Original Article

Is single-catheter technique for coronary angiography an optimal tool for beginners in interventional cardiology?—randomized controlled study TRACT 2: Transradial Coronary Angiography Trial 2

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Background: Transradial coronary angiography can be performed using a dual-catheter technique (DCT) or single-catheter technique (SCT). The current study aimed to compare DxTerity SCT Ultra and the Trapease curve SCT catheters with DCT catheters in procedures performed by young, less experienced, interventional cardiologists.

Methods: For this prospective, single-blinded, randomized study 107 were enrolled and assigned to 1 of 3 groups. They underwent planned coronary angiography at the Second Department of Cardiology Jagiellonian University in Kraków. In groups 1 (n=37) and 2 (n=35), DxTerity SCT Ultra catheters and the Trapease curve were used, respectively. In control group 3 (n=35), standard DCT Judkins catheters were applied. One patient was excluded from group 2, bringing the total number of cases analysed to 106. The study endpoints comprised the percentage of optimal stability, proper ostial artery engagement, a good quality angiogram, the duration of each procedure stage, the amount of contrast and the radiation dose.

Results: The highest percentage of optimal stability was observed in group 1 for the right coronary artery (RCA): 94%, and in group 3, for the left coronary artery (LCA): 85%. The necessity to change the catheter was most common in group 2. Group 1 was characterised by a shorter total procedural time. The contrast volume was higher in group 2, while there were no differences in radiation dose.

Conclusions: SCT is at least as adequate as DCT for young cardiologists. SCT was associated with lower necessity of catheter exchange during RCA visualization. The DxTerity Ultra curve catheter allows shortening the total procedure time.

Keywords: Coronary artery angiography; dual-catheter technique (DCT); novice interventional cardiologists; single-catheter technique (SCT)

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Introduction

Coronary angiography is the reference technique for assessing both the presence and severity of coronary artery disease. The transradial approach (TRA) has been reported to have many advantages over transfemoral procedures (TFA) for percutaneous coronary intervention (PCI) in terms of the presence of significant periprocedural bleeding, vascular complications and major adverse cardiac events, which are associated with a risk of subsequent morbidity, mortality and hospital length of stay after the procedure (1,2). TRA has been recommended as the first choice for vascular access in coronary angiography procedures (3,4), particularly in patients with acute coronary syndromes (5).

Transradial coronary angiography is usually performed using two catheters with different curvatures, one for each coronary artery. Alternatively, transradial coronary angiography can be performed by applying only one catheter fitting into both ostia of the coronary arteries. There is limited data regarding potential performance differences between the single-catheter technique (SCT) compared to the dual-catheter technique (DCT) in modern coronary catheterisation. The present study is regarded as a continuation of the previously published TRACT 1: Trans RAdial Coronary Angiography Trial 1 pilot study (6). As reported in the previous research results, the investigated curves of diagnostic catheters differ in terms of TRA effectiveness. In the TRACT 1 study, the Ultra curve and the Trapease curve catheters had lower rates of catheter replacement, shorter catheter dependent time and lower total contrast volume than the Transformer curve and Tracker curve catheters. Since they appear to be the most optimal for SCT, they were included in this study. Moreover, unlike the previous study, in this trial, coronary angiographies were performed by cardiology fellows in 3rd year of a specialization program in cardiology. They had previous experience of performing at least 200 self-made diagnostic procedures using standard DCT. Thus, the current study is aimed at investigating the efficacy of SCT and comparing the results to the standard DCT in transradial coronary angiography among young adepts of interventional cardiology. We present this article in accordance with the CONSORT reporting checklist (for reporting of Multi-Arm Parallel-Group Randomized Trials) (available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-212/rc).

Methods

This is a prospective, single-blinded, randomised controlled trial. The study comprised 107 patients, enrolled from February 2021 to February 2023. Procedures were conducted at the Second Department of Cardiology, Jagiellonian University in Kraków by three less experienced, young adepts of interventional cardiology. The inclusion criteria were patients' written informed consent, stable coronary artery disease, age above 18, qualification for invasive diagnostic coronary angiography as well as a good pulse found on the radial artery and above, verified in physical examination. Exclusion criteria were a diagnosis of acute coronary syndrome, cardiogenic shock, previous coronary artery bypass grafting, pregnancy, active haemodialysis fistula in the forearm, hyperthyroidism and TRA failure. Patients were assigned to 1 of 3 groups by simple randomization and compared using intention-to-treat analysis. Coronary angiography operators were responsible for enrolling patients who met the inclusion criteria and assigning them to groups. For this purpose, they rolled a dice and, depending on the number of points rolled, assigned the patient to groups according to the following rules: group 1: 1 and 2 points, group 2: 3 and 4, and group 3: 5 and 6. Patients did not know to which group they were assigned. In groups 1 and 2, which consisted of 37 and 35 patients, respectively, DxTerity TRA diagnostic catheters dedicated to the SCT of TRA angiography from Medtronic (Medtronic, Santa Rosa, CA, USA) were used. In group 1, the Ultra Curve catheter 6F was used, while in group 2, the Trapease Curve catheter 6F was applied. For people taller than 175 cm, the above catheters were used in size 4.5, and in sizes 4.0 and 3.5 for people shorter than 175 cm. In group 3, which was the DCT control group consisting of 35 patients, Judkins right 4.0 and Judkins left 3.5 diagnostic catheters were used. One patient from Group 2 was excluded due to the failure of TRA, but the procedure was successfully completed using femoral access. Details of patients' enrolment are shown on *Figure 1*.

Procedures were performed in a standard manner, from right radial access, using 6F vascular sheaths and 5,000 IU unfractionated heparin injection after sheath insertion. To visualise the coronary arteries, standard angiography projections were used: two for the right coronary artery (RCA) and four for the left coronary artery (LCA). The study endpoints were: rating catheter ostial stability, assessing the duration of each procedure step, contrast volume, radiation dose and incidence of complications. Ostial stability was defined as catheter stability and proper engagement of the coronary artery ostia during contrast injection, which was assessed on a 3-point scale

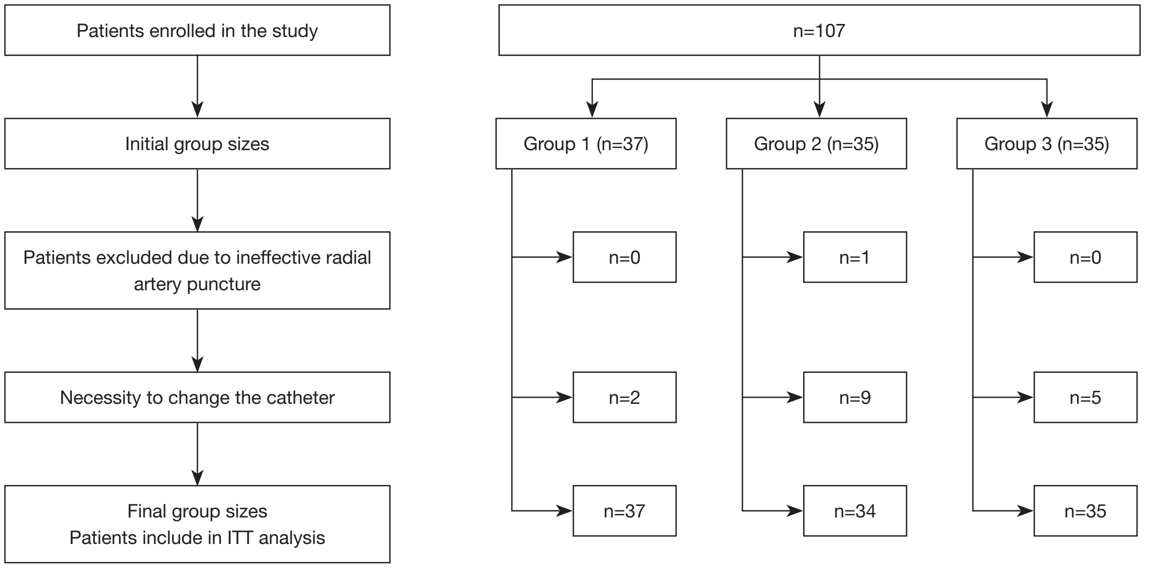

Figure 1 Participant flow diagram. ITT, intention to treat.

for each coronary artery by the operator who performed the angiography. The optimal grade was awarded for the coaxial position of the catheter in the ostium of the coronary artery, followed by optimal filling of the artery with the contrast agent during injection. The suboptimal rate was determined when the catheter fell out from the coronary ostium at least once and its position had to be corrected. Finally, the worst grade was given when ostial engagement was not achieved and the catheter had to be changed. The duration of each procedure step was measured by a technician or non-operating physician accompanying each procedure:

- T1: time needed to introduce the diagnostic catheter, from entering the vascular sheath to reaching the ascending aorta;
- T2: time needed to properly engage the ostium of the RCA by the catheter positioned in the ascending aorta;
- T3: time of fluoroscopy during recording the angiography of the RCA;
- T4: time needed to properly engage the ostium of the LCA by the catheter positioned in the ascending aorta; in group 3, this procedure step comprised of changing the Judkins catheter from the right to left and time needed to properly engage the ostium of the LCA;
- T5: time of fluoroscopy during recording the angiography of the LCA;
- T6: total procedural time.

The volume of contrast (mL) used for finding and visualising each coronary artery was measured and totalled to achieve final amount of contrast. In all procedures, the contrast was injected manually. The radiation dose was measured as air kerma (mGy) and, similarly as in the case of the contrast, it was gauged for each coronary artery and the total given. In each procedure, the operator had to declare which coronary artery would be cannulated first. The incidence of the following complications was investigated: radial artery spasm, pain during catheter insertion, puncture-site haematoma, upper limb haematoma, coronary artery dissection, myocardial infarction, death, catheter fracture or malfunction, or necessity to implement another coronary angiography. Essential information about patients, their comorbidities and basic echocardiography parameters were collected from medical records.

Statistical analysis

Standard descriptive statistics were used to describe the data. Qualitative data are presented as numbers with percentages, and groups were compared using Pearson's chi-square test or Fisher test or Fisher-Freeman-Halton test. The normality of the distribution of quantitative data was investigated using the Shapiro-Wilk test, while homogeneity of variance was examined using Levene's test. Normally distributed data are presented as mean with standard deviation (mean ± SD), and medians with the quartiles 1 and 3 [median (Q1, Q3)] were used for non-

Table 1 Patients' baseline characteristics

Characteristics	Group 1, n=37	Group 2, n=34	Group 3, n=35	P value
Age (years)	68±11	67±10	65±11	0.43
Men	24 (64.9)	16 (47.1)	25 (71.4)	0.10
Body mass (kg)	78±14	77±12	80±12	0.40
Body height (cm)	169±6	168±8	170±7	0.53
BMI (kg/m^2)	27±4	28±4	27±3	0.91
Diabetes	10 (27.0)	14 (41.2)	10 (28.6)	0.40
Diabetes treated with insulin	2 (5.4)	4 (11.8)	3 (8.6)	0.57
Hypertension	29 (78.4)	23 (67.6)	27 (77.1)	0.57
Hypercholesterolaemia	16 (43.2)	15 (44.1)	15 (42.9)	>0.99
Current smoking	11 (29.7)	9 (26.5)	9 (25.7)	0.92
Kidney disease	5 (13.5)	7 (20.6)	3 (8.6)	0.36
Lung disease	6 (16.2)	3 (8.8)	3 (8.6)	0.59
Arrhythmia	13 (35.1)	8 (23.5)	8 (22.9)	0.43
Heart failure	2 (5.4)	6 (17.6)	3 (8.6)	0.25
Prior myocardial infarction	11 (29.7)	13 (38.2)	8 (22.9)	0.39
Prior stroke or TIA	5 (13.5)	4 (11.8)	2 (5.7)	0.57
Prior PCI	7 (18.9)	6 (17.6)	10 (28.6)	0.51
EF (%)	45 [38.5, 53.5]	51 [43.75, 60]	51 [40, 60]	0.22
Diameter of aorta (mm)	35 [33.5, 38.5]	36 [31, 40.5]	37 [34, 40]	0.49
Left ventricle diastole diameter (mm)	56 [51, 57]	55 [51.75, 57.5]	56 [52, 58]	0.98

Values are presented in n (%), mean ± standard deviation or median [Q1, Q3]. BMI, body mass index; TIA, transient ischemic attack; PCI, percutaneous coronary intervention; EF, ejection fraction.

normally distributed data. Quantitative data with normal distribution and homogenous variance were compared using one-way anlysis of variance (ANOVA) with Tukey's *post-hoc* test, otherwise, Kruskal-Wallis one-way ANOVA with Dunn's *post-hoc* test was used. The significance level of α was set at 0.05. All statistics were carried out using PS IMAGO PRO 8.0.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Jagiellonian University (No. 1072.6120.101.2019 issued on 24 April 2019) and informed consent was taken from all the patients.

Results

Baseline characteristics

There were no differences between groups regarding age, sex, basic anthropometric characteristics, comorbidities, previous medical history or basic echocardiographic parameters. Details are presented in *Table 1*.

Ostial stability and engagement of catheters

The highest percentage of optimal rate in the evaluation of catheter ostial stability during RCA imaging was observed in group 1 (94%), followed by group 3 (85%) and group 2 (76%), while suboptimal was most common in group 2 (24%), and similar in groups 3 (3%) and 1 (3%). In the case of LCA, optimal stability was the most common in

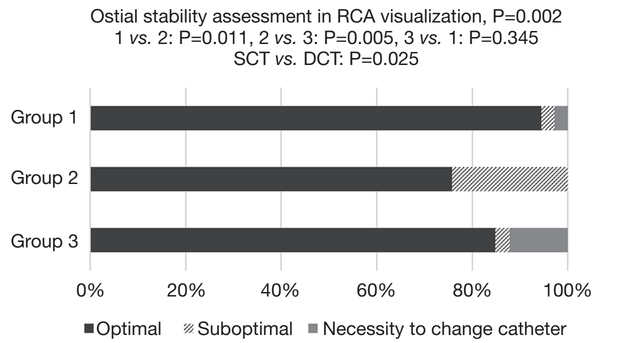

Figure 2 Evaluation of ostial stability in RCA imaging. RCA, right coronary artery; SCT, single-catheter technique; DCT, dual-catheter technique.

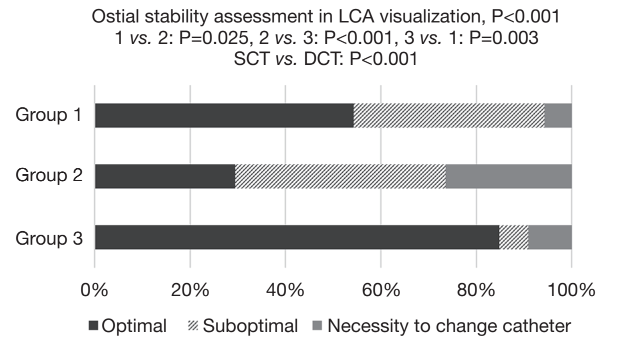

Figure 3 Evaluation of ostial stability in LCA imaging. LCA, left coronary artery; SCT, single-catheter technique; DCT, dual-catheter technique.

group 3 (85%), while in groups 1 (54%) and 2 (29%), it was noticeably lower. The most suboptimal results were observed in group 2 (44%), followed by groups 1 (40%) and 3 (6%). Details regarding RCA are presented in *Figure 2*, and about LCA, in *Figure 3*. Examples of angiograms concerning the tested catheters are shown in *Figure 4*.

The necessity to change the catheter was most common in group 2 and usually occurred during LCA imaging, which is shown in *Table 2*.

Procedural characteristics

The right radial artery was used as vascular access in all procedures. One patient was excluded due to unsuccessful radial artery cannulation, but the procedure was safely completed via femoral access without any complications. In each angiography, RCA was the vessel intended to be visualised as the first one, but the necessity to change the intention occurred twice in group 1.

Duration of each procedural step

Group 1, compared to the other groups, was characterised by a shorter time of proper LCA ostium involvement (T4) and a shorter overall procedure time (T6). Analysis of the time-frames, which directly depend on the catheter type (T1, T2, T4), revealed that the totalled duration of catheter introduction and searching for coronary artery ostia is shorter in group 1 compared to group 2. There were no statistically significant differences in other time-frames between groups. Details are presented in *Table 3*.

Contrast volume and radiation dose

Group 2, compared to the others, was characterised by a larger contrast volume used both for LCA imaging and during the entire procedure. There was no difference in radiation dose. The results are summarized in *Table 4*.

Complications

There were no major complications such as the dissection of a coronary artery, myocardial infarction, death, catheter fracture or malfunction, or necessity for another coronary angiography. Mild complications, which occurred rarely, are presented in *Table 5*.

Treatment pathway after diagnostic catheterisation

Appropriate treatment was initiated for each of the patients in the study based on angiography results, symptoms and patient preferences. Conservative treatment and percutaneous coronary interventions were the most common. In some cases, the Heart Team consultation was needed, mainly to decide between PCI and CABG. One patient from group 3 was qualified for aortic valve reoperation, thus, the numbers in this group do not total 35. Particular information is presented in *Table 6*.

Discussion

Coronary artery disease is reported to be the leading cause of morbidity and mortality worldwide (7). For that reason, optimal tools for its evaluation have been extensively

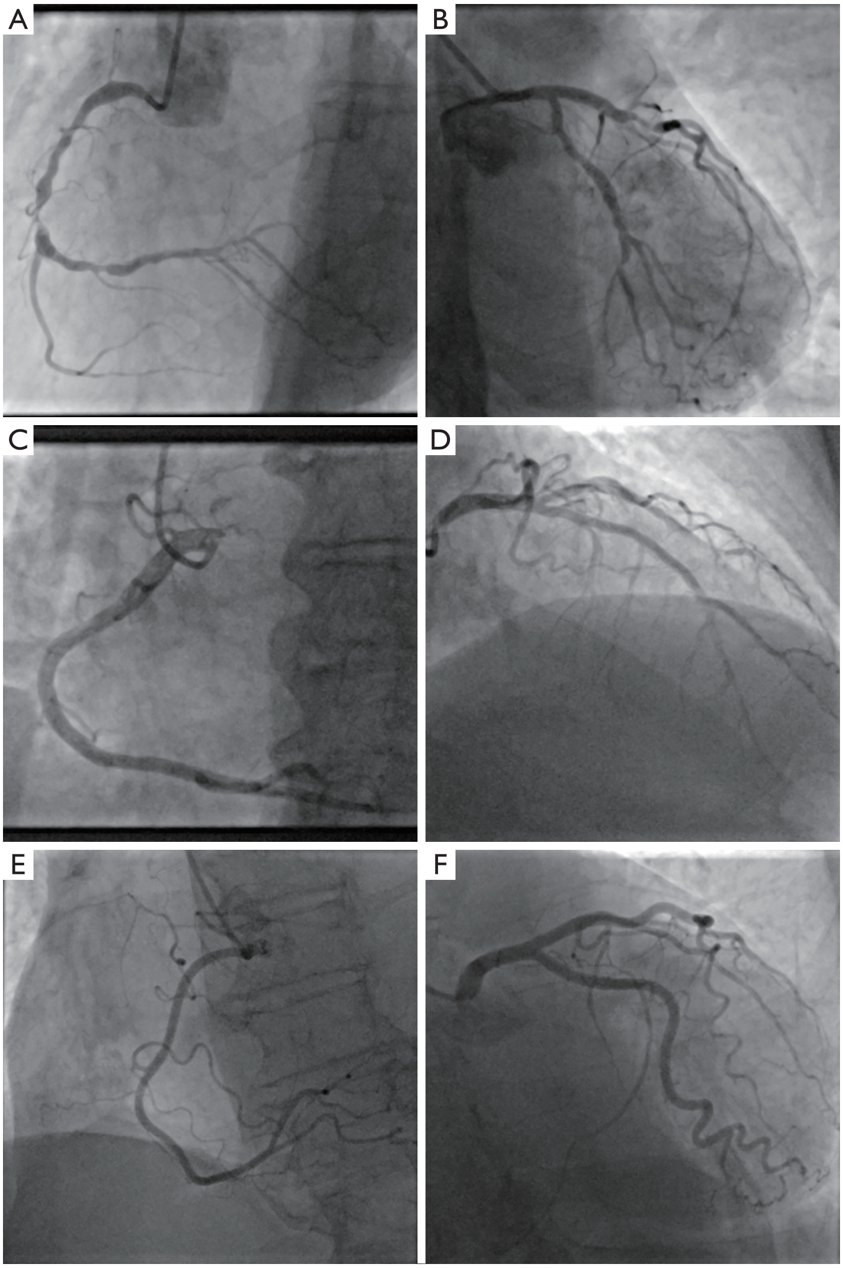

Figure 4 Examples of ostial stability among investigated catheters. (A) Suboptimal visualisation of the RCA with ultra diagnostic catheter; (B) optimal visualisation of the LCA with ultra diagnostic catheter; (C) suboptimal visualisation of the RCA with trap diagnostic catheter; (D) suboptimal visualisation of the LCA with trap diagnostic catheter; (E) optimal visualisation of the RCA with standard Judkins right diagnostic catheter; (F) optimal visualisation of the LCA with standard Judkins left diagnostic catheter. RCA, right coronary artery; LCA, left coronary artery.

searched. Coronary angiography remains an established technique, recommended as the method of choice in patients with suspected coronary artery disease raised by non-invasive methods of coronary ischaemia. Furthermore, due to its broad availability and low-cost (8) as well as the accepted level of potential periprocedural complications, coronary angiography endures a significant role in randomised clinical trials assessing the safety and efficacy of

Table 2 Percentage of procedures requiring a change of catheter

Vessel	Group 1, n=37	Group 2, n=34	Group 3, n=35	P value
RCA	1 (2.7)	0 (0)	4 (11.4)	0.08
RCA between groups	$P_{(1\ vs.\ 2)}$=1.0	$P_{(2\ vs.\ 3)}$=0.114	$P_{(3\ vs.\ 1)}$=0.193	
RCA (SCT *vs.* DCT)	1 (1.4)		4 (11.4)	0.04
LCA	2 (5.4)	9 (26.5)	3 (8.6)	0.025
LCA between groups	$P_{(1\ vs.\ 2)}$=0.021	$P_{(2\ vs.\ 3)}$=0.062	$P_{(3\ vs.\ 1)}$=0.67	
LCA (SCT *vs.* DCT)	11 (15.5)		3 (8.6)	0.379
Total	2 (5.4)	9 (26.5)	5 (14.3)	0.049
Total between groups	$P_{(1\ vs.\ 2)}$=0.021	$P_{(2\ vs.\ 3)}$=0.244	$P_{(3\ vs.\ 1)}$=0.254	
Total (SCT *vs.* DCT)	11 (15.5)		5 (14.3)	1.0

Values are presented in n (%). The numbers do not sum up, because the total means patients with the need to change the catheter, without distinguishing whether the need concerned one or both vessels. RCA, right coronary artery; SCT, single-catheter technique; DCT, dual-catheter technique; LCA, left coronary artery.

Table 3 Time frames of each procedural step

Time frames	Group 1, n=37	Group 2, n=34	Group 3, n=35	P value
T1 (s)	40 [32, 70]	50 [39.75, 80]	40 [28, 90]	0.49
T2 (s)	20 [15, 53.5]	21 [19, 32.5]	20 [15, 52]	0.97
T3 (s)	22.5 [18, 30]	25 [20, 40]	25 [16, 45]	0.75
T4 (s)	30 [20, 52.5]	60 [33.5, 223.5]	65 [42, 90]	<0.001
Post-hoc test	$P_{(1\ vs.\ 2)}$≤0.001	$P_{(2\ vs.\ 3)}$=0.56	$P_{(3\ vs.\ 1)}$≤0.001	
T5 (s)	75 [42.5, 100]	85 [50, 120]	60 [40, 90]	0.27
T6 (s)	340 [270, 420]	430 [300, 600]	420 [300, 540]	0.039
Post-hoc test	$P_{(1\ vs.\ 2)}$=0.03	$P_{(2\ vs.\ 3)}$=0.98	$P_{(3\ vs.\ 1)}$=0.028	
T1 + T2 + T4 (s)	107 [85, 165]	132.5 [108, 284]	155 [95, 250]	0.047
Post-hoc test	$P_{(1\ vs.\ 2)}$=0.019	$P_{(2\ vs.\ 3)}$=0.55	$P_{(3\ vs.\ 1)}$=0.08	

Values are presented in median [Q1, Q3].

Table 4 Summary of contrast volume and radiation dose during the procedure in all groups

Amount of contrast and radiation dose	Group 1, n=37	Group 2, n=34	Group 3, n=35	P value
RCA contrast volume (mL)	15 [15, 21]	20 [15, 25]	17 [12, 25]	0.34
RCA radiation dose (mGy)	22 [9.5, 31.5]	15 [8, 40]	19 [8, 33]	0.98
LCA contrast volume (mL)	36 [30, 50]	50 [40, 80]	40 [30, 50]	0.002
Post-hoc test	$P_{(1\ vs.\ 2)}$=0.001	$P_{(2\ vs.\ 3)}$=0.002	$P_{(3\ vs.\ 1)}$=0.86	
LCA radiation dose (mGy)	41 [30.5, 66.5]	60 [33.5, 93]	41 [21, 65]	0.11
Total contrast volume (mL)	53 [47.5, 70]	67.5 [60, 100]	58 [45, 70]	0.003
Post-hoc test	$P_{(1\ vs.\ 2)}$=0.003	$P_{(2\ vs.\ 3)}$=0.004	$P_{(3\ vs.\ 1)}$=0.98	
Total radiation dose (mGy)	67 [47.5, 127]	83 [45, 129.5]	66 [28, 98]	0.28

Values are presented in median [Q1, Q3]. RCA, right coronary artery; LCA, left coronary artery.

Table 5 Periprocedural complications

Complication	Group 1, n=37	Group 2, n=43	Group 3, n=35	P value
Radial artery spasm	3 (8.1)	2 (5.9)	2 (5.7)	>0.99
Pain during catheter insertion	4 (10.8)	5 (14.7)	4 (11.4)	0.87
Puncture-site haematoma	1 (2.7)	1 (2.9)	1 (2.9)	>0.99
Upper limb haematoma	0	1 (2.9)	0	0.31

Values are presented in n (%).

Table 6 Treatment pathway after diagnostic catheterisation

Treatment pathway	Group 1, n=37	Group 2, n=34	Group 3, n=35	P value
Conservative treatment	9 (24.3)	14 (41.2)	11 (31.4)	0.31
PCI	14 (37.8)	6 (17.6)	10 (28.6)	0.18
FFR	4 (10.8)	5 (14.7)	4 (11.4)	0.87
IVUS	1 (2.7)	0	0	>0.99
CABG	3 (8.1)	1 (2.9)	4 (11.4)	0.48
Heart team	6 (16.2)	8 (23.5)	5 (14.3)	0.59

Values are presented in n (%). PCI, percutaneous coronary intervention; FFR, fractional flow reserve; IVUS, intravascular ultrasound; CABG, coronary artery bypass grafting.

new percutaneous coronary intervention devices.

Currently, the preferable vascular approach for coronary angiography and percutaneous coronary intervention procedures is through the radial artery, which has been reported to be superior in comparison to transfemoral access in terms of haemostasis time, mechanical irritations of vessels and duration of hospitalisation (1,8-10). Despite the previously mentioned advantages, the TRA is regarded as more technically demanding than the transfemoral one and is associated with a longer procedure duration along with greater radiation exposure (11,12), particularly taking procedures provided by less-experienced operators and/or complex patient anatomy into consideration. Therefore, gaining proficiency in the radial approach for coronary angiography would ultimately lead to better patient outcomes.

Catheter selection and engagement techniques are crucial factors for obtaining appropriate image quality of angiograms and successfully completing percutaneous coronary interventions. One of the relatively newly presented ideas in modern cardiac catheterisation is the concept of the SCT implemented to shorten the coronary angiography duration and reduce the risk of vascular spasm related to catheter exchange, while sustaining optimal angiographic image quality. In their pilot study, Kim *et al.* reported that Tiger diagnostic catheters, designed purposely for the mentioned technique, proved to be effective in ostial engagement of both the RCAs and LCAs in 100% and 91% of cases, respectively (13). Consequently, in following years, further investigations on the one-catheter TRA concept, including new generations of catheters, were provided (14,15).

The performance differences between SCT compared to DCT for transradial coronary angiography have been heavily discussed regarding the impact of catheter choice on procedural performance in specific subgroups. Schneider *et al.* conducted a study in which the performance of different catheter concepts was set together with gender. Interestingly, the chosen catheter concept appeared to have less impact on procedural outcomes in female patients, while men patients, particularly of younger age, showed significant differences in angiography time and contrast volume in favour of the DCT (16).

In accordance with the results of our study, the success rate in assessing optimal ostial stability differs between the groups using opposing techniques. The ostial catheter stability itself is recognised as an important factor in creating radiofrequency lesions while performing coronary angiography procedures. In terms of providing ostial stability in the RCA, the Ultra catheter in the SCT appeared to be superior. In addition, the highest rate of necessity to switch the catheter was reported in the group using standard DCT catheters during RCA angiography. However, the best ostial stability regarding the LCA was assessed with the DCT. The results provided in the study are compatible with the data previously reported both in the literature and initial trial (6,17), which leads to the conclusion that the DCT is favoured in engaging the left coronary ostium whilst the one-catheter technique showed advantages in engagement of the right one, regardless of operator experience.

Discussing contrast volume and radiation dose between the groups, statistically significant differences occurred in the TrapEase curve catheter group, as a larger contrast volume was used both for LCA imaging and during the entire procedure. There was no difference in radiation dose. That phenomenon can be explained on the basis of the fact that the necessity to switch to another catheter was more frequently observed in group 2, which consequently leads to the usage of a greater amount of contrast during the procedure. The direct relationship between the experience of the operator, and the parameters of both SCT and DCT in the form of total radiation dose and total contrast volume, is yet to be determined.

Comparing the duration of each procedural step between the groups, a difference in the total procedural time was observed. According to the present study, the shortest time periods were fund in the Ultra group, which corresponds to the main aim of introducing the SCT in clinical practice, which is to decrease the procedure duration. That leads to the conclusion that introducing the SCT among beginners in interventional cardiology would be clinically significant. Despite having less experience in performing coronary angiography among operators, major complications concerning coronary artery dissections, serious adverse events and catheter fracture or malfunction were not observed in the present study. Mild complications, including pain during the catheter insertion, occurred rarely, regardless of the investigated technique, which differs from the 2019 meta-analysis conducted by Alushi *et al.*, in which DCT was connected with a significantly higher rate of radial artery spasm (18). Nevertheless, there is still a need to develop new strategies to avoid the periprocedural complications like radial artery spasm, local hematomas or pain during catheter insertion, which are among the most frequently reported complications while performing coronary angiography from the TRA. The radial artery spasm as the clinically most significant one, is defined as the temporary, sudden narrowing of the radial artery. Its prevention is regarded as essential in reducing the risk of the procedure failure as well as patients' discomfort both during and after the procedure. Taniguchi *et al.* in their recent study revealed that the usage of flow-mediated dilatation before coronary angiography significantly reduced the TRA-related complications, which could be particularly important towards beginners in interventional cardiology (19).

Several limitations of the present study should be recognised. Firstly, the group sample consisted of 107 patients, which is regarded as relatively small. Secondly, the data from the literature are ambiguous in terms of significant differences in procedure outcomes between the left and right radial approach (20). Nevertheless, in the present study, coronary angiographies were provided with right TRA and that factor should be treated as a study limitation for the results cannot be directly referred to the left side. Thirdly, the contrast was injected manually and its volume depended on the operator, which may have influenced the results. The other obvious limitation is the fact that coronary angiographies were performed by different young interventional cardiologists as well as due to the logical settings, operators were not able to use all investigated catheters in one procedure. Finally, due to anatomical variations of the vascular system, procedures cannot be provided fully repeatedly in each patient.

Conclusions

The SCT is at least as effective as the double-catheter one in coronary angiography conducted by young adepts of interventional cardiology. SCT was associated with lower necessity of catheter exchange during RCA visualization. The DxTerity Ultra curve catheter performs best in terms of ostial stability of the SCT catheters tested and allows for shortening procedure time compared to standard, DCT Judkins catheters.

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Footnote

Reporting Checklist: The authors have completed the CONSORT reporting checklist (for reporting of Multi-

Arm Parallel-Group Randomized Trials). Available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-212/rc

Trial Protocol: Available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-212/tp

Data Sharing Statement: Available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-212/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-212/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Jagiellonian University (approval No. 1072.6120.101.2019 issued on 24 April 2019) and informed consent was taken from all the patients.

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