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Radiation Exposure and Vascular Access in Acute Coronary Syndromes: A Randomised Multicentre Trial

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Conflicts of Interest

Dr. Rigattieri reports personal fees from Astra Zeneca, outside the submitted work; Dr. Cortese reports personal fees from The Medicines Company, during the conduct of the study; personal fees from Astra Zeneca, grants and personal fees from Abbott Vascular, grants, personal fees and non-financial support from AB Medica, grants and non-financial support from Innova HTS, grants and non-financial support from Kardia, grants and non-financial support from Stentys, grants from Hexacath, grants from Amgen, outside the submitted work; Dr. Windecker reports personal fees from ASTRA ZENECA, grants from Biotronik, grants and personal fees from Boston Scientific, personal fees from Daiichi Sankyo, grants from Edwards life sciences, grants from Medtronic, outside the submitted work; Dr.Jüni reports other from Abbott Vascular, other from Biosensors, other from Medtronic, other from Johnson & Johnson, other from Ablynx, other from Amgen, other from AstraZeneca, other from Boehringer-Ingelheim, other from Eisai, other from Eli Lilly, other from Exelixis, other from Geron, other from Gilead Sciences, other

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Abstract

Background: It remains unclear whether radial increases the risk of operator or patient radiation exposure when performed by expert operators

Objectives: To determine whether radial access increases radiation exposure

Methods: We randomly assigned 8404 patients, with or without ST-segment elevation acute coronary syndrome, to radial or femoral access for coronary angiography and percutaneous intervention, and collected fluoroscopy time and dose area product (DAP). In the radiation sub-study (RAD-MATRIX), we anticipated that 13 or more operators, each wearing a thorax (primary endpoint), wrist and head (secondary endpoints) lithium fluoride thermo luminescent dosimeter and randomizing at least 13 patients per access site were needed to establish non-inferiority of radial versus femoral access.

Results: Among eighteen operators, performing 777 procedures in 767 patients, the non-inferiority primary endpoint was not achieved (p-value for non-inferiority=0.843). Operator equivalent dose at the thorax was significantly higher with radial than femoral access (77 µSv [IQR:40-112] vs. 41 µSv [IQR:23-59], p=0.02). After normalization of operator radiation dose by fluoroscopy time or DAP, the difference remained significant. Radiation dose at wrist or head did not differ between radial and femoral access. Thorax operator dose did not differ in the right radial (84 µSv [IQR:47-146]) compared to the left radial access (52 µSv [IQR:33-92]; p=0.15) In the overall MATRIX population, fluoroscopy time (10 min; IQR:6-16 vs. 9 min IQR:5-15; p<0.0001] and DAP—available in 7570 procedures and 6902 patients—(65 Gy*cm^2 [IQR:29-120] vs. 59 Gy*cm^2 [26-110]; p=0.0001) were higher with radial as compared to femoral access.

Conclusions: Radial, as compared with femoral access is associated with greater operator and patient radiation exposure when performed by expert operators in current practice. Radial operators and institutions should be sensitized towards radiation risks and adopt adjunctive radio-protective measures.

Key Words: Radiation dose –Radial access –Femoral access –Acute coronary syndromes –PCI

Abbreviations

ACS: acute coronary syndrome
DAP: dose area product
MATRIX: Minimizing Adverse Haemorrhagic Events by TRansradial Access Site and Systemic Implementation of angioX
PCI: percutaneous coronary intervention
STEMI: ST-segment elevationmyocardial infarction

Condensed abstract

Operator radiation exposure during percutaneous coronary procedures for acute coronary syndromes was evaluated in 18 operators participating in the MATRIX trial. Operator equivalent dose was measured after randomization for vascular access (radial vs femoral). The radial approach was associated with a significant higher operator radiation dose compared to femoral access. In term of patient exposure, fluoroscopy time and dose area product were significantly higher with radial as compared to femoral access. Radial operators should pay special attention to radio-protective measures in order to minimize the effects of radiation to patients, staff and themselves.

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Introduction

The use of radial, instead of femoral, access for coronary angiography and percutaneous coronary intervention (PCI) has been associated to lower risk of bleeding, vascular complications and greater survival in patients with acute coronary syndrome undergoing invasive management(1,2). European clinical practice guidelines endorse the use of radial access in patients with non-ST elevation acute coronary syndromes undergoing invasive management with a class I recommendation over femoral access, (3) and the uptake of radial access is increasing worldwide (4).

However, prior studies have raised concerns over the increased risk of radiation exposure for both patients and operators with radial instead of femoral access (5). Only a minority of randomized controlled studies evaluated radiation doses (5), especially in ACS patients(6) and none used dedicated dosimeters to assess operator exposure. As part of the MATRIX (Minimizing Adverse Haemorrhagic Events by TRansradial Access Site and Systemic Implementation of angioX) programme (NCT01433627), (7) we collected fluoroscopy time and dose area product and equipped radial operators consenting to participate with dedicated dosimeters during study conduct to assess operator radiation dose with radial or femoral access.

Methods

Study design and population

The design of the MATRIX trial and of the radiation (RAD-MATRIX) substudy has been previously reported (7,8). Briefly, all patients with an ACS with or without ST-segment elevation myocardial infarction were randomized to radial or femoral access (see web extra material). Only expert radial operators were involved in the RAD-MATRIX substudy.

Study protocol and randomization

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Before the coronary angiography all patients were centrally randomized (1:1) to radial or femoral access for diagnostic angiography and percutaneous coronary intervention if clinically indicated. The randomisation sequence was computer generated and modified using minimisation on intended new or ongoing use of ticagrelor or prasugrel, presence or absence of STEMI, troponin positivity and anticipated use of immediate PCI in non-STEMI patients. Operators participating in the radiation sub-study were to follow central randomization in regards to radial or femoral access for the primary endpoint comparison (operator radiation exposure at thorax), and for the patient radiation exposure comparison. A further randomization was performed in patients centrally allocated to radial access based on the patient identification (ID) number with odd ID numbers assigned to right radial and even ID numbers to left radial access. These patient IDs were automatically generated by the centralized web-based randomization and data capture system, so were not under control of the study personnel. This allowed a fairly balanced proportion of right radial access versus left radial access, used to assess whether the use of left radial as compared to right radial is associated to lower radiation burden (secondary endpoint).

Procedures

Access site management during and after the diagnostic or therapeutic procedure was left to the discretion of the treating physician and closure devices were allowed as per local practice. Standard operator radioprotection was ensured using a lead apron, a thyroid lead collar, lower body X-ray curtain fixed on the angiographic table and an upper mobile leaded glass suspended from the ceiling. Staged procedures were allowed, with no restriction with respect to timing, during which the protocol mandated that the access site remained as originally allocated.

Radiation Measurement

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Radiation measures collected were fluoroscopy time (expressed in minutes) and the DAP (expressed in Gy*cm^2). The DAP is the product of the absorbed dose to air and the cross-sectional area of the X-ray field for all segments of an interventional radiology procedure. This parameter was measured using specially designed ionization chambers mounted at the collimator system and calculated by the software present in each angiographic system. DAP provides a good estimation of the total radiation energy delivered to a patient during a procedure and is correlated with the long-term stochastic risk of cancer (9).

The operator radiation exposure was measured for each participating operator with three dedicated lithium fluoride thermo-luminescent dosimeters with a range of linearity from 1 µGy to 10 Gy, separate for femoral, left radial and right radial randomized access site. They were to be worn during each procedure by the participating operator on the left wrist, at mid thorax level, in the breast pocket outside the lead apron and at head level (in the middle front to measure the eye dose) (Fig S1- S2). The dosimeters used different detectors according to their location (superficial for the wrist, 3 mm depth for the eye and 10 mm depth for the thorax). Each dosimeter was distributed to operators in a sealed envelope and was labelled with operator's code, access site (femoral, right or left radial) and body destination (eye, thorax or wrist – 3 locations time 3 access sites equals 9 dosimeters per operator). No protocol violation was declared by participating operators regarding type and position of dosimeters throughout study execution. All dosimeters were collected for central reading at TECNORAD co. (Verona, Italy) and represent cumulative exposure during all procedures performed by the operator, separate for femoral, left radial, and right radial randomized access site. After central reading and correction for the radiation weighting factor (for X rays this factor is 1) the results were expressed as Equivalent doses in microSievert. The Equivalent dose at thorax was also converted in operator

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effective dose dividing it by a factor 33 according with an apron thickness 0.5 mm lead equivalent with a tube voltage under the table (10). Patient effective dose has been calculated using a conversion factor of 0.20 mSv/Gy*cm^2, as previously shown (11).

Statistical analysis

The primary non-inferiority hypothesis was that radial access was not associated to higher operator radiation dose as compared to femoral access(8).Since dosimeters measure the cumulative procedural radiation dose for each operator, the sample size was calculated for the number of operators (i.e. dosimeters) needed rather than for the number of procedures or patients. Using previous information(12), it was estimated that at least 13 operator dosimeters were needed in order to prove non-inferiority with anabsolute non-inferiority margin of 25 μSv, one-sided alpha level of 0.05 and 80%power. An arbitrary minimum of 13 procedures per operator and per main access site was mandated to minimize the risks of imbalances due to variation in the complexity of the diagnostic or therapeutic procedures within each operator. The non-inferiority test for the primary outcome was performed using a one-sided unpaired t-test to estimate the upper bound of the confidence interval of the difference in thorax radiation dosage comparing radial versus femoral on the operator level. Differently, superiority testing for the primary end-pointwas performed using two-sided Wilcoxon rank-sum unpaired test. A further secondary analysis using a paired Wilcoxon rank-sum test was also performed. Details on the statistical analysis are available in the web extra material.

Endpoints

The primary end-point of the study was the cumulative operator radiation dose at the thorax. Secondary end-points included operator radiation dose at left wrist or at head level, patient procedural radiation dose assessed with DAP values as well as total fluoroscopy time.

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Role of the funding source

The MATRIX program was designed by the last author and approved by the institutional review board at each participating center. The RAD MATRIX substudy(8) was pre-specified in the main study protocol and approved by all participating centers as amended number 5 to the original study protocol. MATRIX was sponsored by the Italian Society of Invasive Cardiology (GISE), a nonprofit organization, and received grant support from The Medicines Company and TERUMO (see Online Appendix). The sponsor and funders had no role in study design, data collection, data monitoring, analysis, interpretation, or writing of the report. Sponsor and companies had no role in study design, data collection, data monitoring, analysis, interpretation, or writing of the report. AS, MR, DH and MV had unrestricted access to all the data of the trial. AS and MV had final responsibility for the decision to submit for publication.

Results

Between October 2011 and November 2014, 8404 patients in 78 centers in Italy, the Netherlands, Spain, and Sweden were randomly allocated to radial (4197 patients) or femoral access (4207 patients). DAP was collected for 6902 patients and a total of 7570 procedures (Online Figure 3). A total of 767 patients undergoing 777 procedures were included in the operator radiation sub-study (RAD MATRIX) performed by 18 operators (Online Figure 3). Four operators refused to further randomize radial patients to left or right radial access (due to the unwillingness to sustain a prolonged uncomfortable position during left radial access in three operators, and in one due to perceived lack of clinical equipoise between left and right radial access) and were excluded from this sub-analysis. As a result, 252 radial procedures were performed in 250 patients by 14 operators, which were allocated to left radial (131 procedures in 130 patients) or right radial access site (121 procedures in 120 patients) (Online Figure 3)

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Procedural Characteristics

Clinical characteristics between radial and femoral groups were similar (Online Table 1). Percutaneous coronary intervention was attempted in more than 80% of the patients in each group (**Table 1**). Patients allocated to the radial group more frequently received the non-randomly allocated access than patients in the femoral group (7% vs. 5%: p=0.0002). In the RAD MATRIX subsample, cross over rates were balanced in the two access groups (**Table 1**).

Patient Radiation Exposure

Median fluoroscopy time was higher in the radial (10.2 min; IQR: 6-16) compared to femoral group (9.1 min; IQR: 5.1-15, p<0.0001, **Table 1**). Median DAP values were also higher in the radial (64.7 Gy*cm^2; IQR: 28.6-120.3) compared to the femoral group (59.1 Gy*cm^2 ;IQR: 25.9-109.5, p=0.0001, **Table 1**). Mean difference of DAP values between radial and femoral access stratified for pre-specified subgroups is shown in Online Figure 4. The results were consistent according to the angiographic system employed (Online Table 3). Fluoroscopy time and DAP values were consistently correlated in the radial (R=0.56) as well as in the femoral group (R=0.56) (Online Figure 5).

Operator Radiation Exposure

<u>Radial or Femoral Access</u>

The primary non-inferiority hypothesis was not reached (mean difference 34.34 µSv with an upper 95% confidence limit of 49.57); p-value for non-inferiority= 0.843); median operator dose per procedure at the thorax level was higher in the radial compared to femoral access group (77 µSv; IQR: 39.9-112 vs. 41 µSv IQR: 23.4-58.5, respectively, p-value for superiority= 0.019, **Central Illustration and Table 2**). A paired analysis yielded identical results**.** After normalization of the operator dose either for fluoroscopy times or DAP, the difference between

radial and femoral access remained significant (Table 2). Procedural operator doses at left wrist and head levels did not differ, although both were numerically higher with radial access (**Central Illustration and Table 2**). The higher radiation dose with radial as compared to femoral access was consistent across individual operators (Online Figure 5).

Left or Right Radial Access

The baseline and procedural features, including DAP and fluoroscopy time, were similar between left and right radial access groups (Online Table 2). Median procedural operator dose at the thorax did not differ in the right radial (84 μSv) compared to the left radial access (52 μSv; p=0.15; **Table 3 and Figure 1**). Compared to femoral access, radiation dose did not differ compared to the left radial access, whereas was significantly higher in the right radial access (Online Tables 4 and 5). The radiation doses at wrist and head did not differ in the right radial compared to the left radial access group (**Table 3 and Figure 1**).

Discussion

Our study is to date the largest study evaluating the radiation exposure in patients and operators during percutaneous coronary interventions with radial or femoral access. Our main finding is that in the setting of ACS with or without ST-segment elevation, operator and patient radiation exposure is higher with radial compared to femoral access. The average increase in radiation exposure for patients undergoing radial instead of femoral access was relatively small, in the range of 10%. However, the radial, compared to femoral access, was associated to an almost two-fold increase in operator radiation exposure at the thorax level. Our results confirm previous observations (13) that DAP is a weak predictor of operator exposure.

In a recent meta-analysis, the difference in patient radiation exposure with radial as compared to femoral access was shown to narrow over time, suggesting that this difference may

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not be present in current practice with experienced radial operators (5). Our findings support the notion that this difference persists in contemporary practice with experienced operators and it may be much greater than previously anticipated especially for complex multivessel intervention, such in non-ST segment elevation MI patients or those with diabetes mellitus.

There are multiple potential explanations for the higher patient and operator radiation exposure associated with radial access. Procedures undertaken via radial access are technically more demanding for operators, especially in case of tortuosity of the subclavian-aortic axis, which can be observed in up to 30% of patients. More intense catheter manipulation is therefore required to overcome the vascular tortuosity and engage the coronary ostia; while the success rate in expert hands is similar to femoral access these maneuvers increase the fluoroscopy time and consequently the radiation dose to patients and operators. Our study confirms previous findings that fluoroscopy time and DAP are correlated and that both are significantly higher in the radial group (5,6).

Other aspects should be considered regarding operator radiation exposure between radial and femoral access. Operator position with respect to X-ray tube and patient can affect radiation exposure by a factor of 40 during percutaneous procedures (14). At variance with operators' position during femoral access, which is well standardized, operators' position during radial access can substantially vary across centers or even within operators of the same center. In many instances, in order to better manipulate the catheter at insertion site in the radial artery, operators are closer to the X-ray tube and are less shielded by the leaded glass mobile panel. Also, the upper ceiling leaded glass is frequently positioned closer to the patient during radial instead of femoral access, in order to have direct access to the arterial sheath. Unfortunately, this translates into a less effective shielding capability from scatter radiation to the operator.

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We did not observe a clear difference in terms of operator radiation dose between right and left radial. Several studies have compared operator radiation dose between radial left or right with inconsistent results (15-19); some showed less operator radiation dose with left instead of right radial but others reported similar radiation dose or higher operator dose with left radial. Various operator positions with respect to X-ray tube and inconsistent locations of mobile shielding devices across operators during right or left radial access may account for such heterogeneous observations.

The absolute increase in DAP values for patients receiving radial instead of femoral access was 5.6 Gy*cm^2. This difference is small and when expressed in terms of patient effective dose is around 1.12mSv. Considering an additional lifetime cancer risk of 2.5%/Sv (1:40000) between age 40 and 60 years (20), radial access would be associated with an increased lifetime cancer risk of 1:35714 (0.0028%). One could consider this an acceptable risk considering that radial instead of femoral access may avoid 6 deaths for every 1000 patients treated (1).

At variance from patients, interventional cardiologists perform thousands of procedures during their lifetime, with the potential for a cumulative effect. Operator exposure was almost twice higher with radial than femoral. Most of the operator body is covered with dedicated shields, such as lead apron and thyroid collar but some operator body regions, such as the head or arms, remain unprotected and directly exposed to radiation. Since a direct correlation between the dose and the risk of cancer even for very low dose of radiation exposure has been suggested (11) and taking also the deterministic risk of radiation into account (i.e. the cumulative risk of cataract) (21) our findings should raise caution within the medical community; the incremental operator effective dose for a single procedure undertaken with radial instead of femoral access is

in the range of 1.1 µSv, corresponding to an additive 330 µSv every 300 procedures. This is similar to an additive radiation exposure of 17 chest X rays.

Some studies suggested significant reductions in operator radiation doses using adjunctive protective drapes placed on patients (22-24) during radial access. Adjunctive personal protections as non-lead protective caps that reduce the head radiation doses should be also considered (25).

Some limitations of our study should be considered. The use of thermoluminescent dosimeters allows only a cumulative analysis of the operator radiation dose. Hence, further analyses of the radiation dose in regards to the complexity of each single procedure performed was not possible, e.g. to target improvements in procedures to reduce radiation exposure. The use of electronic dosimeters that show radiation dose at the end of each procedure would have allowed a better understanding, which factors might ameliorate, or even negate, the differences in radiation exposure observed between radial and femoral access. However, thermoluminescent dosimeters allowed operators to remain blinded to study results. As per study protocol, we did not standardize patient preparation and set-up for radial access but asked each operator to follow his or her routine practice. The inclusion of 18 experienced operators from different centers likely provided a representative sample of current practice with radial access, but cannot be translated to less experienced operators or operators with limited training in the radial access site. The consistency of higher operator radiation exposure across participating operators with radial instead of femoral access suggests that the greater radiation dose is a common issue in current practice. The null finding of right versus left right radial comparison in terms of operator exposure may reflect a power issue and requires further investigation.

Conclusions

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In conclusion, our study shows that radial access is associated with higher operator and patient radiation exposure compared to femoral access. Radial operators and institutions should be sensitized towards radiation risks and adopt adjunctive radio-protective measures.

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PERSPECTIVES

Competency in Medical Knowledge: Radial access as compared to femoral access reduces bleeding and mortality in patients with acute coronary syndrome undergoing invasive management.

Competency in Patient Care: It remains unclear whether radial access increases the risk of operator or patient radiation exposure in contemporary practice when performed by expert operators.

Translational Outlook 1: In this clinical trial that included 8404 patients and 18 radial expert operators equipped with dedicated dosimeters, performing 777 procedures and 767 patients, radial, as compared with femoral access is associated with greater operator and patient radiation exposure.

Translational Outlook 2: Radial operators and institutions should be sensitized towards radiation risks and adopt adjunctive radio-protective measures.

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Figure Legends

Central Illustration: Operator radiation exposure for radial and femoral access. Red boxes: patients randomized to the femoral group. Grey boxes: patients randomized to the radial group.

Figure 1: Operator radiation exposure for left and right radial access. Dark grey boxes: patients randomized to the radial right group. Light grey boxes: patients randomized to the radial left group.

Figure 1. Operator radiation exposure for left and right radial access

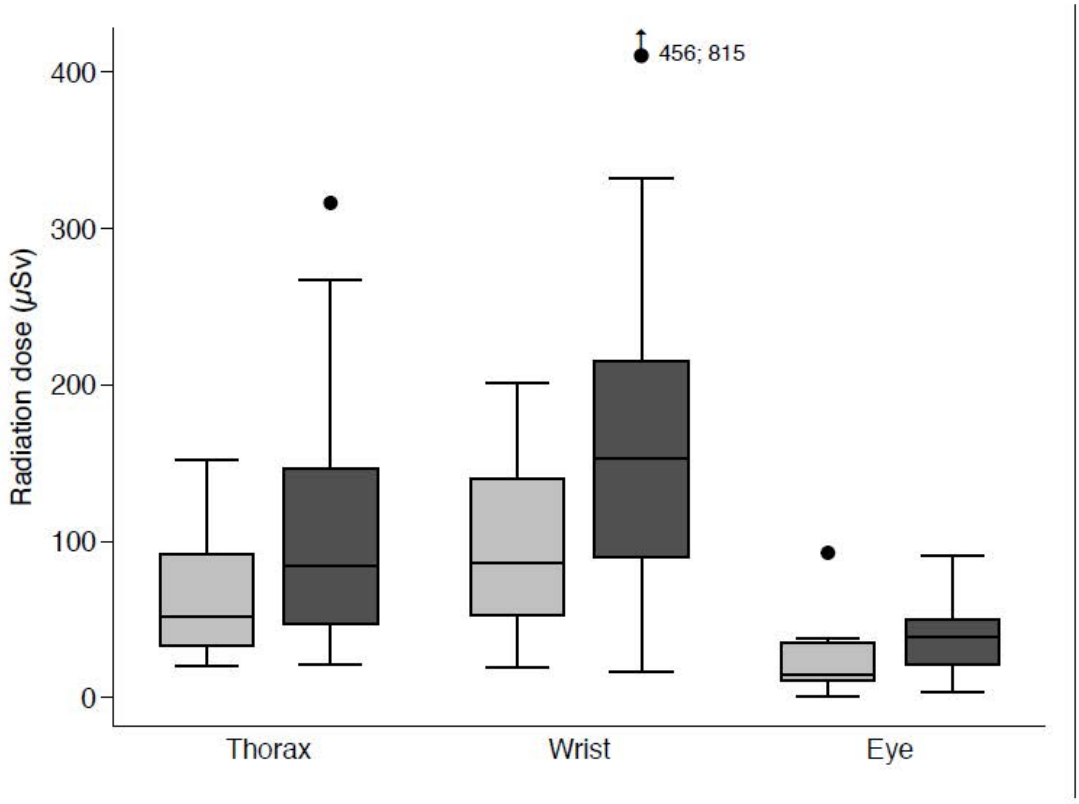

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Table 1. Procedural characteristics of the full MATRIX population and the RAD-MATRIX subsample

	MATRIX			RAD-MATRIX		
	Radial	**Femoral**	**P**	**Radial**	**Femoral**	**P**
Operators	141	155		18	18	
Patients	3448	3454		373	393	
Procedures	3773	3797		379	398	
PCI attempted	3073 (81%)	3094 (82%)	0.971	320 (84%)	324 (81%)	0.284
Number of diagnostic catheters	1.0 ± 0.6	1.0 ± 0.6	0.04	1.0 ± 0.6	1.0 ± 0.6	0.664
Number of guiding catheters	1.6 ± 0.8	1.6 ± 0.7	<0.0001	1.5 ± 0.6	1.6 ± 0.6	0.034
Cross over	273 (7%)	197 (5%)	0.0002	11 (3%)	14 (4%)	0.764
Contrast dose (ml)	163 ± 82	164 ± 86	0.833	170 ± 86	162 ± 81	0.471
Fluoroscopy time (min)	10.2 (6-16)	9.1 (5.1-15)	<0.0001	10 (6-16)	8 (5-14)	0.0004
DAP ($Gy*cm^2$)	64.7 (28.6-120.3)	59.1 (25.9-109.5)	0.0001	74.1 (33.7-130)	67.5 (24.5-114.6)	0.751
Patient Effective dose (mSv)	12.9 (5.7-24.1)	11.8 (5.2-21.9)	<0.0001	14.8 (6.7-26)	13.5 (4.9-22.9)	0.238
PCI Completed	3072 (81%)	3093 (82%)	0.971	320 (84%)	324 (81%)	0.284
Treated artery						
Left main	149 (5%)	122 (4%)	0.082	17 (5%)	21 (7%)	0.878
LAD	1541 (50%)	1534 (50%)	0.656	161 (50%)	154 (48%)	0.463
Left circumflex	876 (29%)	861 (28%)	0.554	87 (27%)	87 (27%)	0.908
Right coronary	1029 (34%)	1029 (33%)	0.850	110 (34%)	112 (35%)	0.868
Number of stents	1.5 ± 0.9	1.5 ± 0.9	0.070	1.6 ± 0.9	1.4± 0.9	0.030
Total stent length (mm)	68 ± 44	67 ± 43	0.276	75 ± 46	68 ± 43	0.131
Thromboaspiration	798 (26%)	827 (27%)	0.498	96 (30%)	88 (27%)	0.681

Results expressed as means± standard deviation, median with interquartile range, or absolute number with percentage in brackets.

652 patients underwent two procedures and eight patients underwent three procedures during index hospitalization

The p-values are estimated accounting for clusters at patient level in the MATRIX population and for clusters both at patient and operator level in the RAD-MATRIX subsample.

DAP, dose area product; LAD, left anterior descending; PCI, percutaneous coronary intervention

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Table 2. Operator radiation exposure for radial and femoral access

	Radial access	Femoral access	Difference between expected and actual sum of ranks for femoral access	P
Operators	18	18		
Procedures	379	398		
Median number of procedures	19.5 (9-23)	16 (10-36)	6	0.849
Thorax dose per procedure (µSv)	77.3 (39.9-112)	40.6 (23.4-58.5)	74	0.019
Wrist dose per procedure (µSv)	117 (68.3-197.8)	74.6 (44.2-115.3)	48.5	0.125
Eye dose per procedure (µSv)	33.9 (14.2-44.8)	20.6 (9.6-32.7)	46	0.146
Operator Effective dose (µSv)	2.3 (1.2-3.4)	1.2 (0.7-1.8)	74	0.019
Dose normalized by FT(µSv/min)				
Thorax dose	5.6 (4-9.8)	3.6 (3-4.9)	69	0.029
Wrist dose	8.8 (6.6-13.7)	5.3 (4.6-9.3)	41	0.195
Eye dose	2.4 (1.5-3.4)	1.7 (1-2.2)	37	0.242
Dose normalized by DAP (µSv/Gy*cm^2)				
Thorax dose	0.8 (0.6-1.1)	0.5 (0.3-0.6)	77	0.015
Wrist dose	1.2 (0.9-2.3)	0.9 (0.6-1.3)	48	0.129
Eye dose	0.3 (0.2-0.5)	0.3 (0.1-0.4)	39	0.217

Results expressed as median with interquartile range

The p-values refer to superiority and come from two-sided unpaired Wilcoxon rank-sum test.

DAP, dose area product; FT, fluoroscopy time

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Table 3. Operator radiation exposure for left and right radial access

	Left radial access	Right radial access	Difference between expected and actual sum of ranks for right radial access	P
Operators	14	14		
Procedures	131	121		
Median number of procedures	6.5 (4-10)	9 (2-14)	-14	0.519
Thorax dose per procedure (µSv)	51.7 (33.2-91.9)	84.2 (47.1-146.1)	-31	0.154
Wrist dose per procedure (µSv)	86.5 (52.6-139.8)	152.6 (89.4-214.6)	-35	0.108
Eye dose per procedure (µSv)	14.8 (11-34.8)	38.6 (21.1-50)	-38.5	0.077
Operator Effective Dose (µSv)	1.6 (1-2.8)	2.6 (1.4-4.4)	-31.0	0.016
Dose normalized by FT (µSv/minute)				
Thorax dose	4.1 (2.5-7.3)	7.1 (4-10.8)	-36.5	0.093
Wrist dose	8.8 (4.6-11)	11.5 (6.4-15.4)	-30	0.168
Eye dose	1.3 (0.6-2.9)	2.6 (1.3-3.9)	-32	0.141
Dose normalized by DAP (µSv/Gy*cm^2)				
Thorax dose	0.6 (0.4-0.8)	0.7 (0.5-1.1)	-27	0.215
Wrist dose	1.0 (0.6-1.2)	1.2 (0.9-2.3)	-25.5	0.241
Eye dose	0.2 (0.1-0.5)	0.3 (0.2-0.5)	-17	0.435

Results expressed as median with interquartile range

The p-values come from two-sided unpaired Wilcoxon rank-sum test.

DAP, dose area product; FT, fluoroscopy time