

## CLINICAL RESEARCH

## Interventional Cardiology

# Radial Versus Femoral Approach for Percutaneous Coronary Diagnostic and Interventional Procedures

## Systematic Overview and Meta-Analysis of Randomized Trials

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<b>OBJECTIVES</b>	We sought to compare, through a meta-analytic process, the transradial and transfemoral approaches for coronary procedures in terms of clinical and procedural outcomes.
<b>BACKGROUND</b>	The radial approach has been increasingly used as an alternative to femoral access. Several trials have compared these two approaches, with inconclusive results.
<b>METHODS</b>	The MEDLINE, CENTRAL, and conference proceedings from major cardiologic associations were searched. Random-effect odds ratios (ORs) for failure of the procedure (crossover to different entry site or impossibility to perform the planned procedure), entry site complications (major hematoma, vascular surgery, or arteriovenous fistula), and major adverse cardiovascular events (MACE), defined as death, myocardial infarction, emergency revascularization, or stroke, were computed.
<b>RESULTS</b>	Twelve randomized trials ( $n = 3,224$ ) were included in the analysis. The risk of MACE was similar for the radial versus femoral approach (OR 0.92, 95% confidence interval [CI] 0.57 to 1.48; $p = 0.7$ ). Instead, radial access was associated with a significantly lower rate of entry site complications (OR 0.20, 95% CI 0.09 to 0.42; $p < 0.0001$ ), even if at the price of a higher rate of procedural failure (OR 3.30, 95% CI 1.63 to 6.71; $p < 0.001$ ).
<b>CONCLUSIONS</b>	The radial approach for coronary procedures appears as a safe alternative to femoral access. Moreover, radial access virtually eliminates local vascular complications, thanks to a time-sparing hemostasis technique. However, gaining radial access requires higher technical skills, thus yielding an overall lower success rate. Nonetheless, a clear ongoing trend toward equalization of the two procedures, in terms of procedural success, is evident through the years, probably due to technologic progress of materials and increased operator experience. (J Am Coll Cardiol 2004;44:349–56) © 2004 by the American College of Cardiology Foundation

The transradial approach for coronary procedures has gained progressive acceptance since its first introduction by Campeau in 1989 (1) for diagnostic coronary angiography and its improvement by Kiemeneij and Laarman (2) for percutaneous transluminal coronary angioplasty (PTCA) and stenting. Subsequently, a widespread diffusion of coronary procedures via the radial artery took place in America (3,4), Asia (5,6), and Europe (7,8).

Indeed, transradial access has been shown by some authors to have several advantages over transfemoral approach. The radial artery is easily compressible, thus bleeding is controllable and hemorrhagic complications are significantly reduced. Moreover, no major nerves or veins are

located near the artery, minimizing the risk of injury of these structures. Finally, postprocedural bed rest is not required, permitting immediate ambulation, more comfort, and early discharge. This last advantage has shown to improve quality of life for patients (9) and to reduce the costs of hospitalization (9,10). Despite this large amount of benefits, the transradial approach is more demanding than transfemoral access and requires a longer learning curve for the operator (11,12). Furthermore, it does not give the possibility to use other devices such as a temporary pacemaker or intra-aortic balloon pump and to perform coronary interventions requiring 8-F catheters. Moreover, it is not always feasible, because some patients may have an anomalous palmar arch that does not provide sufficient blood supply to the hand in case of thrombotic or traumatic occlusion of the radial artery. Indeed, several authors have advocated, before the procedure, the mandatory assessment of adequacy of collateral blood flow from the ulnar artery by means of the Allen test (13), even if some authorities have recently reported no ischemic complications from radial catheterization, irrespective of any evaluation of blood supply to the hand (Y. Louvard and T. Saito, personal

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#### Abbreviations and Acronyms

CABG	= coronary artery bypass graft surgery
CI	= confidence interval
MACE	= major adverse cardiovascular events
OR	= odds ratio
PCI	= percutaneous coronary procedure
PTCA	= percutaneous transluminal coronary angioplasty
SMD	= standardized mean difference
WMD	= weighted mean difference

communications, 2004). Finally, entry site failure is not a remote possibility, often because of anatomic variation and tortuosity of the radial artery (14).

Conversely, the femoral approach is still considered by many as the standard technique because of its optimal catheter control, uncommon thrombotic complications, and immediate access to large-diameter devices. Nonetheless, such advantages are partially offset by bleeding complications, often mandating long bed rest, and the frequent occurrence of peripheral arterial disease, which limit transfemoral cardiac catheterization. The choice of vascular access site is thus in many centers more a matter of tradition, opinion, and expertise than an evidence-based decision.

Several randomized trials have been undertaken to compare the transradial and transfemoral approach, but the majority of them carefully selected a small number of homogeneous patients, were underpowered to detect differences in major adverse events, and yielded somewhat conflicting and inconclusive results. As systematic overviews may thoroughly assess available sources of clinical evidence, achieving more precise effect estimates with greater statistical power (15), we performed a meta-analysis of all trials directly comparing these two vascular access site techniques.

## METHODS

**Search strategy.** The MEDLINE and CENTRAL were searched by a trained investigator (Dr. Agostoni) for eligible studies published between January 1989 and August 2003. An additional search involved mRCT. Search key words included: “random\*,” “transradial,” “radial access,” “radial approach,” and “coronary.” Various combinations of these terms were used depending on the requirements of the data base. No language restriction was used. Conference proceedings from the 2000 to 2003 American College of Cardiology, American Heart Association, European Society of Cardiology, and Transcatheter Cardiovascular Therapeutics annual scientific sessions were also hand-searched. Major reviews regarding the radial approach for coronary procedures were systematically searched. Cross-references and quoted papers were checked, and experts were contacted to identify other relevant trials.

**Selection criteria.** Inclusion criteria for retrieved studies were: 1) a controlled comparison of the radial versus femoral approach for percutaneous coronary angiography or inter-

vention (either PTCA or stenting); 2) randomized treatment allocation; and 3) intention-to-treat analysis. Exclusion criteria were: 1) incomplete follow-up (<80%); and 2) a lack of clear and reproducible results.

**Data abstraction and validity assessment.** Data abstraction was independently performed by two unblinded reviewers (Drs. Agostoni and De Benedictis) on prespecified structure collection forms. There were no divergences in data collection. The study quality was evaluated by the same two investigators according to a score, modified from Jadad et al. (16) and Biondi-Zoccai et al. (17), expressed on an ordinal scale, allocating 1 point for the presence of each of the following: 1) statement of objectives; 2) explicit inclusion and exclusion criteria; 3) description of interventions; 4) objective means of follow-up; 5) description of adverse events; 6) power analysis; 7) description of statistical methods; 8) multicenter design; 9) discussion of withdrawals; and 10) details on medical therapy (e.g., antithrombotic regimens) during and after coronary procedures. Divergencies were resolved by consensus.

**Study characteristics.** The primary clinical outcomes of interest, evaluated at the longest available follow-up, were 1) major adverse cardiovascular events (MACE), including death, myocardial infarction, emergency percutaneous coronary intervention (PCI), or coronary artery bypass graft surgery (CABG) and stroke; 2) entry site complications, including major bleedings (requiring prolonged hospitalization, surgical intervention, or blood transfusion), pseudoaneurysms (requiring surgical or percutaneous intervention), arteriovenous fistulas, limb ischemia resulting in the need for vascular surgery, and nerve damage; and 3) procedural failure, defined as the need to puncture a second access site due to any procedural failure (inability to puncture the entry site artery, failure to cannulate the coronary artery, impossibility to perform the planned PTCA or stenting of the coronary artery) or due to a major access site complication.

Secondary procedural outcomes, pooled from individual studies when available, were: procedural time (in minutes), fluoroscopy time (in minutes), length of hospital stay (in days), and overall hospital costs (in the currency of the country where the trial was performed).

**Data analysis and synthesis.** Statistical analysis was performed using the Review Manager 4.1.1 freeware package (18). Review Manager is a comprehensive statistical and reviewing program, developed and maintained by the Cochrane Collaboration, which includes ad hoc statistical tools for pooled effect estimate calculations, according to several methods (19). Dichotomous variables are reported as proportions and percentages, and continuous variables as mean values. Binary outcomes from individual studies were to be combined with both the Mantel-Haenzel fixed effect model and the DerSimonian and Laird random effects model (19), whereas continuous variables were compared using the DerSimonian and Laird random effects model (19). The odds ratio (OR) and 95% confidence interval (CI) were used as summary statistics for the comparison of dichotomous

**Table 1.** Description of Studies Included in the Meta-Analysis

Study (Ref. #)	Years of Enrollment	Principal Investigator	Location	No. of Patients	Primary End Point	Follow-Up
Grinfeld et al. (4)	1994–1995	L. Grinfeld	Argentina	279	Entry site failure, procedural time	In-hospital
Mann et al. (10)	1994–1995	T. Mann	U.S.	152	Procedural outcome	In-hospital
ACCESS (24)	1993–1995	F. Kiemeneij	Netherlands	600	Entry site failure and complications, procedural outcome	1 month
BRAFE Stent (23)	1994–1995	E. Benit	Belgium	112	Entry site complication, hospitalization time	1 month
Mann et al. (25)	1997	T. Mann	U.S.	142	Procedural outcome	In-hospital
Cooper et al. (9)	1996–1997	C. J. Cooper	U.S.	200	Quality of life, costs	1 week
Monségu et al. (26)	1999	J. Monségu	France	379	Procedural outcome	In-hospital
CARAFE (27)	1998–1999	Y. Louvard	France	210	Procedural outcome, time, complications, hospitalization time	In-hospital
Gorge et al. (28)	2001*	G. Gorge	Germany	430	Procedural time, complications	In-hospital
Moriyama et al. (29)	2002	Y. Moriyama	Japan	200	Procedural time	In-hospital
TEMPURA (30)	1999–2001	S. Saito	Japan	149	MACE	9 months
OCTO-PLUS (31)	2003*	M. Hamon, Y. Louvard	France, England	371	Entry site complications	In-hospital

\*Year of publication.

MACE = major adverse cardiovascular events.

variables between the radial and femoral approach. The weighted mean difference (WMD) and 95% CI were used for continuous variables with the same unit of measure, whereas the standardized mean difference (SMD) was used for continuous variables with a different unit of measure. Reported values were two-tailed, and hypothesis testing results were considered statistically significant at  $p = 0.05$ . Sensitivity and subgroup analyses were performed using the following categories: 1) diagnostic catheterizations (studies with <50% of the patients undergoing PCI were included in this group) versus interventional procedures; 2) elective versus acute settings; 3) higher than median and median versus lower than median quality studies; and 4) after exclusion of studies published as abstracts. Formal Cochran Q chi-square tests were performed to investigate heterogeneity between trials (respective scores, degrees of freedom, and  $p$  values are reported [19]). This study was performed according to established methods (17) and in compliance with the Quality of Reporting of Meta-Analyses (QUORUM) guidelines (20).

## RESULTS

**Search results and study selection.** We found more than 170 citations in MEDLINE and other data sources. Most of them were editorials, reviews, letters, or articles regarding other aspects of the radial approach (anti-spasm therapy, local anesthesia, comparison of different sheaths) or other angiographic studies (carotid, cerebral, or renal). There were 34 observational studies investigating the feasibility and safety of the radial approach in a series of patients. Moreover, we found 15 studies comparing the radial and femoral approach in a nonrandomized fashion (historical controls, case-control studies, and allocation according to operator's ability to perform transradial procedures). We finally identified 14 eligible, randomized clinical trials, and complete articles were retrieved when applicable and checked for

compliance with inclusion and exclusion criteria. Data abstraction was performed and individual researchers contacted in case of incomplete reporting. We excluded two studies (21,22), published as abstracts, because the authors did not provide complete results and the data present in the abstracts were insufficient to be correctly analyzed.

**Study and patient characteristics.** The 12 studies included in the final analysis randomized 3,224 patients: 1,668 to the transradial and 1,556 to the transfemoral approach (4,9,10,23–31). Five studies (4,26,28,29,31) were published only as abstracts, but they were included in the analysis because of the importance of the so-called “gray” literature (32) (Table 1).

Seven studies (4,9,26–29,31) enrolled 2,069 subjects to perform only diagnostic catheterization, whereas five studies (10,23–25,30) involved 1,155 patients for PCI, two of which were done in an urgent setting, involving acute coronary syndromes (25) or acute myocardial infarction (30). The mean age was 65 years. On average, males accounted for 70.8% of subjects. In the majority of the studies, the arterial access was obtained with a 6-F introducer, apart from one in which a 7-F sheath was used in about 74% of patients in the femoral group (25), one in which both 5-F or 6-F introducers were used in the two groups but the size was selected before knowledge of the randomized access site (10), two in which a 5-F (27) or 4-F (28) sheath was used in both groups, one in which a 4-F femoral and 5-F radial sheath was used (26), and one in which a 4-F, 5-F, or 6-F catheter was used (28). Heparin was administered intravenously in all patients undergoing transradial catheterization, both diagnostic and interventional, whereas it was administered in the transfemoral approach subjects only if PCI was planned. Glycoprotein IIb/IIIa inhibitors and thrombolytic agents were used only in two studies (25,31) and in a small number of patients ( $n = 62$  and  $n = 41$ , respectively). All the studies presented

**Table 2.** Description of Populations and Procedures of Included Studies

Study (Ref. #)	Mean Age (yrs)	Males (%)	Antithrombotic Treatment	Experienced Radial Operators*	Sheath Size	Diagnostic Catheterization (%)	PCI		Quality†
							Elective (%)	Urgent (%)	
Grinfeld et al. (4)	63	73	NA	No	NA	100	—	—	1
Mann et al. (10)	62	71	H, ASA	Yes	6-F	—	100	—	7
ACCESS (24)	61	72	H, ASA	Yes	6-F	—	100	—	9
BRAFE Stent (23)	58	100	H, WA, ASA	No	6-F	—	100	—	6
Mann et al. (25)	62	67	H, ASA, TP	Yes	6/7-F	—	—	100	7
Cooper et al. (9)	60	69	H (only radial)	Some	5/6-F	100	—	—	9
Monségu et al. (26)	NA	NA	NA	Some	4/5-F	100	—	—	1
CARAFE (27)	62	78	H, ASA, TP	Yes	5-F	57	43	—	7
Gorge et al. (28)	NA	NA	NA	No	4/5/6-F	74	26	—	1
Moriyama et al. (29)	67	68	NA	Some	4-F	100	—	—	4
TEMPURA (30)	67	82	H, ASA, TP	Yes	6-F	—	—	100	9
OCTO-PLUS (31)	83	53	H, ASA, TP	Yes	NA	51	49	—	7

\*Defined as operators with an elevated number of procedures performed via the radial artery, as stated in this report, or as operators known to use the radial artery as the first-choice approach, as deduced from other published data. †Quality score was expressed on an ordinal scale, ranging from 1 to 10 (see text for details).

ASA = aspirin; F = French; H = heparin; NA = not available; PCI = percutaneous coronary interventions; TP = ticlopidine; WA = warfarin.

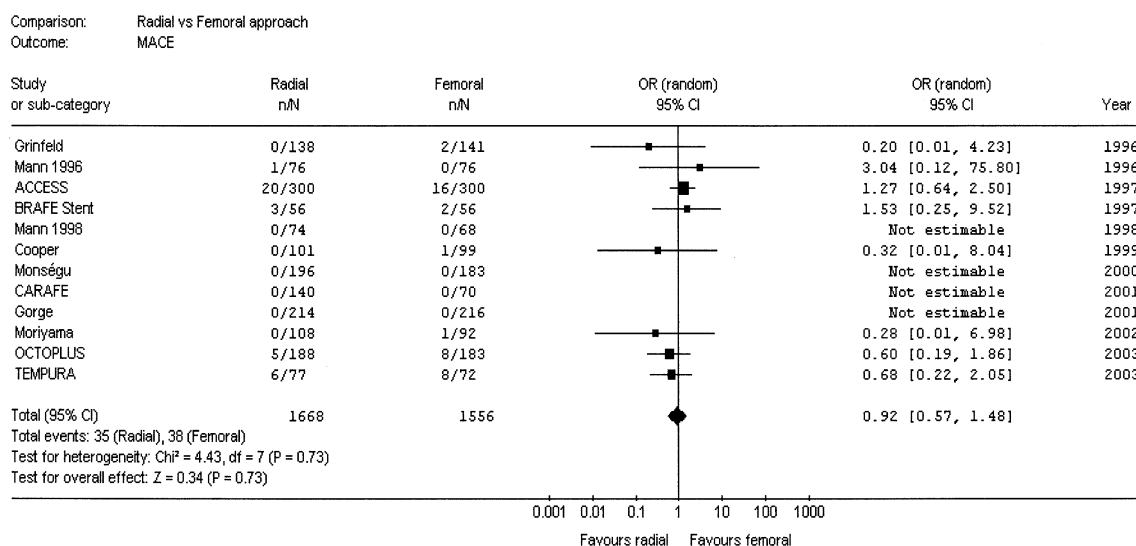
data on the in-hospital follow-up, apart from two in which follow-up data were recorded for one month (23,24) and one for nine months (30) (Table 2).

**Clinical results.** The results of the meta-analysis are presented according to the more robust and conservative random effects method, even if similar results were obtained using a fixed effects method. In terms of MACE (Fig. 1), the transradial and transfemoral approach yielded similar results, with 35 (2.1%) of 1,668 and 38 (2.4%) of 1,556 events in the two groups, respectively (OR 0.92, 95% CI 0.57 to 1.68;  $p = 0.7$ ). The transradial approach was instead significantly superior to femoral access in terms of the risk of entry site complications (5 [0.3%] of 1,472 vs. 39 [2.8%] of 1,373 subjects; OR 0.20, 95% CI 0.09 to 0.42;  $p < 0.0001$ ) (Fig. 2). Conversely, transradial access was associated with a significantly higher number of procedural failures in comparison to femoral access (107 [7.2%] of 1,472 vs. 33 [2.4%] of 1,373 subjects; OR 3.30, 95% CI 1.63 to 6.71;  $p < 0.001$ ) (Fig. 3).

**Additional analysis.** Heterogeneity testing did not show any significant departure from the assumption of statistical homogeneity for MACE and entry site complications. Regarding procedural failure, however, the heterogeneity test appeared statistically significant (chi-square = 18.71,  $df = 10$ ,  $p = 0.044$ ), probably due to an initial learning curve by cardiologists employing the radial technique, thus temporarily favoring the femoral technique, followed by a progressive equalization in technical skills for both the radial and femoral approaches through the years.

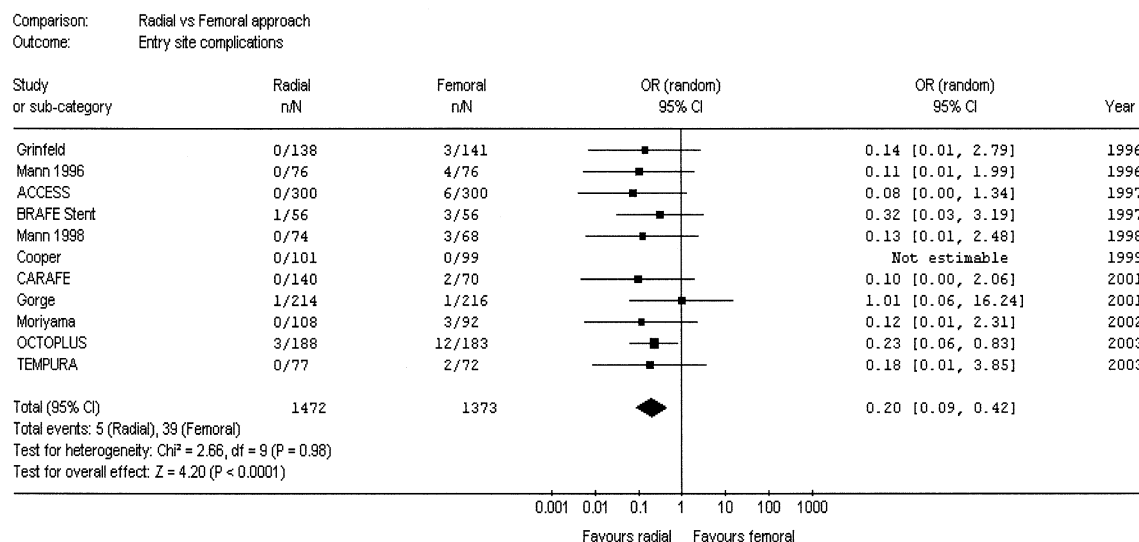
The OR calculations were also performed according to a fixed effects model, yielding similar results with regard to both the direction and magnitude of overall effects, thus confirming the robustness of the results.

Stratification and sensitivity analysis excluding studies published only as abstracts showed similar results to those of the comprehensive analysis. Findings were also comparable after prespecified stratification in higher than median and



**Figure 1.** Overall risk of major adverse cardiovascular events (MACE). CI = confidence interval; OR = odds ratio; year = year of publication.





**Figure 2.** Overall risk of entry site complications. CI = confidence interval; OR = odds ratio; year = year of publication.

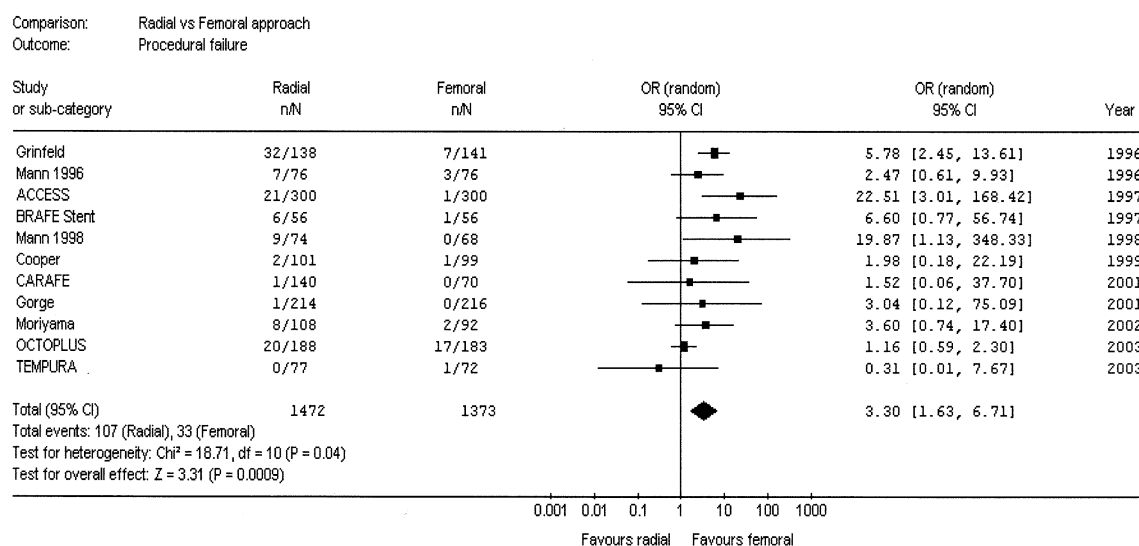
median versus lower than median quality studies, diagnostic versus interventional procedures, and elective versus urgent PCI (Table 3).

**Procedural results.** Secondary procedural outcomes were overall strongly heterogeneous, mainly due to the different clinical settings in which the procedures were performed. Furthermore, the definition of procedural time, which was reported in 11 trials (3,082 patients), varied widely among the studies, ranging from the arterial time to the total catheterization laboratory time (included sheath removal time). This added further heterogeneity to this analysis. However, in the transradial group, the mean procedural time was 35 min, whereas in the transfemoral group, it was 33.8 min. No significant difference was present (WMD 1.62, 95% CI  $-5.10$  to  $8.34$ ). The fluoroscopy time, a more reliable marker of procedural complexity, was assessed in 10 studies (2,970 patients). It was significantly shorter in the

femoral approach group (7.8 min) as compared with the radial group (8.9 min; WMD 1.05, 95% CI  $0.51$  to  $1.60$ ;  $p < 0.001$ ). Regarding length of stay, advantages of the radial approach were evident among all the eight studies (1,844 patients) that evaluated this parameter. The mean hospital stay was 1.8 days in the radial group versus 2.4 days in the femoral group (WMD  $-0.55$ , 95% CI  $-0.82$  to  $-0.29$ ;  $p < 0.001$ ). Finally, total hospital charge, assessed in five studies (853 patients), was lower in the transradial approach as compared with the transfemoral approach (SMD  $-1.43$ , 95% CI  $-2.30$  to  $-0.55$ ;  $p < 0.001$ ).

## DISCUSSION

The present meta-analysis shows that the transradial approach for coronary procedures is a highly safe and effective technique for both transcatheter diagnostic and therapeutic



**Figure 3.** Overall risk of procedural failure. CI = confidence interval; OR = odds ratio; year = year of publication.

**Table 3.** Subgroup and Sensitivity Analyses

Subgroup or Statistical Model for Sensitivity Analysis	No. of Studies (Included Patients)	OR (95% CI)		
		MACE	Entry Site Complications	Procedural Failure
Overall using fixed effect	12 (3,224)	0.90 (0.57–1.43)	0.18 (0.09–0.38)	3.29 (2.22–4.88)
Diagnostic catheterization studies	7 (2,069)	0.47 (0.18–1.24)	0.22 (0.09–0.59)	2.53 (1.14–5.61)
PCI studies	5 (1,155)	1.14 (0.66–1.96)	0.16 (0.04–0.54)	5.17 (1.37–19.55)
High-quality studies	7 (1,824)	0.95 (0.57–1.57)	0.16 (0.06–0.41)	2.69 (0.91–7.92)
Low-quality studies	5 (1,400)	0.72 (0.17–2.93)	0.29 (0.07–1.12)	5.19 (2.59–10.38)
Published studies	7 (1,565)	1.10 (0.64–1.88)	0.15 (0.05–0.46)	4.08 (1.46–11.41)

CI = confidence interval; MACE = major adverse cardiovascular events; OR = odds ratio; PCI = percutaneous coronary intervention.

procedures, yielding similar rates of MACE in comparison to the standard transfemoral access. Furthermore, the radial approach virtually abolishes entry site complications, as indeed only five local complications were found in 1,472 patients, in comparison to significantly higher rates of local vascular complications in patients undergoing transfemoral catheterization. Despite these advantages, radial vascular access is still more challenging, in terms of feasibility and technical success in comparison to transfemoral access, because of a higher proportion of procedural failures, specifically 7.2% versus 2.4%. Overall, the results of this meta-analysis appear quite robust in the light of the lack of heterogeneity among trials for MACE and local complications, as well as coherence between comprehensive and subgroup analyses.

**Limitations and advantages of transradial approach.** Notwithstanding a higher number of procedural failures, an evident trend toward equalization among the two techniques in terms of feasibility is clearly present through the years. Actually, there are several reasons underlying a procedural failure. First, there could be an inability to successfully puncture the radial artery, mostly because of operator skill, vessel tortuosity, or persistent arterial spasm. Second, it may be possible to fail to cannulate the coronary ostia due to difficulty in rotating and manipulating the catheters. Finally, an interventional procedure could fail because of inadequate catheter support or an inability to track the device in the correct place. All of these problems, clearly present in the early and pioneering trials of the 1990s, were far less common in the later studies. This indeed is the most probable explanation for the statistically significant heterogeneity present in the procedural failure analysis. Indeed, when dividing the studies in two subgroups according to the year of publication (before and after 1999), heterogeneity was no longer present (chi-square = 4.20,  $df$  = 4,  $p$  = 0.38 for older studies; chi-square = 2.83,  $df$  = 5,  $p$  = 0.73 for recent studies), and more recent trials showed no significant difference in terms of procedural failure between radial and femoral access (32 [3.9%] of 828 vs. 21 [2.9%] of 732 subjects, respectively; OR 1.39, 95% CI 0.78 to 2.47;  $p$  = 0.3), whereas a strong difference was present in the older trials (75 [11.6%] of 644 vs. 12 [1.9%] of 641 subjects, respectively; OR 6.02, 95% CI 3.07 to 11.79;  $p$  < 0.0001). The relatively high number of femoral failures in the first subgroup is explained by the inclusion of the

OCTO-PLUS trial (31), which selected a very challenging population of patients—all older than 80 years. In this trial, the percentage of failures was similar but elevated with both approaches: 20 (10.6%) of 188 subjects in the radial group and 17 (9.3%) of 183 in the femoral group. In fact, removing the OCTO-PLUS from the recent trials' analysis, radial failures were found in 12 (1.9%) of 640 subjects and femoral failures in 4 (0.7%) of 549 subjects (OR 2.16, CI 95% 0.74 to 6.34,  $p$  = 0.16).

Possibly, this very interesting trend occurred because of an evident improvement of all the materials, properly dedicated to the transradial approach. Indeed, new hydrophilic sheaths have been developed to reduce the incidence of radial artery spasm (33). Moreover, different kinds of pharmacologic cocktails have been investigated to reduce the occurrence of arterial spasm (34,35). Furthermore, novel guiding catheters have been progressively used through the years, so that coronary engagement and balloon or stent delivery were greatly simplified (36,37). However, the most important improvement was that regarding operator skill. In fact, there is clear evidence in all the examined trials that a learning curve is essential. Achieving access to the radial artery is technically more challenging and time-consuming than gaining femoral access, but when the right skills are grasped, the technique is much easier and reliable. Indeed, in our meta-analysis, no statistically significant difference was present in terms of procedural time, despite a strongly significant heterogeneity among studies. Furthermore, the trial with the largest number of patients (24) showed that procedural time for transradial PTCA was longer than that for the transfemoral approach at an interim analysis, but at the end of the trial, it was similar in the two techniques, reflecting the completion of a learning curve. Moreover, in the methods section of some trials, which reported the number of previous procedures performed via the radial artery, it is evident that trials conducted by experienced operators (e.g., more than 1,000 procedures performed via the transradial access before study commencement) (27) showed much lower failure rates than trials in which operators had only limited previous experience in transradial coronary angiography or intervention (23). However, procedural complexity of the transradial approach is still evident and underlined by fluoroscopy time, which was significantly 1 min longer with respect to femoral access.

Of course, the finding of the virtual absence of local

complications in the transradial group is remarkable, with only one arteriovenous fistula detected at one-month follow-up visit in one trial (23), perforation of the brachial artery, requiring surgery, in another study (28), and one hematoma >3 cm that required prolonged hospitalization in a third trial (31). The two other local complications occurred in patients who were randomized to the radial approach, but later underwent coronary procedures from the femoral access, due to crossover (31). In the transfemoral group, the percentage of complications was instead much higher, around 2.8%, including pseudo-aneurysms, arteriovenous fistulas, major bleedings, or large hematomas, sometimes requiring vascular surgery or blood transfusion and significantly prolonging the hospital stay. The radial artery is indeed superficial, and it may be easily compressed, achieving adequate hemostasis without “active” manual compression, but only with a “passive” pressure device or bandage, reducing also the workload of nursing and medical staff. Conversely, transfemoral procedures are constantly burdened by a number of local complications that even closure devices cannot completely avoid (38,39). With the technologic improvements in these devices and increasing experience regarding their use, it should be interesting to perform a direct randomized comparison of coronary procedures via radial versus femoral access with a closure device. To our knowledge, only two nonrandomized studies on this comparison have been published (40,41), and they yielded conflicting results, mainly due to a different completion of a learning curve in both procedures. Another pertinent randomized study was recently presented as an abstract (22), but the results are still unpublished and the data presented in the abstract are insufficient to achieve definitive conclusions.

**Internal and external validity.** Overall, the results of this meta-analysis may be extrapolated to the majority of patients undergoing coronary procedures, as indeed all the clinical settings have been evaluated, ranging from elective diagnostic catheterization to elective PTCA or stenting to urgent PCI. In fact, these data have been also confirmed by several observational registries or retrospective studies, showing the radial approach to be safe and feasible in a large part of clinical practice (42–44) and also in the case of aggressive pharmacologic treatments such as glycoprotein IIb/IIIa inhibitors (8) and oral anticoagulants (45). In addition, the randomized to screened ratio of patients enrolled was quite high (~42%), and the main reasons for exclusion were principally related to the presence of unstable symptoms, when an elective procedure was planned, or to the planned utilization of a device different from the one considered in the study. The only exclusion criterion strictly related to the access site, which can limit the use of the transradial technique in daily clinical practice, was an abnormal Allen test. Indeed, one of the major pitfalls of transradial access is radial artery occlusion due to

thrombosis. Its incidence ranged from 3% to 6% in the studies that planned a Doppler ultrasound examination of the radial artery after the procedure (10,23,24), whereas a loss of radial pulse was present in 0% to 9% of patients in the other trials. No clinical sequelae were signaled after occlusion of the radial artery.

Another issue is regarding the utilization of devices requiring catheters with a larger inner diameter (7-F to 8-F or more). No large-scale trials have been conducted, but some studies have shown the feasibility of 7-F to 8-F transradial procedures (46,47) in selected patients by experienced operators. Of course, these are pioneering reports, and further evaluation is needed with large-scale trials, but technologic improvements associated with increased operator skills may lead to the utilization of transradial access in always more challenging situations without significant harm to patients (48).

**Study limitations.** Among the potential limitations of this meta-analysis, which are well known and have been already reported (15), two trials could not be included because the authors did not provide detailed data. Moreover, procedural and fluoroscopy time, length of stay, and cost analyses showed substantial statistical heterogeneity, casting a shadow of caution on the results and interpretation of these comprehensive pooled effect estimates. Finally, data abstraction and quality assessment were done by independent reviewers, but with for any divergencies, resolution was made by consensus. Thus, the inter-operator agreement could not be quantitatively assessed.

**Conclusions.** This meta-analysis shows that the transradial approach for coronary procedures is a safe technique and yields clinical results similar to transfemoral access. Indeed, the radial approach virtually abolishes vascular entry site complications and permits a wide range of diagnostic and therapeutic interventions. Nonetheless, technical challenges may impose crossover to another approach, with a rate of about 1 in 14. These findings thus support the radial approach as an interesting choice in a broad range of patients, provided that experienced operators, state-of-the-art materials, and willingness to crossover to the femoral approach (“always prep a groin!”) are available.

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