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Radiation safety and vascular access: attitudes among cardiologists worldwide

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ABSTRACT

Objectives: To determine opinions and perceptions of interventional cardiologists on the topic of radiation and vascular access choice.
Background: Transradial approach for cardiac catheterization has been increasing in popularity worldwide. There is evidence that transradial access (TRA) may be associated with increasing radiation doses compared to transfemoral access (TFA).
Methods: We distributed a questionnaire to collect opinions of interventional cardiologists around the world.
Results: Interventional cardiologists (n = 5332) were contacted by email to complete an on-line survey from September to October 2013. The response rate was 20% (n = 1084). TRA was used in 54% of percutaneous coronary interventions (PCIs). Most TRAs (80%) were performed with right radial access (RRA). Interventionalists perceived that TRA was associated with higher radiation exposure compared to TFA and that RRA was associated with higher radiation exposure that left radial access (LRA). Older interventionalists were more likely to use radiation protection equipment and those who underwent radiation safety training gave more importance to ALARA (as low as reasonably achievable). Nearly half the respondents stated they would perform more TRA if the radiation exposure was similar to TFA. While interventionalists in the United States placed less importance to certain radiation protective equipment, European operators were more concerned with physician and patient radiation.
Conclusions: Interventionalists worldwide reported higher perceived radiation doses with TRA compared to TFA and RRA compared to LRA. Efforts should be directed toward encouraging consistent radiation safety training. Major investment and application of novel radiation protection tools and radiation dose reduction strategies should be pursued.
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1. Introduction

The balance between optimizing patient outcomes and reducing procedural complications remains a priority in interventional cardiology. Compared to transfemoral access (TFA) for coronary angiography and intervention, numerous studies have demonstrated reduction in vascular complications with transradial access (TRA), improvements in ambulation time, decreased cost and length of post-procedure hospital stay, and simplified same-day discharge [1–6]. Nonetheless, despite these advantages of TRA, a concern remains about the association between transradial catheterization and increased radiation exposure to both the operator and the patient [7–13]. Minimizing radiation exposure to both the patient and cardiac catheterization laboratory personnel represents a continued challenge associated with all invasive procedures. While the adoption of TRA approach varies, it has been slow in the United States [14], and large differences in TRA adoption and in clinical practice exist worldwide [4]. Perceived increased radiation exposure associated with TRA access has been proposed as a barrier to more widespread adoption in United States. Therefore, we sought to investigate the attitudes and practices of interventional cardiologists around the world in regards to radiation safety. We specifically sought to determine which factors might contribute to the differences in adoption of TRA access, such as current radiation safety practices, including differences in attitudes and procedural practices between TRA versus TFA.

2. Methods

Respondents were interventional cardiologists from various institutions throughout the world. Specifically, surveys were sent to interventional cardiologists on all major continents with a total of 81 countries. A total of 5432 interventional cardiologists and fellows were invited to participate in the survey via emails acquired through the American College of Cardiology (ACC) website, The Society for Cardiovascular Angiography and Interventions (SCAI), Sociedad Latinoamericana de Cardiología Intervencionista (SOLACI), European Society of Cardiology (ESC) and searching various email contact addresses in cardiology journals. A comprehensive 38-question survey (Appendix A) was designed and distributed in a bulk email which contained a cover letter using Qualtrics (www.qualtrics.com, Provo, UT), a professional survey

Abbreviations: TRA, transradial angiography; TFA, transfemoral angiography; RRA, right radial angiography; LRA, left radial angiography; ALARA, *A*s *L*ow *A*s *R*easonably *A*chievable.

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design and distribution website. An initial survey request was sent to all interventional cardiologists followed by a second request two weeks later to those who had not responded to the initial request. Another two weeks later, a final request to complete the survey was sent to those who had not completed or started the survey. Participants were informed that the survey was anonymous and voluntary. No incentive was offered for participation and no penalty for nonparticipation. The surveys were completed between September 8th and October 9th 2013. Approval for the study was obtained from the Institutional Review Board at the University of Illinois at Chicago.

ALARA (acronym for "as low as is reasonably achievable") was defined as making every reasonable effort to maintain exposures to radiation as far as practically possible.

2.1. Statistical analysis

Responses were automatically entered into a database and tabulated by Qualtrics as frequencies and used for descriptive statistics. Chi-square analyses and Fisher exact tests were used to perform group comparisons of categorical outcomes. T-tests were performed to compare continuous variables between groups. Linear regressions estimated with least square methods are performed to evaluate the relationships between various measures of the adoption of TRA and potential factors. All analyses were performed using SAS 9.2 (Cary, NC). A *P* value of less than 0.05 was considered significant for all tests.

3. Results

Of the 5332 interventional cardiologists invited to participate, 1084 (20%) filled out the survey forms. 34 respondents were excluded from the study because they were not currently practicing interventional cardiologists.

3.1. Demographics

Of the 1084 respondents, almost 50% were from North America (including 44% from the United States), 22% from Asia, 8% from South America, and 18% from Europe. Within the United States, 26% were from the Northeast, 25% from the Southeast, 24% from the Midwest, 9% from the Southwest, and 15% from the West Coast (Fig. 1). Respondents' age groups are shown in Fig. 2. Fig. 3 shows the hospital affiliation of the respondents who were evenly distributed between university-based hospitals (39%) and private practice (42%). A minority (19%) of the respondents had less than 5 years of interventional experience (Fig. 4), and most were male (94%).

3.2. Individual and institutional practices

The mean number of diagnostic angiograms performed by our respondents annually was 393 ± 230. The mean number of percutaneous coronary interventions (PCIs) annually was 180 ± 110 (Table 1). Institutional volumes of the respondents were 1227 diagnostic angiograms annually. Importantly, the mean percentage of PCIs performed using the radial approach was 54%, with right radial access being used approximately 80% of the time. 65% of the respondents were mandated to undergo radiation safety training, while 64% reported availability of radiation training at their institution.

3.3. Attitudes of all respondents

Respondents stated that compared to femoral access, radial access has substantially increased radiation exposure (6 on a scale of 1–10, with 10 being "significantly increased radiation dose") and the distribution of responses appeared bimodal (Fig. 5). When asked to quantify the increase associated with radial access, respondents stated that radial access had about a 31% increase in radiation exposure to the clinician and the patient compared with femoral access. Respondents also cared more about the increased radiation exposure to themselves (5.5 out of a 10 point scale with 10 being "utmost concern") versus the patient (4.5 out of 10 on the same scale). Respondents who were overall less concerned about radiation exposure appeared to care more about the patient exposure while the respondents who were overall more concerned about increased radiation exposure were more concerned about the impact on themselves (Fig. 6). Respondents believed that

Fig. 1. Continent and US regions breakdown of respondents. North America 50%, Asia 22%, Europe 18%, South America 8%, Australia 1%, Africa 1%. United States: Northeast 26%, Midwest 24%, Southeast 25%, Southwest 9%, West 16%.

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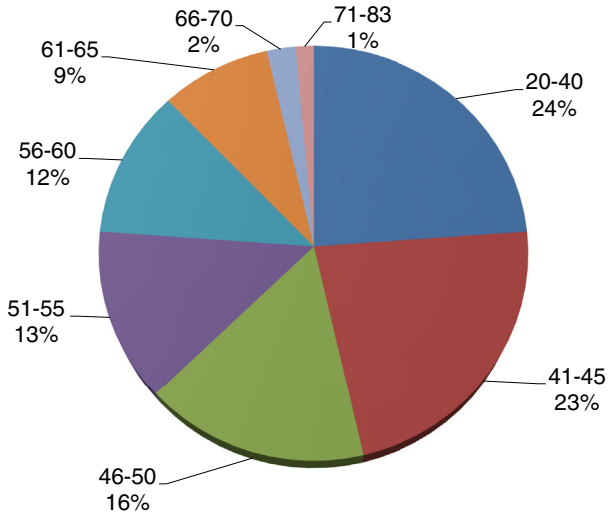

Fig. 2. Age breakdown of respondents.

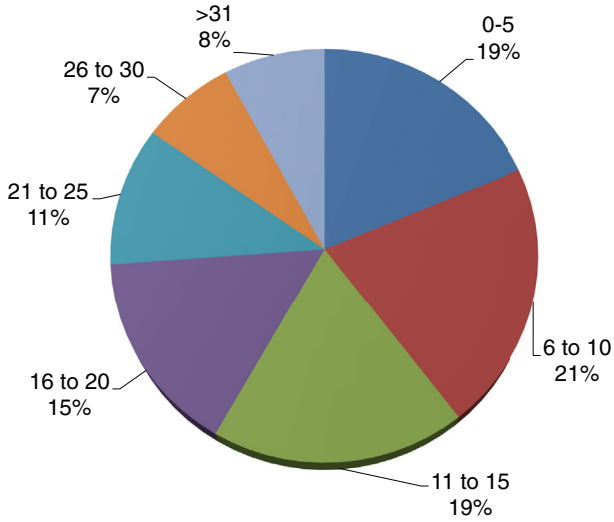

Fig. 4. Operator experience percentage (years).

fluoroscopic time increases on average 23% during radial access compared to femoral during PCIs. Finally, when asked if they would perform more radial access procedures if the radiation exposure was similar or identical to that of femoral access, 47% of interventional cardiologists report that they would do more radial, 37% state that they would not do more radial, and 16% state that they did not know (Tables 2 and 3).

3.4. Radialist attitudes

In multivariate analysis, those who performed more radial access interventions – both left and right access – were more likely to state that radial access has more radiation exposure than femoral access interventions ($P = 0.0001$). In addition, the increased percentage of cases performed with TRA PCI by the respondents was correlated with the concern about radiation exposure to themselves ($P = 0.0001$) and their patients ($P = 0.0226$). Those who perform more TRA procedures were more likely to state that radial access increases fluoroscopy times compared to TFA for both diagnostic angiograms ($P = 0.001$) and PCIs ($P = 0.0001$).

3.5. ALARA considerations

Similarly, the percentage of interventions performed by an interventionalist using the right radial access (RRA) for procedures was significantly associated with attitudes regarding practicing with *As Low As Reasonably Achievable* (ALARA); that is, the clinicians who did more RRA interventions compared to left radial access (LRA) were more likely to give ALARA more importance in their practice ($P = 0.0463$). Clinicians who performed more RRA were also much more concerned about the impact on operator exposure than clinicians who performed more TFA interventions ($P = 0.0478$), and were also more likely to use a dosimeter ($P = 0.0024$). Finally, those who perform more RRA procedures are more likely to state that TRA access increases fluoroscopy times compared to TFA ($P = 0.0139$).

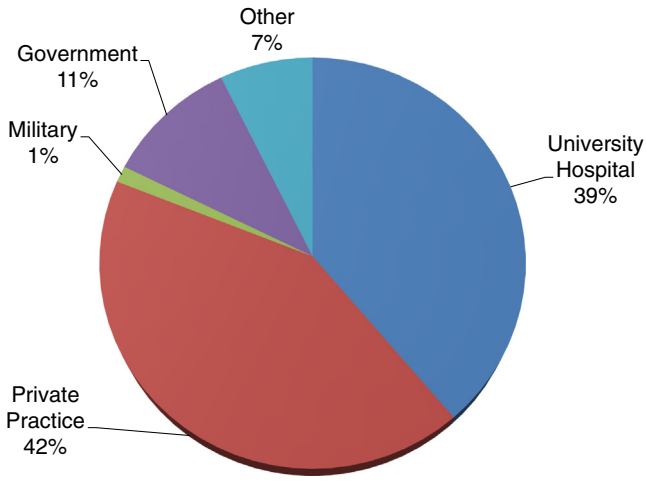

Fig. 3. Hospital affiliation by respondents.

3.6. Operator age, experience, and radiation safety training

Increasing operator age correlated with radiation concern to self and patient; that is, the older the interventional cardiologists are, the more likely they are to indicate that radiation concern to themselves ($P = 0.0207$) and their patients ($P = 0.0443$) factors into their decision to perform interventions or angiograms with TRA or TFA. Older clinicians were more likely to use thyroid collars, as well ($P = 0.036$). In addition, if clinicians either have undergone radiation safety training or have radiation safety training, they are more likely to use the table lead apron ($P = 0.0215$), the fluoroscopy-save feature ($P = 0.0033$) during procedures, and give more importance to ALARA ($P = 0.007$) compared to those who did not undergo training or had no training availability in their respective institution.

Table 1
Baseline characteristics.

Variable	
Age, mean ± SD (years)	48 ± 10.2
Women (%)	6
Interventional Experience (years)	14.52 ± 8.64
Diagnostic cardiac catheterizations per year	393.7 ± 230.84
PCI per year	180 ± 109.5
Urban hospital location (vs. rural) (%)	88%
PCI per institution	1229 ± 1013.98
Radial PCI Operator (%)	53.8 ± 34.746
Radial PCI Institution (%)	45.1 % ± 31.72
Right Radial (%)	79.5 ± 28.3
Cardiac Catheterization Laboratory Age (years)	6 ± 3.95

PCI = percutaneous coronary intervention.
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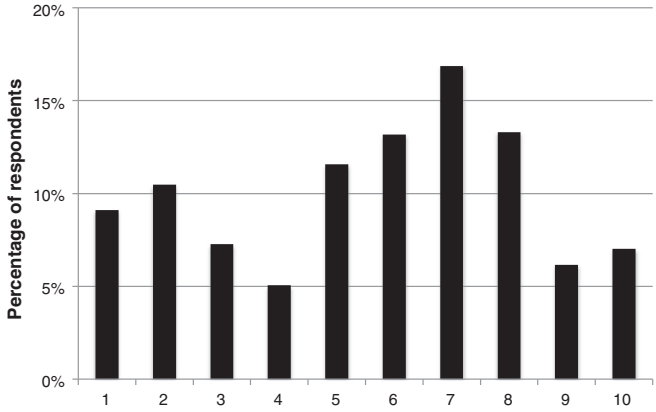

Fig. 5. Perceived increase of radiation with radial access.

3.7. Global analysis — United States operators vs. the world

Stepwise multivariate analysis found that for specific interventions currently used in many catheterization labs around the world, differences existed in US vs. non-US attitudes and practices. Radiation protection drape and radiation protection armboard are more likely to be seen as more important to reduce radiation exposure for non-US respondents; that is, US operators attributed less importance to radiation protection drape ($P = 0.0106$) and radiation protection armboard ($P = 0.0315$) to reduce radiation exposure compared to the rest of the world. In addition, operators from the US also give less importance to ALARA compared to our non-US respondents ($P = 0.0001$), as well as less importance to table-lead aprons ($P = 0.0036$). In addition, our results show that European interventionalists are more likely to be concerned with radiation exposure to themselves ($P = 0.0346$) and their patients ($P = 0.0237$) during TRA interventions compared to other interventionalists around the world.

4. Discussion

In this global survey of interventional and invasive cardiologists, we have demonstrated that: 1) most interventionalists perceived that TRA is associated with increased radiation dose compared with TFA; 2) interventionalists perceived that RRA is associated with higher radiation than LRA, but still perform it more frequently than LRA; 3) US operators tended to use less radiation protection equipment and attributed lower importance to ALARA compared to non-US operators; 4) older interventionalists and those who underwent radiation safety training were more concerned about increased radiation doses and practiced more ALARA and 5) only 2/3 of interventionalists are mandated to undergo radiation safety training.

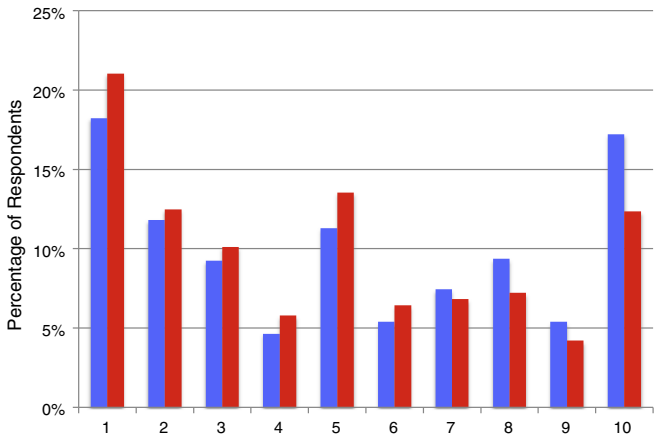

Fig. 6. Operator concern about radiation exposure to self and the patient. Blue bar - concern for self; Red bar - concern for patient.

Table 2
Operator radiation safety importance.

Variable	
Importance of ALARA (scale 1–10)	4.1 ± 1.15
Goggles Importance (scale 1–10)	7.1 ± 3.2
Thyroid Collar Importance (scale 1–10)	9.13 ± 1.8
Table Lead Apron Importance (scale 1–10)	8.8 ± 2.1
Moveable Lead Shield Importance (scale 1–10)	8.5 ± 2.3
Radiation Protection Drape Importance (scale 1–10)	6 ± 3.3
Radiation Protection Armboard Importance (scale 1–10)	5.4 ± 3.3
Dosimeter Importance (scale 1–10)	8.2 ± 2.6
Increasing Distance Importance (scale 1–10)	8 ± 2.6
Fluoroscopy-save Importance (scale 1–10)	7.8 ± 2.59
Radial Impact on Operator Exposure (scale 1–10)	5.6 ± 2.6
Radial Exposure Compared to Femoral Increase (%)	30.9 ± 23.8
Radial Exposure concern to self (scale 1–10)	5.2 ± 3.3
Radiation Exposure concern to the patient (scale 1–10)	4.73 ± 3.1
Fluoroscopy Rate (frames/s)	12.9 ± 5.25
Cine Rate (frames/s)	15.62 ± 5.86
Fluoroscopy Increase Radiation Diagnostic (%)	22.6 ± 22.17
Fluoroscopy Increase in PCI (%)	22.9 ± 22.23

ALARA = as low as reasonably achievable; PCI = percutaneous coronary intervention.

4.1. Radiation exposure and radial access

The percentage of radiation increase associated with TRA has been extensively researched in both prospective and retrospective studies with considerable heterogeneity in the findings and continued uncertainties [11,15–18]. While TRA access is likely associated with increased radiation exposure compared to TFA there are many components related to this increase. Operator experience [17], procedural volume [19], RRA vs. LRA [16], type of shielding [20] and individual operator technical practices [21] have all been demonstrated to account for the observed differences. We found that amongst operators who performed a higher number of coronary angiograms and PCIs using TRA, these clinicians were more likely to state that TRA has *more* radiation exposure than TFA. These high-volume TRA interventionalists also had *more* concern about themselves and for their patients due to the increased radiation exposure than those who performed more TFA. More specifically, they correctly deemed that the TR approach has increased fluoroscopy times in both diagnostic angiograms and interventions [22]. Additionally, we found that our respondents were quite accurate in estimating the increase in radiation exposure with TRA compared to TFA [21]. It can, therefore, be reasonably concluded that contemporary international interventionalists who perform more TRA are quite aware of the majority current literature that reports increased radiation exposure with TRA. Interestingly, in a large randomized clinical trial, more experienced radialists and high-volume centers had near-equivalent radiation doses with TRA and TFA [17]. Therefore, while the high-volume experienced operators in our survey demonstrated high awareness of the radiation concern, in clinical practice they are actually likely to be exposed to equivalent TRA radiation doses compared with TFA. These survey findings additionally confirm that interventionalists are well aware of the presence of a learning curve in adoption and expertise with radial access [19,23]. The responses by more experienced operators suggest that in their practices they do observe reduction in fluoroscopy times with TRA as their dexterity increases over time. The reduction in radiation with increased operator experience coupled with many other benefits of radial approach is likely the contributing factor for continued and growing worldwide penetration of TRA.

4.2. Radiation attitudes and practices

Multiple studies have described statistical differences in radiation exposure between RRA and LRA in both total radiation exposure and

Table 3
Multivariate correlations.

Variable	P value
Goggle use	
PCI per year	0.0158
Thyroid Collar	
Age	0.036
Interventional Experience	0.01
Continent Africa	0.0003
Continent Asia	0.0002
Table Lead Apron	
Non-US	0.0036
North East	0.0496
Radiation Safety Training (Y/N)	0.0215
Government Institution	0.008
Moveable Lead Shield	
Asia	0.0003
Radiation Protection Drape	
Asia	0.0127
Non-US	0.0106
Institution University	0.0443
Radiation Protection Armboard	
Non-US	0.0315
Dosimeter	
Right Radial Percentage	0.0024
Asia	0.025
Northeast	0.0419
Midwest	0.0133
Fluoroscopy-save	
Cine rate	0.034
Undergone Radiation Safety Training (Y/N)	0.0033
Australia	0.0239
University Hospital	0.0295
Private Practice	0.0154
Importance of ALARA	
Right radial Percentage	0.0463
Fluoroscopy frame rate	0.0373
Radiation Training Availability	0.007
Non US	0.0001
Institution military	0.032
Radiation Impact on Operator Exposure	
Radial PCI operator Percentage	0.0001
Right radial percentage	0.0478
Radial Exposure Compared to Femoral Overall	
PCI per year in the institution	0.0403
Radial PCI operator percentage	0.0001
Northeastern US	0.0366
Radial Exposure concern to self	
Age	0.0207
Intervention experience	0.019
Radial PCI operator Percentage	0.0001
Australia	0.0119
Europe	0.0346
Radial Exposure concern to Patient	
Age	0.0443
Radial PCI operator percentage	0.0226
Australia	0.0079
Europe	0.0237
Fluoroscopy Increase Radiation Diagnostic	
PCI per institution per year	0.0005
Radial PCI operator percentage	0.001
Fluoroscopy frame rate	0.0084
Fluoroscopy Increase PCI	
PCI per institution per year	0.0003
Radial PCI operator percentage	0.0001
Fluoroscopy frame rate	0.0373
Radial PCI Institution Percentage	0.0103
Right radial percentage	0.0139
Radiation Safety Training when yes	0.0219

ALARA = as low as reasonably achievable; PCI = percutaneous coronary intervention.

fluoroscopy times, with LRA being associated with reduction in both fluoroscopy times as well as procedure times [24]. In a previous global survey, it was reported that when choosing RRA versus LRA operators in the vast majority of cases (90%) select right radial access [4]. This continued preference for RRA is confirmed in our survey.

4.3. ALARA

At the present time, there is sufficient evidence from several contemporary practice trials that confirms that TRA is associated with increased radiation exposure to the operator [10,15,25]. In our survey, we have confirmed that the interventional community is well cognizant of the increased radiation considerations associated with RRA. Yet, this survey suggests that increased radiation associated with RRA is not a large factor in global interventionalist' continued preference for RRA. Our finding that operators performing RRA paid greater attention to ALARA is important for future developments in TRA and RRA radiation protection strategies. It appears certain that further refinements and innovation in radiation protection are needed to minimize the observed and perceived differences between RRA and LRA/TFA procedures. If indeed the preference for RRA continues, new and recent encouraging efforts aimed at reducing overall radiation dose in the cardiac catheterization laboratory such as new image processing technologies or protocols [26], real time radiation dose monitoring, robotic cardiac intervention [27] and suspended radiation protection systems [28], low-rate fluoroscopy [29] or new radiation reduction education and training methods [30,31] should be aggressively adopted by radialist operators.

Lastly, it is important to emphasize that interventionalists did report awareness of radiation delivered to the patients, albeit less than to themselves. This supports the current understanding that the dose to the patient remains far below the threshold for deterministic effects to be seen [11], while interventionalists are exposed to radiation throughout their careers. We found of particular interest that nearly half the interventionalists felt that they would perform more TRA if the radiation exposure was reduced. This finding is particularly important as it underlines the need for development of more effective strategies to protect interventionalists from radiation exposure associated with both TRA and TFA.

4.4. Limitations

Of the 5432 cardiologists invited to complete the survey, we received 1084 valid responses. This gave us a response rate of 20%, which is a better return than the typical survey [32]. Because the survey was voluntary and all information self-reported, misclassification is possible although the anonymous nature of the survey would be expected to reduce inaccurate reporting. Also, presence of inherent bias cannot be excluded since individuals who have suffered an adverse radiation effect presumably work at institutions that are less radiation safety conscious and are more likely to fill out such a survey. A lack of radiation protection training can be a reason for unsafe practices in the cardiac catheterization laboratory, and there are various reasons why protective tools and procedures may not be utilized; we did not collect data in this particular area. Only 6% of respondents were female and we did not detect any gender differences among respondents. Finally, the voluntary nature of our surveys may include a larger number of respondents who are overall more concerned about radiation and have a higher likelihood of practicing ALARA and following evidence-based recommendations, therefore, biasing our observations.

In conclusion, global interventionalists are well informed about the radiation considerations associated with TRA and RRA. There are differences among interventionalists based on experience, age and geographic area. Most importantly, the need for further radiation safety education is emphasized. Additional research and implementation of new and more effective radiation protection strategies are needed. Increased operator proficiency will likely further reduce radiation dose associated with TRA.

Acknowledgements

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Appendix A

1. Consent for the survey (*yes/no*)
2. In which country do you currently practice? (*list of countries provided*)
3. In which United States State do you practice? (*list of States provided*)
4. What is your age? (*years*)
5. What is your gender? (*male/female*)
6. At what type of institution do you practice? (*university hospital/private practice/military/government/other*)
7. What type of setting do you practice in? (*urban/rural*)
8. Which best describes you? (*attending/fellow/other*)
9. Approximately how long have you been practicing as an interventional cardiologist? (*years*)
10. About how many diagnostic angiograms do you perform annually? (*number*)
11. About how many percutaneous coronary interventions (PCIs) do you perform annually? (*number*)
12. About how many percutaneous coronary interventions (PCIs) does your perform annually? (*number*)
13. About what percentage of your own PCIs are performed using the radial approach? (*percentage*)
14. About what percentage of PCIs in your institution are performed using the radial approach? (*percentage*)
15. When performing PCI using a radial approach, what percentage of the time do you use right radial access? (*percentage*)
16. Are you mandated to undergo radiation safety training? (*yes/no*)
17. Is radiation safety training available at your hospital? (*yes/no*)
18. How often do you practice ALARA (as low as reasonably achievable strategy) during cardiac catheterization laboratory procedures? (*never/rarely/sometimes/often/all the time*)
19. What type of imaging equipment does your cardiac catheterization laboratory use? (*Philips/General Electric/Siemens/Toshiba/Shimadzu/other*)
20. In your primary workplace, how old is the cardiac catheterization laboratory equipment? (*years*)
21. How important is it that you wear or practice each of the following for reducing radiation exposure during percutaneous coronary interventions (PCIs) and angiograms (lead goggles; thyroid collar; table lead apron; moveable lead shield; radiation protection drape; upper extremity radiation protection board; radiation dosimeter; increasing distance/extension tubing; remote injection/power injection systems; use the fluoroscopic save feature)? (*"1" being not important and "10" being significantly important*)
22. In your opinion, what impact does radial access (compared to femoral access) have on operator radiation exposure? (*"1" being not important and "10" being significantly important*)
23. In your opinion, how much do you think radial access increases radiation expo sure compared to femoral access? (*percent*)
24. How important is the concern about radiation exposure to yourself in your choice of access site? (*"1" being not important and "10" being significantly important*)
25. How important is the concern about radiation exposure to the patient in your choice of access site? (*"1" being not important and "10" being significantly important*)
26. Typically, what fluoroscopic rate do you use? (number of frames/second)
27. Typically, what cineangiography ("cine") rate do you use? (*number of frames/second*)
28. In your experience, how much does radial access increase fluoroscopy time for diagnostic angiograms? (*percentage*)
29. In your experience, how much does radial access increase fluoroscopy time for PCI? (*percentage*)
30. Would you perform more transradial access procedures if the radiation exposure was similar to that of femoral interventions? (*yes/no/do not know*)

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