP, Mahmud E. Invasive cardiologists are exposed to greater left sided cranial radiation: The BRAIN study (Brain Radiation Exposure and Attenuation During Invasive Cardiology Procedures). *JACC Cardiovasc Interv.* 2015;8:1197–1206. doi: 10.1016/j.jcin.2015.03.027.
32. Bouville A, Toohey RE, Boice JD Jr, Beck HL, Dauer LT, Eckerman KF, Hagemeyer D, Leggett RW, Mumma MT, Napier B, Pryor KH, Rosenstein M, Schauer DA, Sherbini S, Stram DO, Thompson JL, Till JE, Yoder C, Zeitlin C. Dose reconstruction for the million worker study: status and guidelines. *Health Phys.* 2015;108:206–220. doi: 10.1097/HP.0000000000000231.
33. Picano E, Vañó E, Rehani MM, Cuocolo A, Mont L, Bodi V, Bar O, Maccia C, Pierard L, Sicari R, Plein S, Mahrholdt H, Lancellotti P, Knuuti J, Heidebuchel H, Di Mario C, Badano LP. The appropriate and justified use of medical radiation in cardiovascular imaging: a position document of the ESC Associations of Cardiovascular Imaging, Percutaneous Cardiovascular Interventions and Electrophysiology. *Eur Heart J.* 2014;35:665–672. doi: 10.1093/eurheartj/eh394.
34. Fazel R, Gerber TC, Balter S, Brenner DJ, Carr JJ, Cerqueira MD, Chen J, Einstein AJ, Krumholz HM, Mahesh M, McCollough CH, Min JK, Morin RL, Nallamothu BK, Nasir K, Redberg RF, Shaw LJ; American Heart Association Council on Quality of Care and Outcomes Research, Council on Clinical Cardiology, and Council on Cardiovascular Radiology and Intervention. Approaches to enhancing radiation safety in cardiovascular imaging: a scientific statement from the American Heart Association. *Circulation.* 2014;130:1730–1748. doi: 10.1161/CIR.0000000000000048.
35. Heidebuchel H, Wittkamp FH, Vano E, Ernst S, Schilling R, Picano E, Mont L, Jais P, de Bono J, Piorowski C, Saad E, Femenia F; Reviewers: European Heart Rhythm Association. Practical ways to reduce radiation dose for patients and staff during device implantations and electrophysiological procedures. *Europace.* 2014;16:946–964. doi: 10.1093/europace/eut409.
36. Chambers CE. Occupational health risks in interventional cardiology: expected inherent risk or preventable personal liability? *JACC Cardiovasc Interv.* 2015;8:628–630. doi: 10.1016/j.jcin.2015.01.015.



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Gaita and Eugenio Picano

*Circ Cardiovasc Interv.* 2016;9:

doi: 10.1161/CIRCINTERVENTIONS.115.003273

*Circulation: Cardiovascular Interventions* is published by the American Heart Association, 7272 Greenville  
Avenue, Dallas, TX 75231

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Print ISSN: 1941-7640. Online ISSN: 1941-7632

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