






# EACVI survey on radiation exposure in interventional echocardiography

E. Galli <sup>1\*</sup>, H. Soliman-Aboumarie <sup>2,3</sup>, L. Gargani<sup>4</sup>, P. Szymański<sup>5,6</sup>, A. Gimelli<sup>7</sup>, S.E. Petersen<sup>8</sup>, L.E. Sade<sup>9</sup>, I. Stankovic<sup>10</sup>, E. Donal <sup>1</sup>, B. Cosyns<sup>11</sup>, E. Agricola <sup>12</sup>, M.R. Dweck<sup>13</sup>, N. Ajmone Marsan<sup>14</sup>, V. Delgado<sup>15</sup>, and D. Muraru <sup>16,17</sup>

<sup>1</sup>University of Rennes, CHU Rennes, Inserm, LTSI—UMR 1099, F-35000 Rennes, France; <sup>2</sup>Department of Anesthetics and Critical Care, Harefield Hospital, Royal Brompton and Harefield Hospitals, Guy's and St. Thomas NHS Foundation Trust, London, UK; <sup>3</sup>School of Cardiovascular Sciences and Medicine, King's College, London, UK; <sup>4</sup>Department of Surgical, Medical and Molecular Pathology and Critical Care Medicine, University of Pisa—Pisa, Italy; <sup>5</sup>Centre for Postgraduate Medical Education, Warsaw, Poland; <sup>6</sup>Centre for Clinical Cardiology, National Institute of Medicine MSWiA, Warsaw, Poland; <sup>7</sup>Department of Imaging, Fondazione Toscana Gabriele Monasterio, Via Moruzzi 1, 56124 Pisa, Italy; <sup>8</sup>William Harvey Research Institute, Queen Mary University London, London, UK; <sup>9</sup>University of Pittsburgh Medical Center, Heart and Vascular Institute, Pittsburgh, PA, USA; <sup>10</sup>Faculty of Medicine, Clinical Hospital Centre Zemun, University of Belgrade, Belgrade, Serbia; <sup>11</sup>Cardiology Department, Centrum voor Hart en Vaatziekten (CHVZ), Universitair ziekenhuis Brussel, Brussels, Belgium; <sup>12</sup>Cardiovascular Imaging Unit, IRCCS San Raffaele Scientific Institute, Milan, Italy; <sup>13</sup>BHF Centre for Cardiovascular Science, University of Edinburgh, Chancellors Building, Little France Crescent, Edinburgh EH16 4SB, UK; <sup>14</sup>Department of Cardiology, Leiden University Medical Center, Albinusdreef 2, 2300 RC Leiden, The Netherlands; <sup>15</sup>Department of Cardiovascular Imaging, Hospital Universitari Germans Trias i Pujol, Badalona, Barcelona, Spain; <sup>16</sup>Department of Medicine and Surgery, University of Milano-Bicocca, Milan, Italy; and <sup>17</sup>Department of Cardiology, Istituto Auxologico Italiano, IRCCS, San Luca Hospital, Milan, Italy

Received 14 March 2024; accepted 15 March 2024; online publish-ahead-of-print 18 April 2024

## Aims

The European Association of Cardiovascular Imaging (EACVI) Scientific Initiatives Committee performed a global survey on radiation exposure in interventional echocardiography. The survey aimed to collect data on local practices for radioprotection in interventional echocardiography and to assess the awareness of echocardiography operators about radiation-related risks.

## Methods and results

A total of 258 interventional echocardiographers from 52 different countries (48% European) responded to the survey. One hundred twenty-two (47%) participants were women. Two-thirds (76%) of interventional echocardiographers worked in tertiary care/university hospitals. Interventional echocardiography was the main clinical activity for 34% of the survey participants. The median time spent in the cath-lab for the echocardiographic monitoring of structural heart procedures was 10 (5–20) hours/month. Despite this, only 28% of interventional echocardiographers received periodic training and certification in radioprotection and 72% of them did not know their annual radiation dose. The main adopted personal protection devices were lead aprons and thyroid collars (95% and 92% of use, respectively). Dedicated architectural protective shielding was not available for 33% of interventional echocardiographers. Nearly two-thirds of responders thought that the radiation exposure of interventional echocardiographers was higher than that of interventional cardiologists and 72% claimed for an improvement in the radioprotection measures.

## Conclusion

Radioprotection measures for interventional echocardiographers are widely variable across centres. Radioprotection devices are often underused by interventional echocardiographers, portending an increased radiation-related risk. International scientific societies working in the field should collaborate to endorse radioprotection training, promote reliable radiation dose assessment, and support the adoption of radioprotection shielding dedicated to interventional echocardiographers.

## Keywords

EACVI • survey • architectural shielding • interventional echocardiography • personal protection device • radiation exposure

## Introduction

Over the last decade, the expanding number of complex structural heart procedures requiring advanced, real-time echocardiographic

guidance has led to the development of interventional echocardiography as a specific subspecialty in the field of cardiac imaging.<sup>1</sup>

Interventional echocardiography is associated with important occupational exposure to X-rays. Among the three imaging techniques

\* Corresponding author. E-mail: gallelena@gmail.com

© The Author(s) 2024. Published by Oxford University Press on behalf of the European Society of Cardiology.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

that involve radiation (X-ray fluoroscopy, X-ray CT, nuclear scintigraphy), X-ray fluoroscopy has the potential to deliver the largest dose of radiation to patients, operators, and nearby medical staff, depending on equipment quality and calibration, as well as the approach taken by interventional cardiologists. Compared to interventional radiologists and interventional cardiologists, interventional echocardiographers might be exposed to even higher doses of radiation, as they are often in the closest proximity to the patient and the X-ray source.<sup>2–7</sup> The radiation dose received by interventional echocardiographers is generally highest to the exposed hand and lower body,<sup>2</sup> as confirmed by computer simulations visualizing radiation exposure.<sup>4</sup> This higher exposure is due to several factors which include the proximity of interventional echocardiographers to the radiation source and to the patient (who is by itself an important source of scattered radiation), the heterogeneity of the adopted radioprotection devices, the frequent lack of dedicated shielding, and the insufficient awareness of the radiation-related risk.<sup>8</sup>

Chronic occupational X-ray exposure has been associated with an increased risk of developing cataracts,<sup>9</sup> leukemias, cancers,<sup>10</sup> and also other diseases including early vascular and neurocognitive aging.<sup>11</sup>

Despite the universal recognition of the as low as reasonably achievable (ALARA) principle for radiation exposure and the basic safety standards laid down by the European Council Directive 2013/59/Euratom in 2018,<sup>12</sup> the radiation risk of interventional echocardiographers often remains underappreciated.

Only a report by the American Society of Echocardiography published in 2014 provides generic indications to reduce radiation exposure in sonographers by remembering the four cardinal principles of radioprotection as decreasing the exposure time, increasing the distance from the radiation source, improving education in radioprotection and underscoring the importance of shielding. The same document also highlighted the importance of regular radiation safety training and pointed out the necessity of recognizing echocardiographers as a group of healthcare workers potentially exposed to medical radiation.<sup>8</sup>

The aims of the present Survey endorsed by the European Association of Cardiovascular Imaging (EACVI) Scientific Initiatives Committee were: (1) to collect data in Europe and worldwide on the radioprotection of interventional echocardiographers; (2) to evaluate the availability of dedicated personal protective devices and architectural shielding; (3) to assess the awareness of radiation-related risks; (4) to explore the impact of radiation exposure on pregnancy planning; and (5) to evaluate the perceived impact of motherhood on the career progression of interventional echocardiographers.

## Methods

The Survey was conducted by the EACVI Scientific Initiatives Committee from 10 October to 12 December 2024 and followed the established criteria for surveys of the international EACVI survey network.<sup>13</sup>

The survey was released on an online platform and consisted of 24 questions including single, multiple choice, and open questions addressed to all cardiac imagers performing interventional echocardiography to guide structural heart interventions across Europe and beyond. The invitation to participate in the Survey was disseminated via the EACVI newsletter and social media.

## Results

A total of 258 interventional echocardiographers from 52 countries participated in the survey. Two hundred eighteen participants (85%) were from Europe [Armenia (1), Austria (1), Belgium (4), Bulgaria (1), Croatia (3), Cyprus (1), Czechia (1), France (40), Germany (22), Greece (5), Ireland (1), Italy (24), Lithuania (1), Luxembourg (2), Monaco (1), Netherlands (5), Romania (2), Slovenia (3), Serbia (2), Spain (44), Sweden (2), Poland (28), Portugal (6), Switzerland (6), Ukraine (2), United Kingdom (4)], whereas 40 (15%) were from

non-European countries [Bangladesh (2), Brazil (2), India (4), Canada (1), Egypt (1), Indonesia (2), Japan (4), Libya (1), Mexico (2), Morocco (1), Myanmar (1), Pakistan (2), Saudi Arabia (2), Singapore (1), Sudan (1), United States of America (2), and Uruguay (1)] (Figure 1A).

Gender distribution was quite evenly split, with only a slightly higher prevalence of men (53% vs. 47%, Figure 1B). The majority (72%) of interventional echocardiographers were 30 to 50 years old (Figure 1C). The survey's participants came mainly from Tertiary Care/University Hospitals (76%), followed by secondary care (12%), private (9%) and primary care (3%) hospitals (Figure 1D).

## Interventional echocardiography activity

Interventional echocardiography was the main clinical activity for 34% of the participants, with 12% guiding structural heart procedures several times per week and 34% at least once per week (Figure 2A). The median time spent in the cath-lab each month was 10 (5–20) hours. The most frequently reported kind of procedures monitored by the participants were percutaneous closure of foramen ovale and atrial septal defects (ASDs) (73%), followed by left atrial appendage closure (LAA) (66%), and percutaneous mitral (66%) and tricuspid (43%) valve repair (Figure 2B).

## Monitoring of radiation doses, radiological protection training, and awareness of the occupational radiation risk

To monitor radiation exposure, the survey's responders relied essentially on passive chest dosimeters, which were adopted by 59% of interventional echocardiographers. Only 13% of the participants reported regular use of active (real-time or operational) dosimeters. Similarly, passive finger, lens eye and ankle dosimeters were worn only by 18%, 8%, and 7% of interventional echocardiographers, respectively. Importantly, 31% of the survey's participants did not wear dosimeters during interventional procedures (Figure 3A).

Only 20% of interventional echocardiographers knew the maximal radiation doses authorized by the EURATOM<sup>14</sup> and only 28% were aware of their estimated annual radiation exposure (Figure 3B and C).

Regular and structured radiological protection training was followed by only 28% of interventional echocardiographers. Twenty-eight percent of responders received some sort of non-structured education in radioprotection, whilst 43% did not have any training in radioprotection (Figure 3D).

Interestingly, the majority of interventional echocardiographers (65%) thought that the radiation exposure of the echocardiography operators was higher than that of interventional cardiologists, with a further 17% of that the exposure was similar to that of interventional cardiologists. Only 15% of participants considered the exposure of interventional echocardiographers lower than that of interventional cardiologists, whilst 3% had no specific opinion on this topic.

## Radioprotection devices availability

Concerning the use of wearable radioprotection devices, lead aprons and thyroid collars were used by nearly all interventional echocardiographers who answered the survey (95% and 92%, respectively).

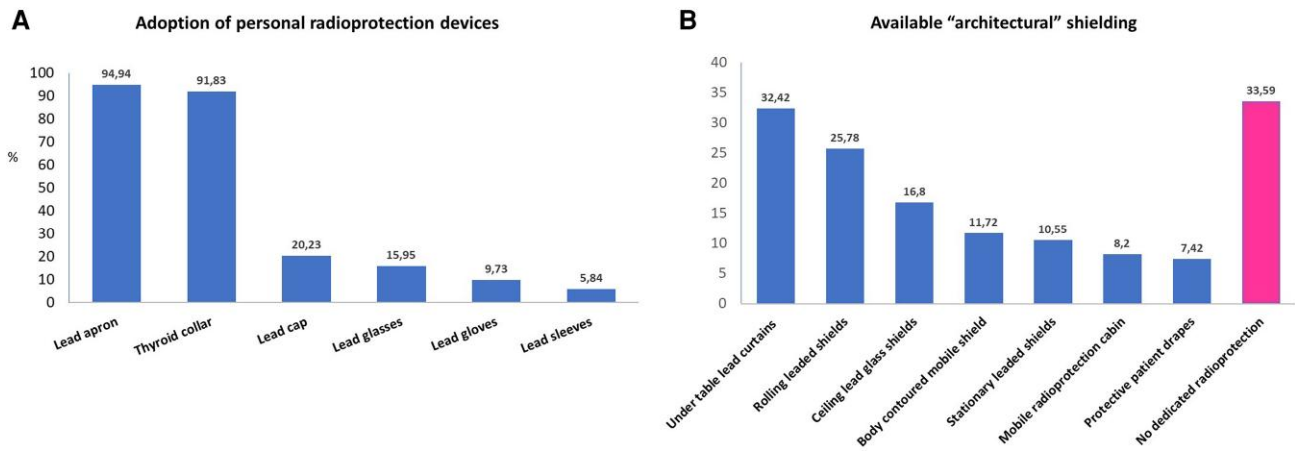
Lead caps, gloves, glasses, and sleeves were routinely used only in 20%, 16%, 10%, and 6% of cases, respectively (Figure 4A).

The availability of architectural or mounted shielding specifically applied for the radioprotection of the interventional echocardiographers was variable. Under-table curtains and rolling lead shields were available for 32% and 26% of the interventional echocardiographers, whereas body-contoured mobile radioprotective shields were available only in 12% of cases. Interestingly, 34% of the interventional echocardiographers did not have dedicated protective shielding during the guidance of structural heart procedure (Figure 4B).



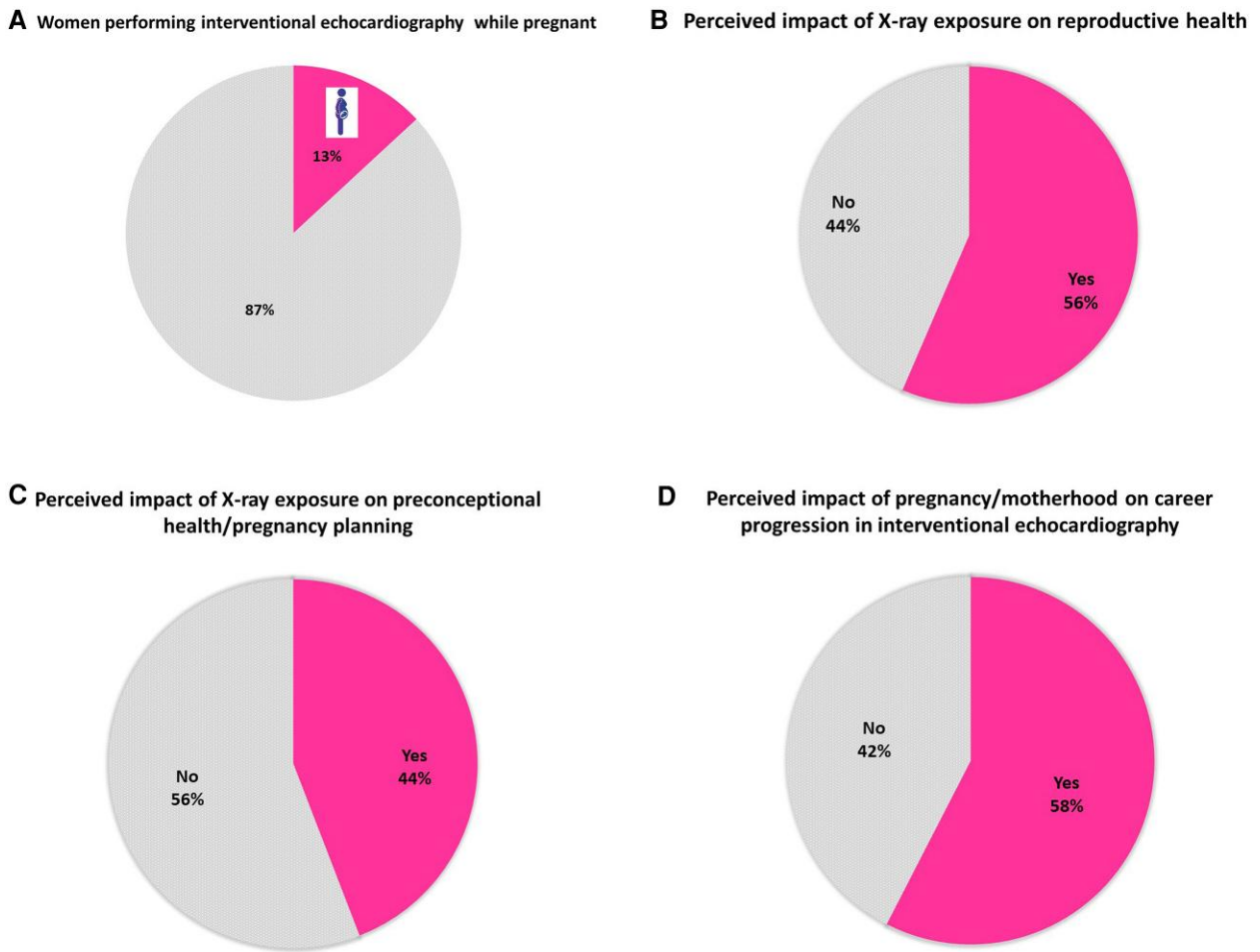






**Figure 4** Personal (A) and architectural (B) radioprotection devices regularly adopted by the survey responders.

Downloaded from https://academic.oup.com/ehj/advance-article/doi/10.1093/ehj/ehj/25/6/727/7651011 by guest on 08 November 2024



**Figure 5** Impact of radiation exposure of reproductive health and pregnancy planning. Percentage of women participating in the survey and performing interventional echocardiography during pregnancy (A), perceived impact of radiation exposure on reproductive health (men and women involved) (B), perceived impact of an activity as interventional echocardiographer on preconceptional health/pregnancy planning (C), and perceived impact of pregnancy/motherhood on career progression in interventional echocardiography (D).

## Personal or architectural protection device use and availability

Personal protection by shielding devices is the pillar to limit X-ray exposure during procedures in the cath-lab according to the ALARA principle.

Our survey revealed that lead aprons and thyroid collars were largely used by interventional echocardiographers. However, the head, hands, arms, and legs, which are highly exposed to X-ray during interventional echocardiography, cannot be adequately protected by the apron. Despite specific personal protection devices such as lead glasses, caps, sleeves, and gloves being effective in reducing irradiation, they were only worn by 6–20% of interventional echocardiographers participating in this survey.

Moreover, because of the position of interventional echocardiographers during structural heart procedures, dedicated architectural shielding is often necessary to significantly reduce the irradiation of echo operators.

Previous studies have shown that ceiling-suspended lead shields<sup>5,6</sup> and lead curtains<sup>6</sup> positioned on the side of the interventional echocardiographers can significantly reduce irradiation. The use of mobile lead cabins can further reduce interventional echocardiographers' exposure, providing full-body protection for the interventional echocardiographer from X-ray exposure.<sup>19</sup>

However, many cath labs and hybrid rooms are still designed and organized to suit the needs of interventional cardiologists rather than other members of the structural heart team. Indeed in our survey, up to one-third of interventional echocardiographers declared not to have any dedicated protective architectural shielding. Consequently, 72% of survey responders felt that the available radioprotection devices were often insufficient and that there was a need for improvement in radioprotection measures for interventional echocardiographers.

## Pregnancy and reproductive concerns related to interventional echocardiographers' activity

The real-life radiation exposure of interventional echocardiographers can vary according to the procedure and the organization of the operator theatre. However, the radiation scattering of the bottom edge of the patient bed is associated with a higher exposure of the pelvic area compared to the thorax, as shown by either direct measurements or computer simulations.<sup>4,20</sup>

In our survey, nearly half of the participants were worried about the potential impact of radiation exposure on their reproductive health.

This might be particularly important for women performing interventional echocardiography in their childbearing age, because of the significant irradiation of the ovaries during the procedures.

Despite these concerns, the present survey did not show significant gender differences in access to interventional echocardiography, with a similar percentage of men and women performing this activity.

However, nearly one-third of women felt that the practice of interventional echocardiography affected their preconception health and their pregnancy planning and more than half perceived that their pregnancy/motherhood negatively impacted their career as interventional echocardiographer.

These aspects might, therefore, contribute to the development of a 'career gap' in the field of interventional echocardiography, as already observed for women in the field of interventional cardiology.<sup>21</sup>

Moreover, in the case of pregnancy, the practice of interventional echocardiography might be problematic because of the risk of foetal irradiation.

In our survey, only 13% of women continued their activities as interventional echocardiographers during pregnancy. In case of pregnancy,

specific precautions to limit irradiation were taken by the hosting institution in 11% of cases. According to the open answers we received, stopping all the activities associated with X-ray exposure was the main measure taken, followed by wearing a double lead apron, weekly dose checks and reducing fluoroscopy exposure.

Several recent consensus documents in the field of interventional cardiology,<sup>22</sup> interventional radiology,<sup>23</sup> and electrophysiology,<sup>24</sup> as well as recommendations from EURATOM<sup>14</sup> and the International Commission on Radiological Protection<sup>17</sup> underscore that an overall foetal radiation dose <1 mSv during pregnancy is acceptable, with a risk of malformation or cancer of 4.07%, similar to that of the general population.<sup>24</sup> Nevertheless, until now, no specific data are available concerning the radiation exposure of pregnant women performing interventional echocardiography. As a consequence, women working as interventional echocardiographers in their childbearing age should be aware that their radiation exposure is probably higher than those of interventional cardiologists, and that radiation protection measures are less well-established for their working category, compared to interventional cardiologists.

Because of the great sensitivity of this issue, it seems reasonable that the decision on whether to continue activity as an interventional echocardiographer during pregnancy is left to the pregnant medical doctor, as recommended by the ICRP.<sup>17</sup>

According to European directives, when pregnant workers are exposed to radiation, employers also have a responsibility to assess the related risks and apply all the necessary protective measures,<sup>14</sup> whilst avoiding professional discrimination in women in the childbearing age.<sup>18</sup>

As the figure of interventional echocardiographer is becoming more common and established for clinical practice, cardiologists aiming to select echocardiography as their main subspecialty should be educated about radiation hazards involved with intraprocedural guidance so that they make an informed decision about whether this is an aspect of their career they wish to pursue.

## Limitations

The survey reflects the answers of a limited number of voluntary participants and may suffer from sampling bias. Also, the interventional echocardiographers' activities were highly heterogeneous in terms of duration and complexity, which might also affect the interpretation of our results. The different perceptions or interpretations of the questions by the responders can also influence the results of the present survey.

## Conclusions

Our data demonstrate wide variability and often underuse of radioprotection devices, highlighting the need for dedicated larger studies and specific actions, guided by both Scientific Societies and International Radioprotection Committees. Structured and regular training appears fundamental to educate interventional echocardiographers about radiation hazards, to instill best practices according to the ALARA principles and to ensure their commitment to maximizing protection. The assessment of the radiation dose should be extensively performed by either passive or active dosimeters. Data of previous studies also suggest that ankle, hand, and eye lens dosimeters might be fundamental to a because of the higher exposure of the extremities and the eyes.

Interventional and hybrid rooms should be specifically designed to offer dedicated protection to interventional echocardiographers by the application of appropriate shielding. Preventive measures should be applied to avoid discrimination and gender gap for interventional echocardiographers. Interdisciplinary education and collaborative efforts within the medical community should enhance awareness and ensure the safety of interventional echocardiographers.

## Acknowledgements

The production of this EACVI survey document is under the responsibility of the Scientific Initiative Committee of the EACVI: Marc R. Dweck (Chair), Tomaz Podlesnikar (Deputy Chair), Ahmet Demirkiran, Emmanuel Androulakis, Gerald Maurer, Giulia Elena Mandoli, Hatem Soliman Aboumarie, Jadranka Separovic Hanzevacki, Jolien Geers, Jose Rodriguez Palomares, Maria Lembo, Robert Manka, Sanjeev Bhattacharyya, Shruti S Joshi, Simona Botezatu, Theo Pezel, Tor Biering-Sørensen. The authors acknowledge all the interventional echocardiographers participating in this survey.

## Funding

None.

**Conflict of interest:** Victoria Delgado received speaker fees from Edwards Lifesciences, GE Healthcare, JenaValve, Medtronic, Novartis and Philips and consulting fees from Edwards Lifesciences, MSD and Novo-Nordisk. Elena Galli received speakers' fees from BMS. Luna Gargani received consulting fees from Caption Health and Sanofi and writing fees from Piccin. Nina Ajmone Marsan received speaker's fees from GE Healthcare, Philips Ultrasound, Abbott Vascular, Omron, Pfizer. Denisa Muraru received speakers' fees from GE Healthcare, Philips, Bristol-Myers Squibb. Steffen Petersen received consulting fees from Circle Cardiovascular Imaging, Inc., Calgary, Canada. Piotr Szymanski received speakers' fees from Novartis and Samsung.

## Data availability

The data underlying this article are provided by the European Association of Cardiovascular Imaging (EACVI) by permission. Data will be shared on request to the corresponding author with permission of the EACVI.

## References

- Lee J, Chen T, Gill E. Interventional echocardiography: opportunities and challenges in an emerging field. *Echocardiography* 2022;**39**:975–84.
- Salaun E, Carles S, Bigand E, Pankert M, Aldebert P, Jaussaud N et al. High radiation exposure of the imaging specialist during structural heart interventions with echocardiographic guidance. *JACC Cardiovasc Interv* 2017;**10**:626–7.
- Olgun Kucuk H, Fetterly KA, Betz JL, Pislaru SV, Rihal CS, Pellikka PA et al. Interventional echocardiographer radiation exposure varies with procedure type and echocardiography modality. *J Am Soc Echocardiogr* 2024;**37**:110–2.
- Kataoka A, Takata T, Yanagawa A, Kito K, Arakawa M, Ishibashi R et al. Body surface radiation exposure in interventional echocardiographers during structural heart disease procedures. *JACC Asia* 2023;**3**:301–9.
- Crowhurst JA, Scalia GM, Whitby M, Murdoch D, Robinson BJ, Turner A et al. Radiation exposure of operators performing transesophageal echocardiography during percutaneous structural cardiac interventions. *J Am Coll Cardiol* 2018;**71**:1246–54.
- Corrigan FE III, Hall MJ, Iturbe JM, Condado JF, Kamioka N, Howell S et al. Radioprotective strategies for interventional echocardiographers during structural heart interventions. *Catheter Cardiovasc Interv* 2019;**93**:356–61.
- McNamara DA, Chopra R, Decker JM, McNamara MW, VanOosterhout SM, Berkompas DC et al. Comparison of radiation exposure among interventional echocardiographers, interventional cardiologists, and sonographers during percutaneous structural heart interventions. *JAMA Netw Open* 2022;**5**:e2220597.
- Mclwain EF, Coon PD, Einstein AJ, Mitchell CKC, Natello GW, Palma RA et al. Radiation safety for the cardiac sonographer: recommendations of the radiation safety writing group for the council on cardiovascular sonography of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2014;**27**:811–6.
- Schueler BA, Fetterly KA. Eye protection in interventional procedures. *Br J Radiol* 2021;**94**:20210436.
- Venneri L, Rossi F, Botto N, Andreassi MG, Salcone N, Emad A et al. 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**:118–24.
- Andreassi MG, Piccaluga E, Del Greco M, Gaita F, Picano E. Occupational health risks in cardiac catheterization laboratory workers. *Circ Cardiovasc Interv* 2016;**9**:e003273.
- Torresin A, Evans S, Lizio D, Pierotti L, Stasi M, Salerno S. Practical recommendations for the application of DE 59/2013. *Radiol Med* 2019;**124**:721–7.
- Haugaa KH, Marsan NA, Cameli M, D'Andrea A, Dweck MR, Carvalho R et al. Criteria for surveys: from the European Association of Cardiovascular Imaging Scientific Initiatives Committee. *Eur Heart J—Cardiovasc Imaging* 2019;**20**:963–6.
- European council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. *Official Journal of the European Communities*.L13 2014;**57**:1–73.
- López PO, Dauer LT, Loose R, Martin CJ, Miller DL, Vañó E et al. ICRP publication 139: occupational radiological protection in interventional procedures. *Ann ICRP* 2018;**47**:1–118.
- O'Connor U, Carinou E, Clairand I, Ciraj-Bjelac O, De Monte F, Domienik-Andrzejewska J et al. Recommendations for the use of active personal dosimeters (APDs) in interventional workplaces in hospitals. *Phys Med* 2021;**87**:131–5.
- Cousins C, Miller DL, Bernardi G, Rehani MM, Schofield P, Vañó E et al. ICRP publication 120: radiological protection in cardiology. *Ann ICRP* 2013;**42**:1–125.
- European Parliament and European Council. Directive 2002/73/EC of the European Parliament and of the Council of 23 September 2002 amending Council Directive 76/207/EEC on the implementation of the principle of equal treatment for men and women as regards access to employment, vocational training and promotion, and working conditions (Text with EEA relevance). *Official Journal of the European Communities* 2002;**45**:15–20.
- Ploux S, Jesel L, Eschalié R, Amraoui S, Ritter P, Haïssaguerre M et al. Performance of a radiation protection cabin during extraction of cardiac devices. *Can J Cardiol* 2014;**30**:1602–6.
- Kumar D, Salian SR, Kalthur G, Uppangala S, Kumari S, Challapalli S et al. Semen abnormalities, sperm DNA damage and global hypermethylation in health workers occupationally exposed to ionizing radiation. *PLoS One* 2013;**8**:e69927.
- Buchanan GL, Paradies V, Karam N, Holmvang L, Mamas MA, Mehili J et al. Overcoming professional barriers encountered by women in interventional cardiology: an EAPCI statement. *Eur Heart J* 2023;**44**:1301–12.
- Best P, Skelding K, Mehran R, Chieffo A, Kunadian V, Madan M et al. SCAI consensus document on occupational radiation exposure to the pregnant cardiologist and technical personnel. *EuroIntervention* 2011;**6**:866–74.
- Dauer LT, Miller DL, Schueler B, Silberzweig J, Balter S, Bartal G et al. Occupational radiation protection of pregnant or potentially pregnant workers in IR: a joint guideline of the Society of Interventional Radiology and the Cardiovascular and Interventional Radiological Society of Europe. *J Vasc Interv Radiol* 2015;**26**:171–81.
- Sarkozy A, De Potter T, Heidbuchel H, Ernst S, Kosiuk J, Vano E et al. Occupational radiation exposure in the electrophysiology laboratory with a focus on personnel with reproductive potential and during pregnancy: a European Heart Rhythm Association (EHRA) consensus document endorsed by the Heart Rhythm Society (HRS). *EP Eur* 2017;**19**:1909–22.