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Radiation Exposure of the Operator During Coronary Interventions (from the RADIO Study)

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We sought to compare operator radiation exposure during procedures using right femoral access (RFA), right radial access (RRA), and left radial access (LRA) during coronary angiography (CA) and percutaneous coronary intervention (PCI). Because of an increased incidence of long-term malignancy in interventional cardiologists, operator radiation exposure is of rising concern. This prospective study included all consecutive patients who underwent elective or emergency CA ± PCI from September 2014 to March 2015. The primary end point was operator radiation exposure, quantified as the ratio of operator cumulative dose (CD) and patient radiation reported as dose-area product (DAP) (CD/DAP). Secondary end points included CD, DAP, and fluoroscopy time (FT). Overall 830 procedures (457 CA [55%] and 373 PCI [45%]) were performed, 455 (55%) through RFA, 272 (33%) through RRA, and 103 (12%) through LRA. The CD/DAP was lower in RFA (0.09 μSv/Gycm^2 [0.02 to 0.20]) compared with RRA (0.47 μSv/Gycm^2 [0.25 to 0.75], p <0.001). The LRA showed lower CD/DAP compared with RRA (p <0.001). CD was significantly lower in RFA (3 μSv [1 to 7]) compared with RRA (12 μSv [6 to 29], p <0.001). The LRA showed lower CD compared with RRA (p <0.001). There were no significant differences in DAP among the 3 access sites. FT was similar for the 3 groups (RFA 7 ± 7, RRA 5 ± 5, LRA 6 ± 5 minutes, RFA vs RRA: p = 1, RFA vs LRA: p = 0.16, RRA vs LRA: p = 0.52). In conclusion, the use of RFA during CA ± PCI is associated with significantly lower operator radiation exposure compared with RRA. LRA is associated with significantly lower operator radiation exposure compared with RRA.

Because of a presumably increased stochastic risk of cancer induction among interventional cardiologists, especially neoplasms of the unprotected brain, nasopharyngeal tract, and upper extremities, operator radiation exposure during coronary angiography (CA) and/or percutaneous coronary intervention (PCI) is of rising concern.[1,2] Therefore, we undertook a comparison of operator radiation exposure during right femoral access (RFA), left radial access (LRA), and right radial access (RRA) during CA and CA followed by ad hoc PCI in a real-world population.

Methods

From September 2014 to March 2015 at the University and Hospital Fribourg, all consecutive procedures of elective or emergency CA and CA followed by ad hoc PCI were prospectively considered for operator radiation exposure measurements. Procedures were performed by 5 senior interventional cardiologists with significant experience (>3,000 PCI each) in both femoral and radial access routes. Selection of the percutaneous access site was left to the discretion of the operator. Crossover access site procedures were excluded. This study was part of the Catheterization Registry Fribourg (CardioFR), which was approved by the Ethics Committee of Canton Vaud (protocol no: 339/14).

The primary end point of the study was operator radiation exposure, expressed as the cumulative equivalent dose (in μSv) over the lead apron at chest level, normalized for the patient radiation exposure (dose-area product [DAP] in Gycm^2). Secondary end points included cumulative dose (CD), DAP, and fluoroscopy time (FT).

Procedures were performed on a digital single-plane cineangiography unit (Allura FD10; Philips Medical Systems, Hamburg, Germany) with an undertable x-ray tube MRC20025 with a magnification factor leading to a field of view of 21 cm and an acquisition frequency of 15 frames/s. All procedures were performed with respect to current guidelines using either 5Fr or 6Fr hydrophilic sheaths. Conventional diagnostic and guiding catheters were used.

The femoral access was achieved, under local anesthesia with 2% rapidocain, through the anterior wall puncture of the artery; 5Fr or 6Fr Terumo (Pinnacle; Terumo Medical, Tokyo, Japan) introducer was placed in the femoral artery. CA and PCI were performed according to standard practice using catheter and drugs left to the discretion of the operator. Hemostasis was achieved using closure devices

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See page 194 for disclosure information.

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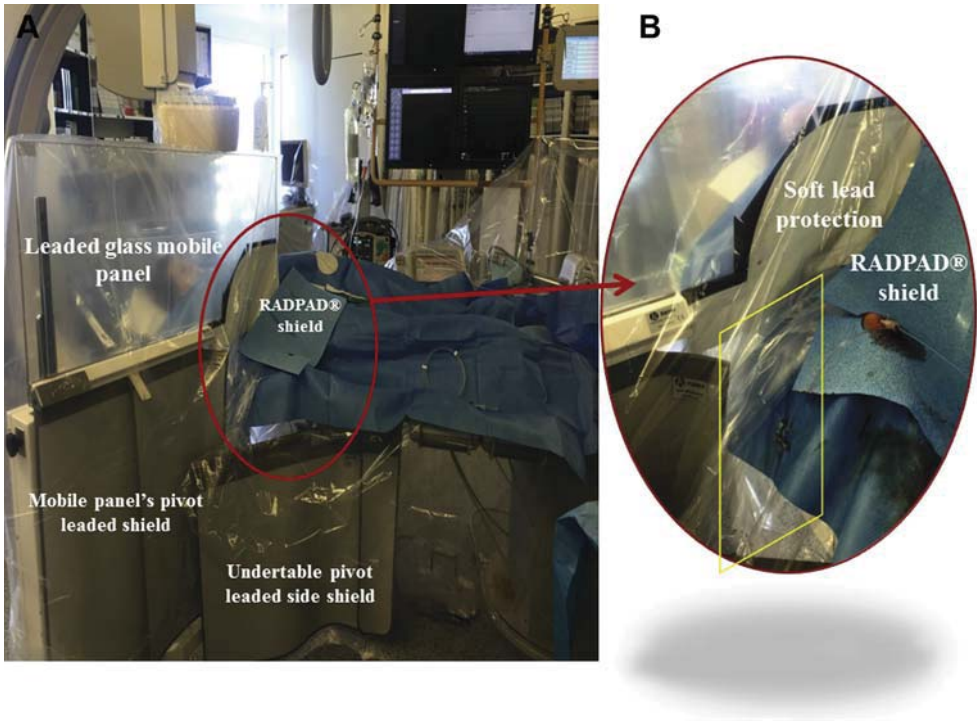

Figure 1. *(A)* Radioprotection equipment and materials. Image acquisition during a right radial case. *(B)* Although the shields are approximated as closely as possible to minimize operator irradiation, there is still a radioprotection gap *(yellow box)*, which is inevitably more important during right radial procedures.

Table 1
Baseline patient and procedural characteristics

	RFA (N=455)	LRA (N=103)	RRA (N=272)	p-values		
				RFA vs. LRA	RFA vs. RRA	LRA vs. RRA
Patients						
Age (years±SD)	68±12	69±10	65±12	1.00	0.02	0.05
Male	310 (68%)	71 (69%)	181 (67%)	1.00	1.00	1.00
Weight (kg±SD)	80±16	80±18	81±16	1.00	1.00	1.00
Height (m±SD)	1.70±0.09	1.70±0.09	1.70±0.09	1.00	1.00	1.00
BMI (kg/m^2±SD)	27±5	27±5	28±5	1.00	1.00	1.00
Procedure						
CA	216 (47%)	65 (63%)	176 (65%)	0.01	<0.01	1.00
CA followed by ad hoc PCI	239 (53%)	38 (37%)	96 (35%)	0.01	<0.01	1.00
Procedural time (min±SD)	20±19	15±11	18±12	0.05	1.00	0.08
Fluroscopy time (min±SD)	7±7	5±5	6±5	0.16	1.00	0.52
Nb of cine-angiograms (n±SD)	954±520	659±351	727±300	<0.001	<0.01	<0.001

Variables are reported in numbers (%) or mean ± SD.

BMI = body mass index; CA = coronary angiography; DAP = dose area product; LRA = left radial access; PCI = percutaneous coronary intervention; RFA = right femoral access; RRA = right radial access; SD = standard deviation.

(Femoseal; St. Jude Medical, St. Paul, Minnesota) or external mechanical compression (Femostop; St. Jude Medical).

After sterile preparation and anesthesia with 2% rapidocain infiltration, radial artery was punctured with a 20-gauge needle. A 0.021 Teflon-sheathed short guidewire was inserted in the needle. A 3.2-section BD Venflon was then inserted in the artery. A Terumo (Pinnacle; Terumo Medical) 0.021 hydrophilic guidewire was advanced through the radial and brachial artery. A 5Fr introducer was then inserted in the radial artery. Vasodilator cocktail consisting of verapamil 3 mg and enoxaparin 3,400 units was administered after sheath insertion. Specific catheters were used for CA and PCI. Exchange to a 6Fr sheath was possible when technically necessary. At the end of the procedure, the sheath was removed and an inflatable pressure band placed to the access site. All radial accesses were performed at the right side of the patient.

Operator protection was ensured with the same equipment for all procedures. A leaded glass mobile panel with a

Table 2
Radiation exposure of the operator and patient

	RFA	LRA	RRA	RFA vs. LRA			RFA vs. RRA			LRA vs. RRA		
				p-value	Adjusted difference (95%CI)	Adjusted p-value	p-value	Adjusted difference (95%CI)	Adjusted p-value	p-value	Adjusted difference (95%CI)	Adjusted p-value
CA and CA followed by ad hoc PCI	N=455	N=103	N=272									
DAP ($Gycm^2$)	36 (22-63)	30 (18-47)	32 (19-52)	0.01	+4 (-11 to 20)	0.57	0.02	+6 (-3 to 15)	0.2	0.84	-1 (-9 to 6)	0.73
CD (μSv)	3 (1-7)	6 (3-11)	12 (6-29)	<0.001	+1 (-3 to 5)	0.63	<0.001	-16 (-22 to 11)	<0.001	<0.001	-20 (-30 to -10)	<0.001
CD/DAP (μSv/$Gycm^2$)	0.09 (0.02-0.20)	0.21 (0.10-0.35)	0.47 (0.25-0.75)	<0.001	-0.01 (-0.06 to 0.05)	0.79	<0.001	-0.36 (-0.43 to 0.28)	<0.001	<0.001	-0.39 (-0.54 to -0.26)	<0.001
CA alone	N=216	N=65	N=176									
DAP ($Gycm^2$)	24 (16-39)	24 (15-35)	27 (17-42)	1.00	-2 (-15 to 12)	0.81	0.81	-6 (-14-2)	0.12	0.67	-4 (-11-3)	0.27
CD (μSv)	2.5 (1-6)	5 (2-10)	10 (6-19)	<0.001	1 (-2 to 4)	0.45	<0.001	-14 (-21 to -8)	<0.001	<0.001	-10 (-18 to -2)	0.01
CD/DAP (μSv/$Gycm^2$)	0.10 (0.03-0.22)	0.21 (0.11-0.38)	0.44 (0.24-0.71)	<0.001	-0.01 (-0.01 to 0.07)	0.91	<0.001	-0.30 (-0.37 to -0.23)	<0.001	<0.001	-0.25 (-0.36 to -0.14)	<0.001
CA followed by ad hoc PCI	N=239	N=38	N=96									
DAP ($Gycm^2$)	54 (34-90)	45 (29-62)	49 (26-71)	0.16	2 (-25 to 30)	0.87	0.07	7 (-10 to 24)	0.42	1.00	3 (-11 to 18)	0.65
CD (μSv)	4 (1-10)	6.5 (3-13)	24 (9.5-45.5)	0.21	-1 (-8 to 6)	0.83	<0.001	-23 (-33 to -13)	<0.001	<0.001	-30 (-53 to -7)	0.01
CD/DAP (μSv/$Gycm^2$)	0.07 (0.02-0.18)	0.19 (0.10-0.34)	0.54 (0.27-0.87)	<0.001	-0.01 (-0.01 to 0.09)	0.86	<0.001	-0.47 (-0.61 to -0.34)	<0.001	<0.001	-0.55 (-0.87 to 0.25)	0.001

Values are reported in medians (interquartile range: P25 to P75).
CA = coronary angiography; CD = cumulative dose; DAP = dose area product; LRA = left radial access; PCI = percutaneous coronary intervention; RFA = right femoral access; RRA = right radial access; SD = standard deviation.

patient contour cutout (0.5 lead equivalent; MAVIG, Munich, Germany) was positioned at the left side of the operator. An undertable pivot-leaded side shield (0.5-mm lead equivalent) was mounted to the side of the table. An additional soft lead shield was adjusted in the contour cut of the leaded glass mobile panel to minimize radiation exposure. The 37 × 42 cm upper-shield flap (RADPAD, Worldwide Innovations & Technologies, Inc, Kansas City, USA) was placed over the access site in each procedure to reduce scatter radiation (Figure 1). Additional radiation protection materials were standardized for all operators and included a lead apron, thyroid lead collar, and leaded glasses. All procedures were performed from the patients' anatomical right side.

Operator radiation was measured using individual electronic dosimeters (DoseAware; Philips Healthcare, Best, The Netherlands) positioned on the sternum, outside the lead apron. The dosimeters are silicon-based semiconductor detectors with a dose-response between 1 μSv and 10 Sv, in steps of 1 μSv (calibrated in ambient equivalent dose Hp(10)) and a temporal resolution of 1 second. The following parameters were recorded for each procedure: (1) operator CD through the use of dedicated readout software (DoseView), measured by the individual dosimeters; (2) FT; (3) number of cine angiograms (NC); and (4) the DAP-normalized CD defined as the dose (μSv) received by the operator with each $Gycm^2$ applied to the patient (known as the exposure factor) has been advocated[3] and applied to our study as it isolates differences in patient radiation among the 3 vascular access sites. Patient radiation dose was expressed as DAP. Furthermore, radiation exposure of the assistant nurse, the first nurse on the operator's right side, was assessed using similar dosimeters, in a subgroup of consecutive procedures, with the aim to compare radiation exposure of the operator versus assistant nurse.

All statistical analyses were performed using dedicated software (Stata, version 13; StataCorp LP, College Station, Texas) at a 2-tailed significance level of alpha <0.05. Baseline patient and procedural characteristics, and variables assessing radiation exposure of the operator, were compared among the 3 vascular access sites. Categorical variables are reported as counts and percentages; continuous variables are reported as mean and SD or as median with 25% to 75% interquartile range according to their distribution. Normality was assessed by visual inspection of histograms, the computation of Q-Q plots and the Shapiro-Wilk test. Categorical variables were compared using the chi-square or Fisher's exact test as appropriate. Continuous variables were analyzed using the 1-way ANOVA or the Wilcoxon rank-sum test according to their distribution. To account for differences of the individual operators on radiation exposure according to access site, we computed a generalized linear model including the individual operators as potential confounders of the overall treatment effect. To account for multiple comparisons, p values are Bonferroni adjusted, that is, multiplied by the number of comparisons. Comparison of radiation exposure between the operator and the first assistant was assessed using the paired student's *t* test or the signed-rank Wilcoxon test according to distribution.

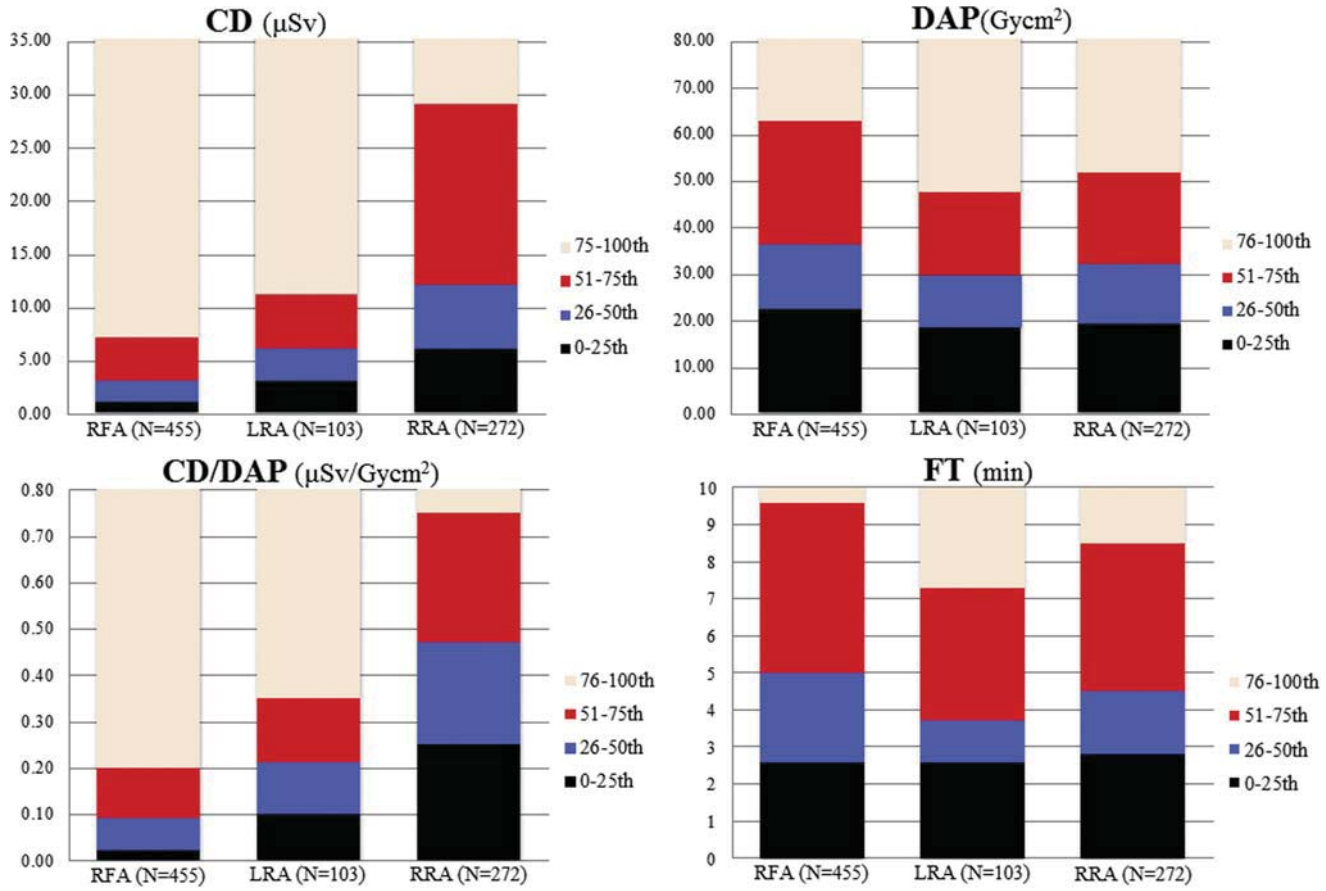

Figure 2. Operator CD, patient radiation dose (DAP), operator radiation exposure (CD/DAP), and FT for all procedures: CA and CA followed by ad hoc PCI. Columns: 3 vascular access sites in percentiles (colors): black: 0 to 25th, blue: 26 to 50th, red: 51 to 75th, and beige: 76 to 100th, median values on the board of blue and red columns.

Results

During September 2014 and March 2015, 849 consecutive procedures for elective or emergency CA and CA followed by ad hoc PCI were performed in our catheterization laboratory with a dedicated dosimeter for radiation evaluation. Nineteen procedures (1.8%) were excluded because of a crossover in access sites. No patient was excluded because of lesion or procedural complexity. Finally, 830 consecutive procedures were included in the trial, 457 CA alone (55%) and 373 CA followed by ad hoc PCI (45%). With regard to vascular site, 455 procedures (55%) were carried out using the RFA, 103 (12%) using the LRA, and 272 (33%) using the RRA. Baseline patient characteristics were generally well balanced and depicted in Table 1. Analysis of procedural characteristics as listed in Table 1 revealed no difference in FT among the groups and showed a significantly greater NC in RFA compared with LRA and RRA group and in RRA compared with the LRA group, probably reflecting higher procedural complexity.

The radiation exposure of the assistant nurse standing at the operator's right side was also assessed in a subgroup of first 293 consecutive procedures, 152 CA alone (52%) and 141 CA followed by ad hoc PCI (48%), 164 (56%) through RFA, 49 (17%) through LRA, and 80 (27%) through RRA.

Table 2 and Figure 2 list patient and operator radiation exposure. Adjusted CD was significantly lower in RFA compared with RRA but not to LRA. CD was lower for procedures using LRA than RRA. Patient radiation dose expressed by DAP did not significantly vary among the 3 access sites. Operator radiation dose reported as the DAP-normalized CD was significantly higher in the RRA compared with the RFA and LRA group for all procedures, procedures with CA alone, and procedures with CA followed by ad hoc PCI. There were no significant differences between the RFA and the LRA for any kind of procedure. Table 3 indicates DAP, CD, and DAP-normalized CD for the individual operators. A significantly higher radiation exposure comparing the RRA with the RFA was consistently found for all operators. Significant differences in radiation exposure between RFA and LRA and RRA and LRA were found only for 2 of the 5 operators. Radiation exposure for elective and urgent procedures is provided in Table 4. During elective procedures, radiation exposure was lower for RFA compared with RRA, but not to LRA. However, LRA showed a lower DAP-normalized CD compared with RRA ($p < 0.001$). In addition to the aforementioned differences, LRA was associated with a higher radiation exposure than RFA, when only urgent procedures were considered

Table 3
Radiation exposure according to the individual operator

	RFA	LRA	RRA	p-values		
				RFA vs. LRA	RFA vs. RRA	LRA vs. RRA
CA andCA followed by ad hoc PCI						
Operator 1	N=39	N=77	N=88			
DAP ($Gycm^2$)	31 (20-59)	28 (17-41)	32 (19-55)	0.28	1.00	0.16
CD (μSv)	9 (4-15)	6 (4-11)	15.5 (8-33)	0.08	<0.01	<0.001
CD/DAP (μSv/$Gycm^2$)	0.28 (0.16-0.44)	0.23 (0.14-0.35)	0.51 (0.37-0.84)	0.33	<0.001	<0.001
Operator 2	N=132	N=3	N=28			
DAP ($Gycm^2$)	44 (31-90)	67 (37-90)	36 (18-56)	1.00	0.07	0.20
CD (μSv)	1 (0-2)	1 (0-3)	1 (0.5-7.5)	1.00	<0.01	1.00
CD/DAP (μSv/$Gycm^2$)	0.01 (0-0.04)	0.01 (0.00-0.04)	0.05 (0.00-0.17)	1.00	<0.01	0.53
Operator 3	N=98	N=1	N=3			
DAP ($Gycm^2$)	36 (21-67)	73	135 (14-166)	0.73	0.60	1.00
CD (μSv)	4 (2-10)	7	87 (25-484)	1.00	<0.01	0.02
CD/DAP (μSv/$Gycm^2$)	0.10 (0.05-0.19)	0.09	1.78 (0.64-2.90)	1.00	<0.01	0.36
Operator 4	N=139	N=12	N=69			
DAP ($Gycm^2$)	30 (17-54)	36 (24-128)	33 (22-50)	0.23	0.49	0.82
CD (μSv)	4 (1-6)	1.5 (1-3.5)	12 (7-36)	0.16	<0.001	<0.001
CD/DAP (μSv/$Gycm^2$)	0.10 (0.05-0.18)	0.05 (0.01-0.08)	0.45 (0.24-0.78)	<0.01	<0.001	<0.001
Operator 5	N=47	N=10	N=84			
DAP ($Gycm^2$)	35 (21-51)	27 (14-49)	30 (17-47)	0.92	0.40	1.00
CD (μSv)	7 (4-13)	12 (11-37)	12 (8-28)	0.04	<0.001	0.81
CD/DAP (μSv/$Gycm^2$)	0.21 (0.12-0.35)	0.59 (0.44-1.43)	0.48 (0.32-0.72)	<0.01	<0.001	0.55

Values are reported in medians (interquartile range: P25 to P75).
CA = coronary angiography; CD = cumulative dose; DAP = dose area product; LRA = left radial access; PCI = percutaneous coronary intervention; RFA = right femoral access; RRA = right radial access; SD = standard deviation.

Table 4
Radiation exposure of the operator and patient stratified by operator

	RFA	LRA	RRA	Crude p-values			Adjusted p-values		
				RFA vs. LRA	RFA vs. RRA	LRA vs. RRA	RFA vs. LRA	RFA vs. RRA	LRA vs. RRA
CA and CA followed by ad hoc PCI									
Elective	N=285	N=90	N=206						
DAP ($Gycm^2$)	34 (21-57)	32 (19-48)	31 (19-50)	0.37	0.41	1.00	0.77	0.35	0.72
CD (μSv)	3 (1-6)	6 (3-12)	11 (6-25)	<0.001	<0.001	<0.001	0.36	<0.001	<0.01
CD/DAP (μSv/$Gycm^2$)	0.09 (0.03-0.20)	0.22 (0.12-0.35)	0.43 (0.23-0.72)	<0.001	<0.001	<0.001	0.13	<0.001	<0.001
Urgent	N=170	N=13	N=66						
DAP ($Gycm^2$)	41 (25-84)	25 (12-44)	38 (21-57)	0.02	0.11	0.29	0.69	0.62	0.16
CD (μSv)	3 (1-10)	4 (1-6)	17.5 (8-41)	1.00	<0.001	<0.001	<0.01	<0.001	0.001
CD/DAP (μSv/$Gycm^2$)	0.08 (0.02-0.19)	0.15 (0.10-0.21)	0.55 (0.37-0.85)	0.16	<0.001	<0.001	<0.01	<0.001	<0.001

Values are reported in medians (interquartile range: P25 to P75).
CA = coronary angiography; CD = cumulative dose; DAP = dose area product; LRA = left radial access; PCI = percutaneous coronary intervention; RFA = right femoral access; RRA = right radial access; SD = standard deviation.

($p < 0.01$). In the subgroup of the first consecutive 293 procedures, operator exposure was significantly higher compared with the assistant nurse's as listed in Table 5 for all procedures and by access site.

Discussion

The main findings of the current prospective trial are the following: (1) interventional Cardiologists are exposed to a lower degree of radiation when performing CA or CA followed by ad hoc PCI through the RFA rather than the RRA; (2) interventional cardiologists are exposed to a lower degree of radiation when performing CA or CA followed by ad hoc PCI using the LRA rather than the RRA; and (3) the operator is more exposed to radiation compared with the assistant nurse standing at his right side during the procedures.

Transradial cardiac catheterization is known to be associated with an increased operator radiation dose even for highly experienced interventional cardiologists and despite the use of radioprotection optimization techniques.[4–9] Data are limited with regard to operator radiation exposure when right and left radial accesses are compared,[10–13] with most investigators reporting lower radiation levels for LRA, alike

Table 5
Comparison of radiation exposure between operator and assistant nurse

CA and CA followed by ad hoc PCI (N=293)	Operator	Assisstant nurse	p-value
DAP ($Gycm^2$)	32 (20-53)	32 (20-53)	1.00
CD (μSv)	5 (1-13)	2 (1-5)	<0.001
CD/DAP (μSv/$Gycm^2$)	0.16 (0.04-0.46)	0.07 (0.03-0.13)	<0.001
RFA (N=164)			
CD/DAP (μSv/$Gycm^2$)	0.06 (0.01-0.18)	0.06 (0.03-0.11)	<0.05
LRA (N=49)			
CD/DAP (μSv/$Gycm^2$)	0.23 (0.10-0.45)	0.06 (0.04-0.10)	<0.001
RRA (N=80)			
CD/DAP (μSv/$Gycm^2$)	0.51 (0.32-0.81)	0.10 (0.06-0.17)	<0.001

Values are reported in medians (interquartile range: P25 to P75).

CA = coronary angiography; CD = cumulative dose; DAP = dose area product; LRA = left radial access; PCI = percutaneous coronary intervention; RFA = right femoral access; RRA = right radial access; SD = standard deviation.

to initial scientific concerns and despite the operator's inconvenience when leaning over to reach the patient's left side. To our knowledge, this is the first single-center trial to compare operator radiation exposure among these 3 vascular access sites for CA and CA followed by ad hoc PCI. Recently, the Randomized Evaluation of Vascular Entry Site and Radiation Exposure trial[14] evaluated patient and operator radiation exposure among the 3 access sites RFA, LRA, and RRA and included only CA procedures without CA followed by ad hoc PCI procedures. It reported higher operator radiation for LRA using air kerma as primary end point, which is not the ideal patient exposure metric, although also analyzing DAP as a secondary end point and found an FT much shorter than our study's, presumably because PCIs were excluded. Furthermore, the population included in the Randomized Evaluation of Vascular Entry Site and Radiation Exposure trial shows a median weight and height of 64 to 65 kg and 163 to 164 cm, respectively, resulting subsequently in lower DAP values (in the order of 26 $Gycm^2$ per procedure).

Both procedure-related and operator-related factors appear responsible for the differences in operator radiation exposure per vascular access site. It has been reported that increased operator radiation exposure during radial access, as opposed to femoral access, is related to increase in FT, reflecting technical difficulties and to the slightly closer operator's position to the x-ray tube and to the patient, compared with femoral access.[5,15,16] In contrast, decreased operator radiation dose and shorter FT have been reported when using LRA compared with RRA.[10,11,17–20] In our study, there are some details in radiation protection techniques that should be taken into consideration: First, during RRA procedures, the leaded glass mobile panel is positioned less proximally to the table compared with LRA and RFA to facilitate the right radial access. The radioprotection gap which is inevitably created between the leaded glass mobile panel and the patient table is more pronounced during RRA procedures, thus creating a considerable source of radiation exposure to the operator (Figure 1). Second, when using RRA, the operator is positioned closer to the x-ray tube and closer to the patient compared with both LRA and RFA procedures, increasing the effect of the patient as the main source of scatter radiation to the operator. Furthermore, technical challenges in maneuvering catheters into the coronary vessels can lead in longer FT. In particular, the vascular anatomy associated with the right radial artery, including the right subclavian artery-common brachiocephalic trunk bifurcation and the common brachiocephalic trunk-aorta bifurcation, could account for tortuosity and calcifications that could impair procedural success. In considering the left radial artery, the left subclavian artery stems directly from the aortic arch, thus reducing the technical challenges in catheter manipulation, whereas in the right femoral artery there is no such issue at all. Finally, further technical difficulties associated with radial artery access include spasm or tortuosity of the radial artery, which could increase fluoroscopy and procedure times. Nonetheless, in our study, FT did not differ significantly among the 3 access sites, suggesting a high level of operator experience across the 3 groups. On the contrary, the longer procedural times and the greater NC in the femoral group reflect a higher complexity of procedures being performed through this access, while still benefitting from decreased operator radiation exposure compared with the 2 radial groups.

The present study confirms the greater radiation exposure of the operator compared with the first assistant who is standing at his right side, regardless of the vascular access site. This is expected because of the nurse's greater distance from the source of radiation and from the patient. Most authors studying operator radiation dose issues report results normalized per procedure and not per-patient radiation dose measured as DAP. This means that whether the dose is higher for femoral or radial approach will be a result of both the higher or lower DAP (and FT), the distance effect, and radiation protection aspects. If the dose is normalized per DAP, one can isolate, to a certain extent, the first 2 issues, and the results will then be mostly related to the radiation protection level and the distance between operator and patient.[21] Our results in terms of procedure (fluoroscopy and procedural times) and radiation dose of the operator (CD) and the patient (DAP) are in line with published data in the literature. Although not randomized, the present study reflects operator radiation exposure in a real-world population in everyday clinical practice, despite a bias in the choice of vascular access site by the operator. Furthermore, the 3 groups were homogenous with regard to characteristics that influence operator and patient irradiation such as patients' body mass index and procedural and FTs, thus reflecting a representative sample of a real-world population without exclusion of emergent or complex procedures. The greater NC in the RFA group compared with the LRA and RRA groups and in the RRA compared with the LRA group probably suggests increased procedural complexity and could be reflected in the higher patient irradiation (DAP) in the RFA group compared with the 2 radial groups. The normalization, however, of the operator irradiation for patient irradiation takes into consideration such parameters as procedural complexity and patient corpulence, thus accurately reflecting the actual operator radiation dose, and is dependent only on the following 2 parameters: (1) the degree of radioprotection itself and (2) the distance between patient and operator. Therefore, interpretation of results using the DAP-normalized operator radiation

dose allows for isolation and meaningful evaluation of technical differences among the 3 vascular access sites based on the positioning of radioprotection equipment, the operator's position, and his distance from the patient and the x-ray tube.

This was a nonrandomized, single-center study. Therefore, these results have to be interpreted with caution for other catheterization laboratories because of possible differences in operator experience, training and techniques, radioprotection materials, and devices. Furthermore, procedures were performed by 5 different, although highly experienced, interventional cardiologists implicating differences in catheterization techniques, procedural and FTs, NC, and thus effecting individual radiation dose. Finally, in our study, operator dose was measured by 1 single dosimeter positioned externally to the sternum, with no possibility to measure and compare radiation exposure of other corporal areas.

Disclosures

The authors have no conflicts of interest to disclose.

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