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Research Article

A RETROSPECTIVE ANALYSIS OF RADIAL ARTERY OCCLUSION RATES IN ACS PATIENTS UNDERGOING TRANSRADIAL PCI: A SINGLE-CENTER EXPERIENCE

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ABSTRACT

Aim: Transradial access (TRA) has become the preferred approach for percutaneous coronary intervention (PCI) due to reduced vascular complications. However, radial artery occlusion (RAO) remains a recognized complication. We evaluated RAO rates in acute coronary syndrome (ACS) patients undergoing transradial PCI at a high-volume center and compared outcomes between those receiving ticagrelor versus clopidogrel.

Materials and Methods: We retrospectively analyzed 240 ACS patients who underwent transradial PCI from June 1, 2022 to June 1, 2024 at Konya City Hospital, Department of Cardiology. All patients received standard heparin (weight-based), immediate sheath removal, and radial compression with Terumo or Shunmei close pads. Barbeau Test results at follow-up (1 month) were used to detect RAO (Type D waveform). Clinical and laboratory characteristics, including echocardiographic ejection fraction (EF), were compared between ticagrelor and clopidogrel groups.

Results Mean age was 60.4±11.2 years, and 71.7% were male. Overall, 66.7% presented with ST-elevation myocardial infarction (STEMI) and 33.3% with non-STEMI (NSTEMI). Laboratory profiles and EF (~48%) did not differ between ticagrelor (n=140) and clopidogrel (n=100) groups. Radial artery patency was high: only 5 patients (2.1%) had RAO (Barbeau Type D). No significant difference in RAO rates was observed between ticagrelor (2.1%) and clopidogrel (2.0%) groups (p=0.96).

Conclusion: In this retrospective analysis, standardized transradial PCI procedures achieved low RAO rates (~2%) with no significant difference between ticagrelor and clopidogrel. These findings underscore the safety and efficacy of radial interventions when performed by experienced operators using best practices, and confirm that RAO should be viewed as a manageable complication.

Keywords: Radial artery occlusion, Transradial PCI, Acute coronary syndrome, Ticagrelor, Clopidogrel

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INTRODUCTION

Transradial access (TRA) for percutaneous coronary intervention (PCI) has become the preferred approach in contemporary practice due to improved safety and patient comfort. Since its first description by Campeau in 1989, radial artery access has been adopted worldwide, especially in acute coronary syndromes (ACS), because it significantly reduces access-site complications compared to transfemoral access(1,2). Large randomized trials and meta-analyses have demonstrated that TRA is associated with a markedly lower risk of major bleeding and vascular complications, as well as reduced mortality in STEMI, when compared with transfemoral access(3). These benefits have led to a Class I recommendation for the "radial-first" strategy in ACS management guidelines(4).

Despite these advantages, transradial PCI is not without drawbacks. Radial artery occlusion (RAO) is recognized as the most common complication of TRA(5). RAO occurs when the radial artery thrombosis after the procedure, potentially precluding future use of that artery for repeat access, coronary bypass grafting, or arteriovenous fistula creation. Reported RAO incidence varies widely in literature, from <1% up to ~10% in contemporary series, depending on patient factors, procedural technique, and how and when patency is assessed(6).

Notably, many cases of RAO are asymptomatic due to the hand's dual blood supply, and clinically evident ischemia is exceedingly rare(7). Indeed, major trials often did not report RAO in outcomes, considering its clinical significance to be low; for example, in the RIVAL trial symptomatic RAO occurred in only 0.2% of cases(2). Nonetheless, preventing RAO is important to preserve the radial artery for future interventions. Measures known to reduce RAO include adequate intraprocedural heparinization, use of smaller sheaths, and adoption of patent hemostasis (allowing some antegrade flow during compression)(6). The Barbeau test – a plethysmographic assessment of collateral hand perfusion – and its reverse application are commonly used to evaluate radial artery patency post-procedure, classifying waveforms from Type A (normal) to Type D (absent, indicating occlusion) (8). Such noninvasive tests enable detection of RAO in follow-up. Such noninvasive tests enable detection of RAO in follow-up.

Given the emphasis on TRA standardization and RAO prevention, we undertook a retrospective study at Konya City Hospital, Department of Cardiology to examine real-world outcomes of radial access PCI in ACS patients. In our high-volume center, experienced operators and trained nursing staff adhere to protocols aimed at minimizing complications, including strict avoidance of sheath reuse, use of dedicated radial compression devices, and routine pharmacological spasm prophylaxis. We specifically sought to determine the incidence of radial artery occlusion using the Barbeau test in the follow-up of these patients and to compare outcomes between those treated with ticagrelor versus clopidogrel as part of dual antiplatelet therapy (DAPT). Our hypothesis was that consistent technique and post-procedural care would yield low RAO rates, and that there would be no significant difference in RAO between patients on ticagrelor vs. clopidogrel.

MATERIALS AND METHODS

Study design and population

This study was designed as a single-center retrospective analysis. We reviewed the records of the Konya City Hospital Cardiology Outpatient Clinic to identify all ACS patients who underwent PCI via transradial approach between June 1, 2022 and June 1, 2024. Patients were eligible if they were adults (>18 years) diagnosed with an acute coronary syndrome (either ST-elevation MI or non-ST-elevation MI) and had their index PCI performed through the transradial route. We included both primary PCIs for acute ST-elevation MI and urgent/elective PCIs for non-ST-elevation MI, provided the radial artery was used as the access site for the procedure. Patients were excluded if they had incomplete records of follow-up or radial patency assessment, if they required conversion to another access site (e.g. femoral crossover) during the procedure, or if they had a documented occlusion of the ipsilateral radial artery prior to the procedure. In total, 240 patients met the inclusion criteria and were analyzed. These patients represent the full cohort of ACS PCI cases via radial access in the defined period at our institution.

Ethical approval

The study protocol was approved by the institutional ethics committee. Specifically, ethical approval was obtained from the Necmettin Erbakan University Ethics Committee (Approval No: 2024/5140). Given the retrospective nature of the study, the need for individual informed consent was waived. All patient data were handled confidentially and in accordance with the Declaration of Helsinki principles.

PCI procedure and peri-procedural management

All procedures were performed by experienced interventional cardiologists following a standardized

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radial PCI protocol. Upon arrival to the catheterization laboratory, patients underwent sterile preparation of the right radial artery area (left radial was used in a few cases based on operator discretion or anatomical considerations). Local anesthesia with 2% lidocaine was administered at the wrist. A radial artery puncture was obtained and a 6 French hydrophilic sheath was inserted in all cases. Immediately after sheath insertion, an intra-arterial "radial cocktail" was given to prevent arterial spasm and thrombosis: this consisted of unfractionated heparin (administered as weight-adjusted bolus: 100 IU/kg) along with vasodilators. Nitroglycerin (100–200 μg intra-arterial) was given to prevent radial artery spasm, and either verapamil (2.5–5 mg) or nicardipine (250–500 μg) was administered intra-arterially as a calcium-channel blocker for spasm prophylaxis (choice based on availability). In cases of inferior MI with suspected right ventricular involvement (a small subset of hemodynamically sensitive patients), vasodilators were used cautiously: if profound hypotension was present, lower doses (e.g., 100 μg nitroglycerin and 250 μg nicardipine) were given incrementally to relieve any catheter-induced spasm without compromising systemic pressure. Procedural sedation and analgesia were minimized in STEMI cases but used as needed for patient comfort in NSTEMI cases.

Coronary interventions were then performed according to standard practice for ACS. All patients received guideline-directed therapy during PCI (loading doses of P2Y12 inhibitor if not already given, intravenous weight-based heparin to maintain adequate activated clotting time, etc.). The culprit lesion was treated with balloon angioplasty and stenting as appropriate. Radial access was maintained throughout the procedure without the need for access crossover in the analyzed cohort (by design, any crossover cases were excluded). At the conclusion of the angioplasty, the sheath was removed immediately in the catheterization laboratory. Hemostasis was achieved using a dedicated radial compression device. We used either the Terumo TR Band® (Terumo Medical Corporation) or an equivalent device (Shunmei radial compression pad) depending on availability – both of which are adjustable compression bands applied to the wrist. The nursing team was trained in a patent hemostasis protocol: the device's pressure was slowly released until adequate pulsatile flow was detected in the distal radial or ulnar pulse (verified by plethysmography or oximetry), ensuring that complete occlusive pressure was avoided while still preventing bleeding. The typical compression duration was around 2 hours, with gradual deflation.

Medications and follow-up

All patients were maintained on dual antiplatelet therapy after PCI as per ACS guidelines. Aspirin 80 mg daily (low-dose aspirin) was prescribed lifelong, and a P2Y12inhibitor was given for at least 12 months. In our cohort, either ticagrelor 90 mg twice daily or clopidogrel 75 mg daily was used, based on clinical judgement, patient comorbidities, and contraindications. Ticagrelor was generally preferred as first-line for ACS, with clopidogrel reserved for patients with high bleeding risk, advanced age, or intolerance to ticagrelor. In this retrospective sample, 140 patients (58%) were discharged on ticagrelor and 100 patients (42%) on clopidogrel. All patients were also prescribed high-intensity statin therapy (atorvastatin 80 mg daily) and other secondary prevention medications per guidelines (β-blockers, ACE inhibitors, etc., as appropriate). Patients were followed up in the cardiology outpatient clinic typically 4 weeks after discharge. At the first follow-up visit, a focused assessment of the radial access site was performed. Patency of the radial artery was evaluated using the reverse Barbeau test in the clinic. For this test, the patient's ipsilateral ulnar artery was briefly occluded while a pulse oximeter sensor on the index finger monitored the plethysmographic waveform. Restoration or persistence of the waveform during ulnar compression was classified according to Barbeau's criteria: Type A (no change in waveform amplitude, indicating normal radial patency), Type B (slight blunting of the waveform), Type C (loss of waveform followed by recovery within 2 minutes, suggesting marginal flow), or Type D (absence of waveform – indicating an occluded radial artery). We recorded the Barbeau test result for each patient from the clinic notes. In addition, the radial pulse was palpated and any signs of hand ischemia were checked.

Data collection and definitions

Using a standardized data collection form, we abstracted patient demographics and clinical characteristics from the hospital information system. Baseline variables included age, sex, and major cardiovascular risk factors such as diabetes mellitus (DM) and hypertension (HTN). We also noted the ACS subtype for each patient – whether the presentation was ST-elevation myocardial infarction (STEMI) or non-ST elevation MI (NSTEMI). For STEMI cases, further detail on infarct location was recorded: anterior, inferior, lateral STEMI, or STEMI equivalent (true posterior or left bundle branch block presentation). These categorizations were based on ECG findings at presentation. "Inferior STEMI with right ventricular involvement" was noted when inferior MI criteria were

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Table 2. Baseline Laboratory Data and EF by P2Y12 Inhibitor Group

Parameter	Total (N=240)	Ticagrelor (n=140)	Clopidogrel (n=100)	p-value
Hemoglobin, g/dL	13.7 ± 1.4	13.8 ± 1.3	13.6 ± 1.5	0.42
WBC, ×10³/μL	9.1 ± 2.6	9.2 ± 2.5	9.0 ± 2.6	0.63
Platelets, ×10³/μL	232 ± 54	234 ± 50	229 ± 58	0.59
Urea, mg/dL	36 ± 10	35 ± 9	37 ± 10	0.23
Creatinine, mg/dL	1.07 ± 0.21	1.06 ± 0.20	1.08 ± 0.22	0.44
Sodium, mEq/L	139 ± 3	139 ± 2	139 ± 3	0.77
Potassium, mEq/L	4.1 ± 0.4	4.1 ± 0.4	4.0 ± 0.4	0.49
LDL-C, mg/dL	123 ± 31	122 ± 29	125 ± 33	0.40
HDL-C, mg/dL	42 ± 7	41 ± 6	42 ± 7	0.58
Triglycerides, mg/dL	155 ± 52	158 ± 50	151 ± 54	0.41
EF, %	48.1 ± 6.8	48.3 ± 6.7	47.9 ± 6.9	0.72

WBC: White blood cell count, LDL-C: Low-density lipoprotein cholesterol, HDL-C: High-density lipoprotein cholesterol, EF: Ejection fraction
*Subcategories of STEMI are shown as a percentage of the total cohort; p-values for subcategory distribution are exploratory.
ACS: Acute coronary syndrome, PCI: Percutaneous coronary intervention, TEMI: ST-segment elevation myocardial infarction
NSTEMI: Non-ST-segment elevation myocardial infarction

present along with ST elevation in V4R, indicating right ventricular infarct; this subgroup corresponded to the cases where additional hemodynamic precautions were taken as described. The primary outcome of interest was radial artery occlusion (RAO) at follow-up, defined as a Barbeau Type D result (absent waveform) on the affected side. A Type C waveform (dampened with delayed recovery) was considered a partial occlusion or reduced radial flow, while Types A and B were considered patent radials. We also collected any documented complications during the periprocedural period (e.g., significant hematoma, radial artery spasm requiring intervention, etc.), although no major access-site complications were reported in the dataset. Radial artery spasm (RAS) during the procedure was defined by clinical criteria (pain and resistance on catheter manipulation requiring extra vasodilator or sheath removal). We stratified the analysis by P2Y12 inhibitor (ticagrelor vs. clopidogrel) to explore if there were differences in outcomes. The ticagrelor group and clopidogrel group were compared in terms of baseline characteristics, incidence of RAO, and other variables. Secondary outcomes included any difference in RAO according to ACS type (STEMI vs NSTEMI) and the distribution of Barbeau test categories in our cohort.

Statistical analysis

All data were analyzed using standard statistical software (IBM SPSS Statistics, version 25). Continuous variables such as age are presented as mean ± standard deviation. Categorical variables (e.g., sex, risk factors, RAO occurrence) are presented as counts and percentages. For group comparisons, we used the chi-square test (or Fisher's exact test where appropriate) for categorical variables, and Student's t-test for continuous variables. A two-sided p-value <0.05 was considered statistically significant. No imputation was done for missing data; only patients with complete follow-up data were included. Given the observational design, no formal sample size calculation was performed beforehand, but the sample of 240 was deemed adequate to observe clinically relevant differences in RAO based on expected incidence (~5%). The results are presented with an emphasis on real-world distribution of patient characteristics and outcomes. Tables were constructed to summarize key findings, including a baseline characteristics table and an outcomes table comparing RAO rates between subgroups.

RESULTS

Patient characteristics

A total of 240 patients met the inclusion criteria, comprising 172 men (71.7%) and 68 women (28.3%). The overall mean age was 60.4 ± 11.2 years. Table 1 summarizes the baseline characteristics of the cohort, including a breakdown by P2Y12 inhibitor group (ticagrelor vs. clopidogrel). The distribution of cardiovascular risk factors reflected a typical ACS population: 36% had diabetes mellitus and 51% had a history of hypertension. Nearly half (45%) were current smokers at the time of the index MI. There were no statistically significant differences in the prevalence of diabetes, hypertension, or smoking between the ticagrelor-treated group and the clopidogrel group ($p > 0.05$ for each), indicating broadly similar risk profiles.

Regarding the ACS type, 160 patients (66.7%) presented with STEMI and 80 (33.3%) with NSTEMI. Among the STEMI cases, the infarct location was anterior in 40%,

MMDJ
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Table 3. Radial Artery Patency Outcomes by Antiplatelet Therapy Group

Follow-Up Radial Patency (Barbeau Test)	Ticagrelor (n=140)	Clopidogrel (n=100)	p-value
Patent radial (Type A or B)	130 (92.9%)	95 (95.0%)	0.45
Partial flow reduction (Type C)	6 (4.3%)	4 (4.0%)	0.91
Complete RAO (Type D)	3 (2.1%)	2 (2.0%)	0.96
Any RAO (C or D)	9 (6.4%)	6 (6.0%)	0.90

RAO: Radial artery occlusion, Type A/B/C/D: Barbeau classification of radial artery patency (Type A = normal waveform, Type B = mild dampening, Type C = severe dampening with delayed recovery, Type D = no flow/occlusion)

inferior in 45%, and lateral in 10%, with the remaining 5% presenting as true posterior or with a "true" new left bundle branch block (STEMI equivalent). Inferior STEMIs with right ventricular involvement were documented in approximately 10% of all STEMI patients. The proportion of STEMI vs NSTEMI was similar between the ticagrelor and clopidogrel groups (p=0.62), though numerically a slightly higher fraction of STEMI patients received ticagrelor consistent with its guideline-preferred use in higher-risk presentations. All patients underwent successful urgent PCI of the culprit lesion via radial access. As per protocol, all patients received aspirin and a loading dose of either ticagrelor or clopidogrel; 58% were discharged on ticagrelor and 42% on clopidogrel, as noted. Baseline medical therapy (including statins and anticoagulation) was uniform across groups.

Patients in the ticagrelor and clopidogrel groups were largely comparable. The ticagrelor cohort was on average ~3 years younger than the clopidogrel cohort (59.2 vs 62.0 years) and had a slightly higher proportion of anterior MIs, but these differences did not reach statistical significance. Importantly, the procedural details (radial sheath size, heparin dose, use of closure device) were consistent across both groups by study design. No significant differences in procedural complications were noted between the groups; the overall radial artery spasm incidence during PCI was low (approximately 5% by chart documentation of difficult catheter manipulation or need for additional vasodilators), and spasm occurred with similar frequency in ticagrelor and clopidogrel patients.

A short panel of laboratory results is shown in Table 2, including hemogram, renal function, electrolytes, lipid parameters, and echocardiographic EF. The mean EF in the overall cohort was 48.1±6.8%, with no significant difference between ticagrelor (48.3±6.7%) and clopidogrel (47.9±6.9%) groups (p=0.72). Similarly, there were no statistically significant group differences in hemoglobin, WBC, platelets, urea, creatinine, sodium, potassium, or lipid profiles.

Comparison of ticagrelor vs. clopidogrel groups

We found no significant difference in radial artery occlusion rates between patients who received ticagrelor versus clopidogrel as the P2Y12 inhibitor. In the ticagrelor group (n=140), RAO (Type D Barbeau) occurred in 3 patients (2.1%). In the clopidogrel group (n=100), RAO occurred in 2 patients (2.0%). This difference (2.1% vs 2.0%) was not statistically significant (p = 0.96). The rates of partial occlusion (Type C) were similarly low in both

Table 4. Multivariable Logistic Regression Analysis of Independent Predictors for Partial (Type C) and Complete (Type D) Radial Artery Occlusion (RAO)

Variable	Type C (Partial) RAO OR (95% CI); p-value	Type D (Complete) RAO OR (95% CI); p-value
Age (per 1-year increment)	1.02 (0.98–1.07); p=0.30	1.03 (0.96–1.11); p=0.44
Female sex	2.33 (1.01–5.42); p=0.04	2.86 (1.04–7.86); p=0.042
Diabetes mellitus	1.42 (0.54–3.76); p=0.48	1.14 (0.28–4.63); p=0.86
Hypertension	1.11 (0.44–2.81); p=0.82	1.20 (0.32–4.48); p=0.79
Current smoker	1.63 (0.66–4.03); p=0.28	1.88 (0.53–6.67); p=0.32
STEMI (vs. NSTEMI)	1.25 (0.44–3.55); p=0.68	1.65 (0.37–7.40); p=0.51
Ticagrelor (vs. Clopidogrel)	1.08 (0.36–3.25); p=0.89	1.02 (0.21–4.98); p=0.98

RAO, radial artery occlusion; OR, odds ratio; CI, confidence interval; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction. Forest plot summarizing the adjusted odds ratios (OR) with corresponding 95% confidence intervals (CI) for predictors of partial (Type C, left panel) and complete (Type D, right panel) radial artery occlusion (RAO). Odds ratios greater than 1 indicate higher odds of RAO, while those less than 1 indicate lower odds. The vertical dashed red line at OR=1 indicates no association. Female sex is highlighted due to its statistical significance as an independent predictor for both partial and complete RAO.

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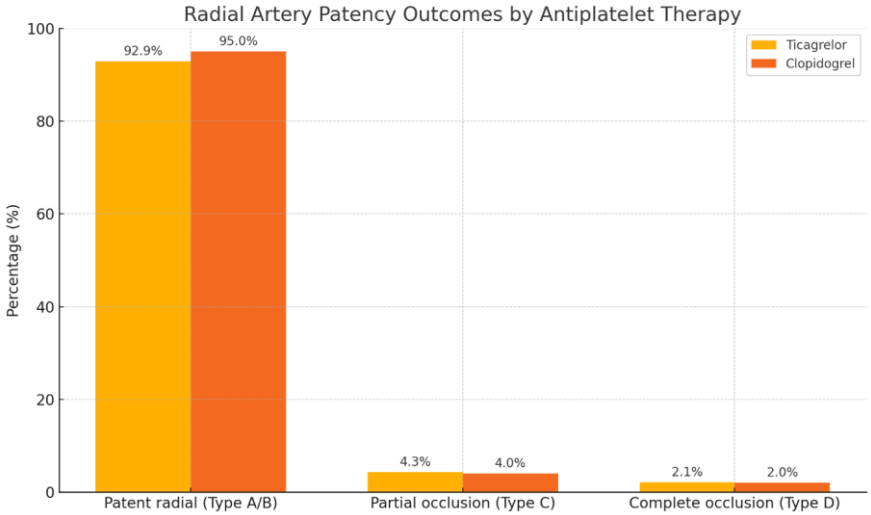

Figure 1. Radial artery patency outcomes based on antiplatelet therapy (ticagrelor vs. clopidogrel). The percentages of patent radial arteries (Type A/B), partial occlusion (Type C), and complete occlusion (Type D) are depicted for each group. Both groups show similarly high radial artery patency, emphasizing that there was no statistically significant difference between the two antiplatelet medications.

groups (approximately 4–5% each, p = 0.88). Table 3 details the patency outcomes by group. Radial artery patency outcomes between ticagrelor and clopidogrel groups are visually compared in Figure 1, highlighting the similarly high rates of patency and low occlusion incidences in both groups. Essentially, radial patency remained high (>95%) irrespective of which antiplatelet agent was used, aligning with the expectation that all patients were on DAPT (aspirin plus a P2Y12 agent) which would mitigate thrombosis. There were also no differences in any other secondary outcomes between the two groups. For example, the incidence of radial artery spasm during the procedure was 5.7% in ticagrelor patients vs 5.0% in clopidogrel patients (p = 0.82), and no significant differences in bleeding or hematoma at the wrist were observed. Thus, from a vascular access standpoint, ticagrelor and clopidogrel appeared equivalent in our cohort.

When considering the entire cohort, we also examined whether certain subgroups had higher RAO rates results demonstrate that with uniform technique, the incidence of radial occlusion was low and not

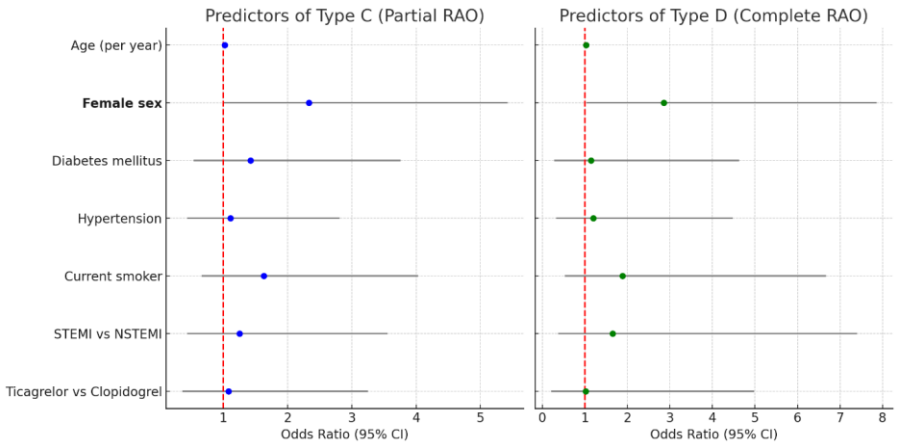

Figure 2. Illustrating Predictors of Partial (Type C) and Complete (Type D) Radial Artery Occlusion (RAO)
Forest plot summarizing the adjusted odds ratios (OR) with corresponding 95% confidence intervals (CI) for predictors of partial (Type C, left panel) and complete (Type D, right panel) radial artery occlusion (RAO). Odds ratios greater than 1 indicate higher odds of RAO, while those less than 1 indicate lower odds. The vertical dashed red line at OR=1 indicates no association. Female sex is highlighted due to its statistical significance as an independent predictor for both partial and complete RAO.

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meaningfully influenced by the choice of ticagrelor vs clopidogrel.

To further elucidate independent predictors of radial artery occlusion (RAO), we conducted separate multivariable logistic regression analyses for partial (Type C) and complete (Type D) occlusion. Neither age, diabetes mellitus, hypertension, smoking status, ACS type (STEMI vs. NSTEMI), nor choice of P2Y12 inhibitor (ticagrelor vs. clopidogrel) emerged as significant predictors in our analysis. However, female sex was identified as a significant independent predictor of both Type C RAO (OR 2.33, 95% CI: 1.01–5.42, p=0.04) and Type D RAO (OR 2.86, 95% CI: 1.04–7.86, p=0.042). Detailed results of this analysis are provided in Table 4, and illustrated visually in Figure 2.

DISCUSSION

In this retrospective study of ACS patients undergoing transradial PCI at a high-volume center, we found that standardized radial access practices yielded excellent outcomes with minimal complications. The rate of radial artery occlusion at follow-up was only ~2%, which is lower than many reports in the literature (commonly ~5% or higher)(6). This favorable result can be attributed to multiple factors: experienced operators, adherence to best practices for RAO prevention, and robust post-procedure care. All procedures were performed by interventional cardiologists well-versed in the transradial technique, reflecting the importance of the operator learning curve. It is well documented that proficiency in TRA comes with experience and that higher-volume radial operators have lower rates of access failure and complications(9,10). Our hospital's commitment to a "radial-first" approach has been reinforced by regular training programs for physicians and nursing staff, ensuring competence in puncture technique, catheter manipulation, and hemostasis management. This likely contributed to the nearly zero rate of major access-site complications in our cohort (no large hematomas or vessel injuries requiring intervention).

Nursing care and protocol standardization played a pivotal role in our outcomes. We implemented a patent hemostasis protocol for all patients, as recommended by current consensus to reduce RAO(6). The nursing team underwent specific training to gradually deflate the compression device while maintaining a palpable pulse, a technique shown to preserve radial lumen patency. We also strictly avoided reuse of any sheath or introducer and limited the indwelling time of the sheath by removing it immediately after PCI. Prolonged compression and indwelling sheaths are known contributors to RAO, so our practice of prompt sheath removal and careful pressure application was crucial(11). Additionally, the use of hydrophilic-coated sheaths and appropriate sheath size (6F in all cases) minimized endothelial trauma. The fact that our RAO rate was below that seen in many multi-center studies suggests that meticulous technique can indeed mitigate this complication in real-world practice. Of note, our RAO cases were asymptomatic and detected only by planned screening, underscoring the quiescent nature of this issue and the need for active surveillance to truly know one's RAO rates(12-14). Encouragingly, some of the partial occlusions in our study recanalized over time, in line with reports that spontaneous reperfusion of the radial artery can occur in weeks after an occlusion if collateral flow is present(15).

Importantly, we found no difference in RAO incidence between ticagrelor and clopidogrel-treated patients, supporting the notion that the choice of P2Y12 inhibitor does not appreciably impact radial artery patency as long as the patient is on DAPT. Both groups had similarly low RAO rates (~2%). There has been interest in whether more potent platelet inhibition (ticagrelor) might further reduce thrombotic occlusions of the radial artery compared to clopidogrel, but our data did not show any such benefit – likely because even clopidogrel (in combination with aspirin) provides sufficient antithrombotic effect to prevent most RAOs. This finding is consistent with a recent observation that dual-antiplatelet therapy is associated with lower RAO than single-antiplatelet therapy, but within dual therapy options, no major difference was evident(15). In clinical practice, therefore, the selection of ticagrelor vs. clopidogrel can be guided by ischemic vs. bleeding risk considerations in ACSwithout worrying about any impact on radial artery occlusion(16).

Another notable aspect of our practice is the aggressive prevention and management of radial artery spasm (RAS). Radial spasm can cause significant patient discomfort and procedural difficulty, and it has an indirect relationship with RAO (severe spasm can injure the endothelium and promote thrombosis). We routinely administered intra-arterial nitroglycerin and a calcium-channel blocker to all patients at the start of the case. The importance of such vasodilator use is supported by guidelines – the American Heart Association recommends intra-arterial verapamil, diltiazem, or nicardipine (in addition to nitroglycerin) during TRA to prevent spasm(17). In our lab, we preferentially used nicardipine as the antispasmodic agent when available. Nicardipine has emerged as an effective

MMDJ
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alternative to verapamil, with evidence suggesting it causes less pain upon injection and is equally efficacious in preventing spasm(17). Our low spasm incidence (~5%) attests to the effectiveness of this pharmacological prophylaxis. In the few cases where severe spasm did occur (notably, two cases in inferior STEMIs with hypotension), additional doses of nitroglycerin and nicardipine were successful in relieving the spasm, allowing the procedure to continue. No patient required conversion to femoral access due to spasm. We concur with other reports that diligent use of vasodilators and gentle catheter manipulation can keep radial spasm and associated complications to a minimum(18). The use of a long hydrophilic sheath that limits artery contact (and immediate removal post-procedure) likely also contributed to the low incidence of both spasm and RAO.

Our discussion of RAO must also address its clinical significance. While RAO is the most frequent complication of transradial catheterization, in practical terms it rarely causes clinical harm(2,3,19). In our study, none of the RAO cases had any ischemic symptoms. This aligns with the broader literature – permanent ischemic damage to the hand from RAO is exceedingly uncommon due to the compensatory flow from the ulnar artery and palmar arches(20). The main consequence of RAO is the loss of that artery as a future access route or bypass conduit. Given the low morbidity of RAO, some have considered it an acceptable trade-off for the bleeding reduction benefits of TRA. We believe that RAO should be viewed as a manageable complication rather than a deterrent to radial access. Even in the rare scenario of bilateral RAO, alternative strategies (such as distal radial access in the anatomical snuffbox or using the ulnar artery) have been explored to maintain a radial approach. Additionally, if RAO is recognized early (e.g., within days), interventions like ipsilateral ulnar compression to promote retrograde flow, or a short course of anticoagulation, can lead to recanalization in a significant number of cases(15). Therefore, the presence of RAO risk should not dissuade operators from choosing radial access; instead, the focus should be on implementing measures to minimize RAO occurrence. Our center's outcomes reinforce that with proper technique, RAO can be kept to very low levels, enhancing the overall safety profile of TRA. Moreover, the absence of major bleeding and vascular complications in our study echoes the well-known benefit of radial PCI in ACS(21). In fact, the literature shows a 77% reduction in major vascular complications with TRA , and our real-world data support this – we observed no access-site bleeding requiring transfusion or intervention, which is particularly relevant in an ACS population often receiving potent anticoagulation and antiplatelet therapy(22).

Finally, it is worth highlighting the system-wide approach we employed: from pre-procedure assessment (Allen's or Barbeau test to ensure dual circulation before radial puncture) to intraprocedural protocols (anticoagulation, vasodilators) to post-procedure care (patent hemostasis, follow-up checks). This comprehensive approach required coordination between physicians, nurses, and technicians. We believe this model can serve as a reference for other institutions aiming to improve their transradial outcomes. The low RAO rate and high patient safety achieved are likely generalizable to similar tertiary care settings with dedicated training. Our findings add to the growing evidence that radial interventions can be performed safely on a broad scale, and challenges like RAO can be effectively mitigated in the "real world" outside of controlled trials.

Study limitations: As a retrospective single-center study, our analysis has inherent limitations. We relied on available documentation for follow-up patency; although the Barbeau test was routinely done, we did not universally confirm RAO with ultrasound, so there is a possibility of misclassification (the reverse Barbeau test, while fairly accurate, can overestimate RAO in some cases.However, given our careful protocol, we suspect false positives were few. The sample size (especially for RAO events) was relatively small, limiting power to detect subtle differences or predictors of RAO. Additionally, the comparison between ticagrelor and clopidogrel was not randomized; while groups were similar, unmeasured confounders could exist. Nonetheless, the lack of any trend in RAO difference supports our conclusion of no major effect. Finally, our follow-up period focused on the early post-PCI phase (around 1 month); long-term patency of the radial artery beyond that was not systematically tracked. Some RAO might occur later or recanalization might occur later – these dynamics were outside our study scope.

CONCLUSION

In this two-year retrospective study, we found that using the radial artery for PCI in patients with acute coronary syndrome was highly effective and associated with very low complication rates. Radial artery occlusion occurred rarely (~2%) and did not differ significantly between patients treated with ticagrelor or clopidogrel. Importantly, female patients were at a somewhat higher risk of radial artery occlusion, highlighting the need for

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additional vigilance in this group. Our findings reinforce that when experienced medical teams follow careful techniques—such as proper anticoagulation, routine use of vasodilators, and meticulous hemostasis—radial interventions can be performed safely and effectively with minimal complications.

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Data availibity statement
The data underlying this article will be made available by the corresponding author upon reasonable request.

Declaration of competing interest
The authors declare no competing interests.

Ethics
The study protocol was approved by the Necmettin Erbakan University Ethics Committee (Approval No: 2024/5140). The requirement for informed consent was waived due to the retrospective design.

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