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Version of Record: https://www.sciencedirect.com/science/article/pii/S0002870320301228
Manuscript_96bf56199b594de71156346e8205d93b

Radial Versus Femoral Artery Access for Percutaneous Coronary Artery Intervention in Patients with Acute Myocardial Infarction and Multivessel Disease Complicated by Cardiogenic Shock: subanalysis from the CULPRIT-SHOCK trial

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short title: arterial access for PCI in cardiogenic shock

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Word count: 4837, Tables 3, Figures 3

Structured abstract

Background The use and impact of transradial artery access (TRA) compared to transfemoral artery access (TFA) in patients undergoing percutaneous coronary intervention (PCI) for acute myocardial infarction (MI) complicated by cardiogenic shock (CS) remains unclear.

Methods This is a post-hoc analysis of the CULPRIT-SHOCK trial where patients presenting with MI and multivessel disease complicated by CS were randomized to a strategy of culprit-lesion-only or immediate multivessel PCI. Arterial access was left at operator's discretion. Adjudicated outcomes of interest were the composite of death or renal-replacement therapy (RRT) at 30-day and one-year. Multivariate logistic models were used to assess the association between the arterial access and outcomes.

Results Among the 673 analyzed patients, TRA and TFA were successfully performed in 118 (17.5%) and 555 (82.5%) patients, respectively. TRA was associated with lower 30-day rate of death or RRT compared to TFA (37.3% vs. 53.2%, respectively, adjusted Odds Ratio [aOR]: 0.57; 95% confidence interval [CI] 0.34-0.96), lower 30-day rates of death (34.7% vs. 49.7%, respectively; aOR: 0.56; 95%CI 0.33-0.96) and RRT (5.9% vs. 15.9%; aOR: 0.40; 95%CI 0.16-0.97). No significant differences were observed regarding the 30-day risks of type 3 or 5 BARC bleeding and stroke. The observed reduction of death or RRT and death with TRA was no longer significant at one-year (44.9% vs 57.8%; aOR: 0.85; 95%CI 0.50-1.45 and 42.4% vs. 55.5%, aOR: 0.78; 95%CI 0.46-1.32, respectively).

Conclusions In patients undergoing PCI for acute MI complicated by CS, TRA may be associated with improved early outcomes, while the reason for this finding needs further research.

Key words: myocardial infarction; cardiogenic shock; transradial artery access; percutaneous coronary intervention

Abbreviations

AKI: Acute kidney injury

aOR: Adjusted Odds ratio

CI: Confidence interval

CULPRIT SHOCK: Culprit Lesion Only PCI versus Multivessel PCI in Cardiogenic Shock

CS: Cardiogenic shock

MI: Myocardial infarction

PCI: Percutaneous coronary intervention

STEMI: ST segment elevation myocardial infarction

TFA Transfemoral artery access

TRA: Transradial artery access

INTRODUCTION

A growing body of evidence from large randomized trials and real-world observational studies has led to a generalization of transradial artery access (TRA) over transfemoral artery access (TFA) in patients undergoing percutaneous coronary intervention (PCI) for ST-segment elevation myocardial infarction (STEMI)(1–7). TRA has been associated with a lower risk of vascular complications, access site bleeding, acute kidney injury (AKI), and more remarkably, a survival benefit0(3, 5, 6, 8–11). Therefore, international guidelines recommend TRA as the standard approach, if performed by an experienced operator and in the absence of overriding procedural considerations(12–16). Whether the beneficial impact of TRA remains consistent in patients undergoing primary PCI for acute MI complicated by cardiogenic shock (CS) is less clear. CS represents a life-threatening situation, where the hemodynamic instability and the potential need for mechanical hemodynamic support may render TRA for primary PCI more challenging(17). Although observational studies have suggested TRA to be associated with improved outcomes in this setting, there remains a dearth of data from randomized trials(18–23). In fact, in previous randomized controlled trials comparing TRA to TFA, patients with CS were excluded (9, 24) or modestly represented (3, 25, 26). Our aim was to assess the use and association between the type of vascular route with early and late outcomes in patients randomized in the Culprit Lesion Only PCI versus Multivessel PCI in Cardiogenic Shock (CULPRIT-SHOCK) trial.

METHODS

This is a post-hoc analysis of the CULPRIT-SHOCK trial, whose design and results have been previously described(27–29). Briefly, the CULPRIT-SHOCK trial was an investigator-initiated, international, multicenter, open-label study where patients presenting with acute MI and multivessel coronary artery disease complicated by CS were randomized, in a 1:1 ratio, to a strategy of culprit-lesion-only PCI (with optional staged revascularization) or immediate multivessel PCI. In all patients, the culprit lesion was treated first, with the use of standard PCI techniques and with the recommended use of drug-eluting stents. In the culprit-lesion-only group, staged revascularization was performed according to the patient clinical status and the presence of residual ischemia. In the multivessel PCI group, any >70% stenosis of major coronary arteries (i.e. ≥ 2 mm diameter), including chronic total occlusion, were recommended to be treated with immediate PCI following the treatment of the culprit lesion, with a recommended maximum dose of contrast material of 300 mL. The indication for other therapy, including the use of mechanical circulatory support, was left to the discretion of the local physician, in accordance with generally accepted intensive care guidelines. The investigation was approved by the ethic committee or institutional review board of each participating center and written informed consent was obtained with the use of a prespecified process that varied slightly according to the country(28). The type of vascular access was left at the discretion of local operators. Patients undergoing brachial arterial access or concomitant TRA and TFA for the PCI procedures were excluded from this study. The CULPRIT-SHOCK trial was supported by a grant agreement (602202) from the European Union Seventh Framework Program and by the German Heart Research Foundation and the German Cardiac Society. The authors are solely responsible for the design and conduct of this study, all study analyses, the drafting and editing of the papers and its final contents.

Study objective

Our objective was to evaluate the association between the type of vascular approach and early and late outcomes. Early outcomes of interest were the primary endpoint of the CULPRIT SHOCK trial, defined as the composite of all-cause death or severe renal failure leading to renal-replacement therapy within 30 days after randomization, as well as each individual component, the 30-day composite of type 3 or 5 bleeding academic research consortium (BARC) bleeding and the 30-day risk of stroke. Late outcomes of interest were the one-year risk of all-cause death or renal-replacement therapy and all-cause death. Events were defined as previously reported and adjudicated by an independent clinical event committee(27–29). Specific follow-up was performed at 30 days, 6 months and one year by means of structured telephone interviews, with any potential endpoint events verified by review of original records. Death registries were searched to identify or confirm all deaths.

Statistical analysis

Categorical variables were described as proportion and compared with Chi-square test or Fisher's exact test. Continuous variables were described as mean ± standard deviation or median (Q1; Q3) and compared using Student's t-test or Wilcoxon rank-sum test. As previously published, event rates were compared using Chi-square test(28, 29). Kaplan-Meier curves were also used to show event rates over time with classification according to the arterial access and compared using log-rank test. Patients without event were censored at 30 days or one-year (for renal-replacement therapy or BARC type 2, 3 or 5 bleeding, deceased patients without event were censored at the date of death). A multivariate logistic regression model was used to evaluate the independent association between vascular access and outcomes. For each outcome, vascular access was adjusted on baseline clinical and procedural characteristics possibly associated with outcomes in univariate analysis ($p<0.2$) or significantly different between the two vascular accesses and clinically relevant (see **Online Tables 1** and **2**). Several sensitivity analyses were performed. A dedicated multivariate

logistic regression model (stepwise method with entry level of 0.2 and stay level of 0.05) was performed to determine the independent predictors of the vascular access among baseline characteristics. A model adjusted on consistent covariates as well as the effective revascularization strategy undergone by the patients was performed to account for cross-overs among the groups of randomization. In another sensitivity analysis, the association between arterial accesses and outcomes was evaluated using a marginal logistic regression adjusted on consistent covariates to account for the correlation among patients managed in the same center (cluster analysis per center). Finally, the bleeding risk according to the arterial access was also evaluated in the subgroups of patients with whom a mechanical circulatory support was not used. Results were interpreted in term of adjusted odd ratios with their associated 95% confidence intervals. A p-value <0.05 was considered significant unless otherwise specified. All statistical analyses were performed with SAS release 9.4 (SAS Institute Inc, Cary, NC) statistical software package.

RESULTS

Population characteristics

Of the 686 randomized patients with available informed consent, a total of 673 (98.1%) patients were included in this analysis, among whom TRA and TFA were performed in 118 (17.5%) and 555 (82.5%) patients, respectively (**Figure 1**). Baseline and procedural characteristics are detailed in **Table 1** and **Table 2**. TFA patients came with more frequent history of arterial hypertension and TRA patients more frequently presented with STEMI. Mild hypothermia, mechanical ventilation and catecholamine therapy were more frequently used among TFA patients although time until hemodynamic stabilization was significantly longer with TRA patients. In a dedicated multivariate logistic regression model, a medical history of systemic hypertension, the presence of left bundle branch block, and mechanical ventilation prior to percutaneous coronary intervention were significantly associated with lower use of TRA (**Online Table 3 and 4**).

Arterial access and early outcomes

The univariate association of TRA with outcomes at 30 days is detailed in the **Figure 2**. After adjustments for baseline and procedural characteristics, TRA was significantly associated with a reduced risk of the composite of all-cause death or renal replacement therapy, as well as each individual endpoint (**Table 3** and **Graphical abstract**). Results remained consistent in the sensitivity analysis adjusted on the revascularization strategy (**Online Figure 1**), and the sensitivity cluster analysis per center (**Online Figure 2**). There was no significant difference in the risk of stroke at 30 days between TRA and TFA (5.9% vs. 2.9%, respectively, p=0.16). There was no significant difference in the risk of BARC type 3 or 5 bleeding associated with the use of TRA or TFA (13.6% vs. 13.7%, respectively, p=0.97), in the overall population (**Online Figure 3**). In a sensitivity analyses only including patients with whom mechanical

circulatory support was not used, the risk of BARC type 3 or 5 bleeding at 30 days was numerically lower with TRA compared to TFA (6.9% vs. 10.6%, respectively), albeit not reaching statistical significance (p=0.30).

Arterial access and late outcomes

The univariate association of TRA with outcomes at one year is detailed in the **Figure 2** and **Online Figure 4**. After adjustments for baseline and procedural characteristics, use of TRA was not significantly associated with the composite of all-cause death or renal replacement therapy as well as all-cause death. Of note, no significant interactions between the coronary revascularization strategies (i.e. culprit-lesion-only or multivessel PCI) and arterial accesses were observed for any early and late outcomes.

DISCUSSION

The main findings of the present analysis are as follows: in patients undergoing PCI for acute myocardial infarction with multivessel coronary artery disease complicated by CS, TRA is used in less than 20% of the cases and is associated with a significant reduction of all-cause mortality and renal-replacement therapy at 30 days compared to TFA. This difference is no longer significant after adjustment for baseline and procedural characteristics at one-year follow-up.

Despite being the most frequently used arterial route for PCI in Western European countries, where the recruiting sites of the present study were located, TRA was only used in a minority of patients in this trial. There may be several reasons for this finding. Hemodynamic instability may result in weaker or even absent radial pulse, thus hindering the achievement of swift radial arterial access. In fact, CS has been previously reported as an independent risk factor for TRA failure(30). This technical impediment may have been one of the reasons, for otherwise TRA-experienced operators, to perform PCI with TFA in order to avoid any delay in achieving coronary reperfusion. Moreover, a TFA approach may be subsequently used for percutaneous mechanical circulatory support concomitant to PCI or following the procedure. Notwithstanding these considerations, TRA was associated with improved early outcomes, including a 30-day survival benefit, which is consistent with the results of previous large randomized trials as well as meta-analyses, in patients with or without CS(3, 6, 18, 21, 22, 25).

Nonetheless, the previously reported survival improvement with TRA over TFA has been most frequently credited to a reduction of major bleeding, which was not present in our study(5, 9, 10). The absence of significant difference in the rates of bleeding between TRA and TFA may be partially explained by a reduced effect of oral P2Y12 inhibitors in the setting of CS which may be associated with impaired intestinal absorption(31). Moreover, there was

a large use of mechanical circulatory support devices in both groups of patients, which may further increase the risk of vascular complications and bleeding, not related to the PCI access site(32). In this study, the localization of the bleeding (i.e. access site related or non-access site related) was not considered in the adjudication process and the impact of TRA on access site related bleeding in patients undergoing PCI for acute MI complicated with CS remains therefore unclear. This would warrant further investigation as a previous study reported non-access site related bleeding to be predominant in the setting of acute MI managed in radial centers(33). Another interesting finding of the study was the significant reduction of severe renal failure leading to renal-replacement therapy associated with TRA. There exists a growing body of evidence linking TRA to a reduction of AKI following PCI(34–36). Particularly, the recent AKI-Minimizing Adverse Haemorrhagic Events by Transradial Access Site and Systemic Implementation of Angiox (AKI-MATRIX) substudy reported a lower rate of post-PCI in-hospital AKI in patients randomized to TRA compared to TFA(8). Of note, a quantitative positive interaction testing was reported in patients with Killip class III or IV, suggesting that the benefit of TRA was greater in this high-risk population. The mechanisms by which TRA could prevent AKI may not be limited to the reduction of periprocedural bleeding. TFA may result in scraping of the descending aorta atherosclerotic debris, leading to potential atheroembolic renal complications, with the worst clinical manifestation being the cholesterol embolization syndrome(37, 38). Rothenbüler et al., in a post-hoc, hypothesis-generating analysis of the MATRIX trial, provided a mechanistic explanation for the mortality benefit associated with TRA, predominantly involving the prevention of AKI rather than bleeding(39, 40). A retrospective analysis of a large database reported that although bleeding was a risk factor of AKI, the lower odds of AKI with TRA was not mediated by a reduction in bleeding(34). The present study adds to the current knowledge by showing an association between TRA use and a lower need for renal-

replacement therapy in hemodynamically unstable patients. This may have led to the reduced all-cause mortality, independently of a reduction of bleeding. Of note, there was no significant difference between the two arterial accesses in the amount of contrast dye used.

There exists a dearth of data evaluating the impact of arterial routes on long-term outcomes in patients undergoing PCI for acute MI in the setting of CS(18). Although TRA was associated with an absolute reduction of all-cause death or renal-replacement therapy and all-cause death at one year of 12.9% and 13.1%, respectively, compared to TFA, this difference was no longer significant after adjustment for baseline and procedural characteristics. However, as mortality as well as the need for renal-replacement therapy in patients with CS mainly occurred within the first 30 days, it is likely that the present analysis lacks the necessary statistical power to comprehensively evaluate the impact of TRA on one-year outcomes(29).

Study limitations

This is a post-hoc analysis of a randomized trial where the type of arterial route was left at the local operator's discretion. Thus, unmeasured confounding variables may have persisted, despite adjustment for baseline and procedural covariates. Particularly, one cannot exclude a potential geographic or center bias regarding the choice of vascular access in patients with CS, although the sensitivity cluster analysis per center reported consistent results. There may also have been a selection bias in the choice of the vascular access as suggested by the multivariate analysis showing that the presence of left bundle branch block and mechanical ventilation prior to randomization, reflecting more serious cases in general, related positively with TFA. Use of percutaneous closure device in case of TFA as well as the impact of the timing and type of all mechanical circulatory support devices were not available and could therefore not be included in the multivariate model. The level of expertise of recruiting sites and individual operators with respect to TRA technique was not collected, nor were the use of ultrasound or palpability of the radial artery pulse. Incidence of access site related vascular

complications was not evaluated. Finally, there was a sample size imbalance in the groups of analyzed patients with a smaller number of patients undergoing TRA compared to TFA, potentially resulting in underpowered analyses. Consequently, the present study should be considered as hypothesis-generating and only a dedicated randomized trial comparing vascular access for PCI in patients presenting with acute MI complicated by CS could provide a definitive answer.

CONCLUSION

In patients undergoing PCI for an acute MI with multivessel coronary artery disease complicated by CS, a TRA approach may be associated with improved early outcomes.

Funding acknowledgements

The CULPRIT-SHOCK trial was supported by a grant agreement (602202) from the European Union Seventh Framework Program and by the German Heart Research Foundation and the German Cardiac Society.

Disclosures

Dr. Zeymer reports personal fees from Astra Zeneca, Bayer, Boehringer Ingelheim, BMS, Novartis, Sanofi, MSD, The Medicines Company, Pfizer, Daiichi Sankyo, Eli Lilly, Abiomed, outside the submitted work.

Dr. Montalescot: reports the following disclosures during the past 2 years research Grants to the Institution or Consulting/Lecture Fees from ADIR, Amgen, AstraZeneca, Bayer, Berlin Chimie AG, Boehringer Ingelheim, Bristol-Myers Squibb, Beth Israel Deaconess Medical, Brigham Women's Hospital, Cardiovascular Research Foundation, Celladon, CME Resources, Daiichi-Sankyo, Eli-Lilly, Europa, Elsevier, Fédération Française de Cardiologie, Fondazione Anna Maria Sechi per il Cuore, Gilead, ICAN, Janssen, Lead-Up, Menarini, Medtronic, MSD, Pfizer, Sanofi-Aventis, The Medicines Company, TIMI Study Group, WebMD.

Dr. Windecker has received research, educational, and training grants from Amgen, Abbott, Bayer, Bristol-Myers Squibb, Boston Scientific, Biotronik, Medtronic, Edwards Lifesciences, St. Jude, and Terumo.

Dr. Silvain reports reports consulting fees from Astra-Zeneca, Bayer, Boehringer-Ingelheim, CSL Berhing, Gilead Science; and Sanofi Aventis; Speaker honoraria from AstraZeneca, Amgen, Bayer, Algorythm, and Sanofi-Aventis; and travel support from Amgen, Astra-Zeneca, Bayer, and Bristol-Myer Squibb.

Dr. Kerneis has received research grants from Sanofi, Institut Servier and Fédération Française de Cardiologie; consultant fees from Bayer and AstraZeneca.

Dr. Lattuca has received research grants from Biotronik, Daiichi-Sankyo and Fédération Française de Cardiologie; consultant fees from Daiichi-Sankyo and Eli Lilly; and lecture fees from AstraZeneca and Novartis.

Dr. Michel Zeitouni has received research grants from Federation Française de Cardiologie and Institut Servier.

Dr. Collet has received research grants or honorarium from AstraZeneca, Bayer, Bristol-Myers Squibb, Daiichi-Sankyo, Eli-Lilly, Fédération Française de Cardiologie, Lead-Up, Medtronic, MSD, Sanofi-Aventis, and WebMD.

All other authors do not report any disclosure relative to this study.

References

1. Beygui F, Bertrand O, Montalescot G. Chapter 31: Transradial Approach for Diagnostic Coronary Angiography and Intervention. In: Textbook of Interventional Cardiology, 7th edition. ELSEVIER, :516.

2. Bertrand OF, Jolly SS, Rao SV, et al. Meta-analysis comparing bivalirudin versus heparin monotherapy on ischemic and bleeding outcomes after percutaneous coronary intervention. Am. J. Cardiol. 2012;110:599–606.

3. Valgimigli M, Gagnor A, Calabró P, et al. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial. Lancet Lond. Engl. 2015;385:2465–2476.

4. Vranckx P, Frigoli E, Rothenbühler M, et al. Radial versus femoral access in patients with acute coronary syndromes with or without ST-segment elevation. Eur. Heart J. 2017;38:1069–1080.

5. Valgimigli M, Frigoli E, Leonardi S, et al. Radial versus femoral access and bivalirudin versus unfractionated heparin in invasively managed patients with acute coronary syndrome (MATRIX): final 1-year results of a multicentre, randomised controlled trial. Lancet Lond. Engl. 2018;392:835–848.

6. Ferrante G, Rao SV, Jüni P, et al. Radial Versus Femoral Access for Coronary Interventions Across the Entire Spectrum of Patients With Coronary Artery Disease: A Meta-Analysis of Randomized Trials. JACC Cardiovasc. Interv. 2016;9:1419–1434.

7. Feldman DN, Swaminathan RV, Kaltenbach LA, et al. Adoption of radial access and comparison of outcomes to femoral access in percutaneous coronary intervention: an updated report from the national cardiovascular data registry (2007-2012). Circulation 2013;127:2295–2306.

8. Andò G, Cortese B, Russo F, et al. Acute Kidney Injury After Radial or Femoral Access for Invasive Acute Coronary Syndrome Management: AKI-MATRIX. J. Am. Coll. Cardiol. 2017.

9. Bernat I, Horak D, Stasek J, et al. ST-segment elevation myocardial infarction treated by radial or femoral approach in a multicenter randomized clinical trial: the STEMI-RADIAL trial. J. Am. Coll. Cardiol. 2014;63:964–972.

10. Kinnaird T, Anderson R, Gallagher S, et al. Access Site and Outcomes for Unprotected Left Main Stem Percutaneous Coronary Intervention: An Analysis of the British Cardiovascular Intervention Society Database. JACC Cardiovasc. Interv. 2018;11:2480–2491.

11. Porto I, Bolognese L, Dudek D, et al. Impact of Access Site on Bleeding and Ischemic Events in Patients With Non-ST-Segment Elevation Myocardial Infarction Treated With Prasugrel: The ACCOAST Access Substudy. JACC Cardiovasc. Interv. 2016;9:897–907.

12. Roffi M, Patrono C, Collet J-P, et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without

Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). Eur. Heart J. 2016;37:267–315.

13. van Diepen S, Katz JN, Albert NM, et al. Contemporary Management of Cardiogenic Shock: A Scientific Statement From the American Heart Association. Circulation 2017;136:e232–e268.

14. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). Eur. Heart J. 2018;39:119–177.

15. Neumann F-J, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur. Heart J. 2019;40:87–165.

16. Mason PJ, Shah B, Tamis-Holland JE, et al. An Update on Radial Artery Access and Best Practices for Transradial Coronary Angiography and Intervention in Acute Coronary Syndrome: A Scientific Statement From the American Heart Association. Circ. Cardiovasc. Interv. 2018;11:e000035.

17. Dangas G, Guedeney P. Prediction, staging, and outcomes of ischaemic cardiogenic shock after STEMI: a complex clinical interplay. Eur. Heart J. 2018;39:2103–2105.

18. Bernat I, Abdelaal E, Plourde G, et al. Early and late outcomes after primary percutaneous coronary intervention by radial or femoral approach in patients presenting in acute ST-elevation myocardial infarction and cardiogenic shock. Am. Heart J. 2013;165:338–343.

19. Mamas MA, Anderson SG, Ratib K, et al. Arterial access site utilization in cardiogenic shock in the United Kingdom: is radial access feasible? Am. Heart J. 2014;167:900-908.e1.

20. Roule V, Lemaitre A, Sabatier R, et al. Transradial versus transfemoral approach for percutaneous coronary intervention in cardiogenic shock: A radial-first centre experience and meta-analysis of published studies. Arch. Cardiovasc. Dis. 2015;108:563–575.

21. Pancholy SB, Palamaner Subash Shantha G, Romagnoli E, et al. Impact of access site choice on outcomes of patients with cardiogenic shock undergoing percutaneous coronary intervention: A systematic review and meta-analysis. Am. Heart J. 2015;170:353–361.

22. Rodriguez-Leor O, Fernandez-Nofrerias E, Carrillo X, et al. Transradial percutaneous coronary intervention in cardiogenic shock: a single-center experience. Am. Heart J. 2013;165:280–285.

23. Romagnoli E, De Vita M, Burzotta F, et al. Radial versus femoral approach comparison in percutaneous coronary intervention with intraaortic balloon pump support: the RADIAL PUMP UP registry. Am. Heart J. 2013;166:1019–1026.

24. Jolly SS, Yusuf S, Cairns J, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomised, parallel group, multicentre trial. Lancet Lond. Engl. 2011;377:1409–1420.

25. Romagnoli E, Biondi-Zoccai G, Sciahbasi A, et al. Radial versus femoral randomized investigation in ST-segment elevation acute coronary syndrome: the RIFLE-STEACS (Radial

Versus Femoral Randomized Investigation in ST-Elevation Acute Coronary Syndrome) study. J. Am. Coll. Cardiol. 2012;60:2481–2489.

26. Le May M. The SAfety and Efficacy of Femoral Access vs RadIal Access in STEMI: The SAFARI-STEMI Trial. 2019.

27. Thiele H, Desch S, Piek JJ, et al. Multivessel versus culprit lesion only percutaneous revascularization plus potential staged revascularization in patients with acute myocardial infarction complicated by cardiogenic shock: Design and rationale of CULPRIT-SHOCK trial. Am. Heart J. 2016;172:160–169.

28. Thiele H, Akin I, Sandri M, et al. PCI Strategies in Patients with Acute Myocardial Infarction and Cardiogenic Shock. N. Engl. J. Med. 2017;377:2419–2432.

29. Thiele H, Akin I, Sandri M, et al. One-Year Outcomes after PCI Strategies in Cardiogenic Shock. N. Engl. J. Med. 2018;379:1699–1710.

30. Abdelaal E, Brousseau-Provencher C, Montminy S, et al. Risk score, causes, and clinical impact of failure of transradial approach for percutaneous coronary interventions. JACC Cardiovasc. Interv. 2013;6:1129–1137.

31. Orban M, Mayer K, Morath T, et al. Prasugrel vs clopidogrel in cardiogenic shock patients undergoing primary PCI for acute myocardial infarction. Results of the ISAR-SHOCK registry. Thromb. Haemost. 2014;112:1190–1197.

32. Thiele H, Ohman EM, Desch S, Eitel I, de Waha S. Management of cardiogenic shock. Eur. Heart J. 2015;36:1223–1230.

33. Barthélémy O, Silvain J, Brieger D, et al. Bleeding complications in primary percutaneous coronary intervention of ST-elevation myocardial infarction in a radial center. Catheter. Cardiovasc. Interv. 2012;79:104–112.

34. Kooiman J, Seth M, Dixon S, et al. Risk of acute kidney injury after percutaneous coronary interventions using radial versus femoral vascular access: insights from the Blue Cross Blue Shield of Michigan Cardiovascular Consortium. Circ. Cardiovasc. Interv. 2014;7:190–198.

35. Andò G, Costa F, Boretti I, Trio O, Valgimigli M. Benefit of radial approach in reducing the incidence of acute kidney injury after percutaneous coronary intervention: a meta-analysis of 22,108 patients. Int. J. Cardiol. 2015;179:309–311.

36. Guedeney P, Sorrentino S, Vogel B, Baber U, Claessen BE, Mehran R. Assessing and minimizing the risk of percutaneous coronary intervention in patients with chronic kidney disease. Expert Rev. Cardiovasc. Ther. 2018;16:825–835.

37. Keeley EC, Grines CL. Scraping of aortic debris by coronary guiding catheters: a prospective evaluation of 1,000 cases. J. Am. Coll. Cardiol. 1998;32:1861–1865.

38. Kronzon Itzhak, Saric Muhamed. Cholesterol Embolization Syndrome. Circulation 2010;122:631–641.

39. Rothenbühler M, Valgimigli M, Odutayo A, et al. Association of acute kidney injury and bleeding events with mortality after radial or femoral access in patients with acute coronary syndrome undergoing invasive management: secondary analysis of a randomized clinical trial. Eur. Heart J. 2019.

40. Kerneis M, Silvain J, Montalescot G. Kidney in the transformation matrix. Eur. Heart J. 2019;40:1233–1235.

Table 1 Baseline characteristic

	Total (n=673)	Radial access (n=118)	Femoral access (n=555)	p-value
Age, years	68.6 ± 11.4	67.5 ± 12.4	68.8 ± 11.1	0.41
Male sex	516/673 (76.7%)	94/118 (79.7%)	422/555 (76.0%)	0.40
Body mass index, kg/m²	27.3 ± 4.3	27.3 ± 5.0	27.4 ± 4.2	0.65
Cardiovascular risk factors				
Current smoking	171/647 (26.4%)	37/113 (32.7%)	134/534 (25.1%)	0.09
Hypertension	397/661 (60.1%)	58/117 (49.6%)	339/544 (62.3%)	0.01
Hypercholesterolemia	226/658 (34.3%)	39/116 (33.6%)	187/542 (34.5%)	0.86
Diabetes mellitus	216/659 (32.8%)	31/117 (26.5%)	185/542 (34.1%)	0.11
Prior myocardial infarction	111/661 (16.8%)	21/118 (17.8%)	90/543 (16.6%)	0.75
Prior stroke	47/664 (7.1%)	6/118 (5.1%)	41/546 (7.5%)	0.35
Prior peripheral artery disease	80/665 (12.0%)	16/118 (13.6%)	64 /547(11.7%)	0.57
Prior chronic kidney disease	44/663 (6.6%)	8/118 (6.8%)	36/545 (6.6%)	0.95
Prior percutaneous coronary intervention	125/661 (18.9%)	15/118 (12.7%)	110/543 (20.3%)	0.06
Prior coronary artery bypass graft	32/665 (4.8%)	2/118 (1.7%)	30/547 (5.5%)	0.08
Resuscitation before randomization	357/672 (53.1%)	54/118 (45.8%)	303/554 (54.7%)	0.08
Fibrinolysis <24 h before randomization	33/671 (4.9%)	7/117 (6.0%)	26/554 (4.7%)	0.56
ST-segment elevation myocardial infarction	406/653 (62.2%)	85/114 (74.6%)	321/539 (59.6%)	0.003
Anterior ST-segment elevation myocardial infarction	217/402 (54.0%)	49/85 (57.6%)	168/317 (53.0%)	0.45
Left bundle branch block	98/654 (15.0%)	6/114 (5.3%)	92/540 (17.0%)	0.001
Heart rate, beats/min	90.5 (72.0-108.0)	89.5 (70.0-109.0)	91.0 (73.0-107.0)	0.48
Systolic blood pressure, mmHg	100.0 (85.0-125.0)	95.0 (85.0-120.0)	100.0 (85.0-125.0)	0.19
Diastolic blood pressure, mmHg	60.0 (50.0-80.0)	60.0 (50.0-73.0)	61.0 (50.0-80.0)	0.32
Mean blood pressure, mmHg	75.0 (63.3-93.3)	70.0 (62.7-87.3)	76.7 (63.3-93.3)	0.18
Arterial lactate >2.0 mmol/L	435/654 (66.5%)	70/114 (61.4%)	365/540 (67.6%)	0.20
Number of affected vessels				0.14
1	5/673 (0.7%)	0/118	5/555 (0.9%)	
2	241/673 (35.8%)	51/118 (43.2%)	190/555 (34.2%)	
3	427/673 (63.4%)	67/118 (56.8%)	360/555 (64.9%)	
Vessel related to the infarction*				0.64
Left anterior descending artery	273/656 (41.6%)	48/114 (42.1%)	225/542 (41.5%)	
Left circumflex artery	137/656 (20.9%)	22/114 (19.3%)	115/542 (21.2%)	
Right coronary artery	180/656 (27.4%)	31/114 (27.2%)	149/542 (27.5%)	
Left main artery	59/656 (9.0%)	13/114 (11.4%)	46/542 (8.5%)	
Bypass graft	7/656 (1.1%)	0	7/542 (1.3%)	
≥1 chronic total occlusion*	154/656 (23.5%)	25/114 (21.9%)	129/542 (23.8%)	0.67
SYNTAX score*	25.0 (17.5-32.0)	24.0 (18.0-31.3)	25.0 (17.5-32.5)	0.97
Left ventricular ejection fraction**	30.0 (25.0-40.0)	35.0 (25.0-44.0)	30.0 (24.0-40.0)	0.34

*according to central corelab, ** n=250 (46 radial and 204 femoral)

Table 2. Procedural characteristics

	Total (n=673)	Radial access (n=118)	Femoral access (n=555)	p-value
Stent in culprit lesion				0.66
Any	639/673 (94.9%)	113/118 (95.8%)	526/555 (94.8%)	
Bare metal stent	36/639 (5.6%)	6/113 (5.3%)	30/526 (5.7%)	
Drug-eluting stent	603/639 (94.4%)	105/113 (92.9%)	498/526 (94.7%)	
Bioresorbable scaffold in culprit lesion	5/639 (0.8%)	2/113 (1.8%)	3/526 (0.6%)	
Aspiration thrombectomy of culprit lesion	98/673 (14.6%)	22/118 (18.6%)	76/555 (13.7%)	0.17
TIMI grade for blood flow of culprit lesion*				
Before percutaneous coronary intervention				0.001
3	217/652 (33.3%)	23/113 (20.4%)	194/539 (36.0%)	
Other than 3	435/652 (66.7%)	90/113 (79.6%)	345/673 (64.0%)	
After percutaneous coronary intervention				0.35
3	492/630 (78.1%)	83/111 (74.8%)	409/519 (78.8%)	
Other than 3	138/630 (21.9%)	28/111 (25.2%)	110/519 (21.2%)	
Immediate percutaneous coronary intervention of non-culprit lesion	350/673 (52.0%)	59/118 (50.0%)	291/555 (52.4%)	0.63
Immediate complete revascularization achieved	301/673 (44.7%)	52/118 (44.1%)	249/555 (44.9%)	0.87
Periprocedural use of bivalirudin	39/673 (5.8%)	6/117 (5.1%)	33/555 (5.9%)	0.73
Periprocedural use of GPIIbIIIa inhibitors	146/672 (21.7%)	35/117 (29.9%)	111/555 (20.0%)	0.02
Total dose of contrast material, mL	220.0 (155.0-300.0)	240.0 (160.0-300.0)	220.0 (154.0-300.0)	0.60
Total duration fluoroscopy, min	15.8 (9.2-25.0)	16.0 (11.4-26.2)	15.4 (9.0-25.0)	0.25
Staged PCI of non-culprit lesions	67/673 (10.0%)	15/118 (12.7%)	52/555 (9.4%)	0.27
Induced mild hypothermia	221/671 (32.9%)	26/118 (22.0%)	195/553 (35.3%)	0.006
Mechanical circulatory support	190/673 (28.2%)	31/118 (26.3%)	159/555 (28.6%)	0.60
Mechanical ventilation	543/670 (81.0%)	81/117 (69.2%)	462/553 (83.5%)	<0.001
Duration of mechanical ventilation, days	3.0 (1.0-8.0)	3.0 (1.0-8.0)	3.0 (1.0-7.0)	0.54
Use of catecholamines	602/670 (89.9%)	99/117 (84.6%)	503/553 (91.0%)	0.04
Duration of catecholamines, days	2.0 (1.0-5.0)	3.0 (1.0-6.0)	2.0 (1.0-5.0)	0.06
Time to hemodynamic stabilization, days	3.0 (1.0-6.0)	4.0 (1.0-8.0)	3.0 (1.0-6.0)	0.04
Duration of intensive care treatment, days	5.0 (2.0-11.0)	6.0 (2.0-11.0)	5.0 (2.0-11.0)	0.49
Subsequent medications in patients who survived until hospital discharged				
Statin	332/356 (93.3%)	69/77 (89.6%)	263/279 (94.3%)	0.15
Beta-blocker	325/356 (91.3%)	67/77 (87.0%)	258/279 (92.5%)	0.13
ACE or ARB inhibitors	312/356 (87.6%)	59/77 (76.6%)	253/279 (90.7%)	<0.001
Aspirin	350/356 (98.3%)	77/77 (100.0%)	273/279 (97.8%)	0.35
Clopidogrel	159/356 (44.7%)	37/77 (48.1%)	122/279 (43.7%)	0.50
Prasugrel	122/356 (34.3%)	18/118 (23.4%)	104/279 (37.3%)	0.02
Ticagrelor	142/356 (39.9%)	37/77 (48.1%)	105/279 (37.6%)	0.10

*according to central corelab; TIMI: Thrombolyse In Myocardial Infarction; ACE: angiotensin-converting enzyme; ARB: angiotensine receptor blocker

Table 3. Early and late outcomes according to the arterial access

	Radial access (n=118)	Femoral access (n=555)	Unadjusted OR (95%CI)	p-value	Adjusted OR (95%CI)	p-value
30-day outcomes						
All-cause death or renal replacement therapy*	44 (37.3%)	295 (53.2%)	0.52 (0.35-0.79)	0.002	0.57 (0.34-0.96)	0.036
All-cause death*	41 (34.7%)	276 (49.7%)	0.54 (0.36-0.81)	0.003	0.56 (0.33-0.96)	0.034
Renal replacement therapy†	7 (5.9%)	88 (15.9%)	0.33 (0.15-0.74)	0.005	0.40 (0.16-0.97)	0.043
1-year outcomes						
All-cause death or renal replacement therapy‡	53 (44.9%)	321 (57.8%)	0.59 (0.40-0.89)	0.010	0.85 (0.50-1.45)	0.552
All-cause death§	50 (42.4%)	308 (55.5%)	0.59 (0.39-0.88)	0.009	0.78 (0.46-1.32)	0.346

*N=593 patients, covariates of adjustment are: age, sex, body mass index, smoking status, hypercholesterolemia, diabetes mellitus, prior chronic kidney disease, prior PCI, arterial lactate>2mmol/L at baseline, need for mechanical ventilation before randomization, culprit left main or left anterior descending coronary artery, ≥ 1 chronic total coronary occlusion, mechanical circulatory support, mild hypothermia, mechanical ventilation, use of catecholamine therapy, pre-PCI Thrombolysis In Myocardial Infarction (TIMI) flow 3 and randomized coronary revascularization strategy. † N=596 patients, covariates of adjustment are: body mass index, hypertension, diabetes mellitus, prior chronic kidney disease, anterior ST-segment elevation, ≥ 1 chronic total coronary occlusion, mechanical circulatory support, mild hypothermia, mechanical ventilation, use of catecholamine therapy, pre-PCI Thrombolysis In Myocardial Infarction (TIMI) flow 3 and randomized coronary revascularization strategy. ‡N=594, covariates of adjustment are: age, body mass index, smoking status, hypercholesterolemia, diabetes mellitus, previous stroke, prior chronic kidney disease, previous CABG, arterial lactate>2mmol/L at baseline, need for mechanical ventilation before randomization, fibrinolysis before randomization, culprit left main or left anterior descending coronary artery, ≥ 1 chronic total coronary occlusion, mechanical circulatory support, mild hypothermia, mechanical ventilation, use of catecholamine therapy, pre-PCI Thrombolysis In Myocardial Infarction (TIMI) flow 3, periprocedural use of GP IIb/IIa inhibitors and randomized coronary revascularization strategy. § N=595, covariates of adjustment are: age, sex, body mass index, smoking status, hypercholesterolemia, diabetes mellitus, prior chronic kidney disease, prior stroke, previous CABG, arterial lactate>2mmol/L at baseline, need for mechanical ventilation before randomization, culprit left main or left anterior descending coronary artery, ≥ 1 chronic total coronary occlusion, mechanical circulatory support, mild hypothermia, mechanical ventilation, use of catecholamine therapy, pre-PCI Thrombolysis In Myocardial Infarction (TIMI) flow 3, periprocedural use of GP IIb/IIa inhibitors and randomized coronary revascularization strategy. OR: Odds Ratio; CI: confidence interval.

Figure titles and legends

Figure 1 Flow chart

Figure 2 Unadjusted Kaplan Meier curves of the 30-day and 1-year outcomes

No.: Number

Graphical abstract: Radial versus femoral arterial access in patients undergoing PCI for acute myocardial infarction complicated by cardiogenic shock

PCI: percutaneous coronary intervention: CI: Confidence interval

Figure 1 Flow chart

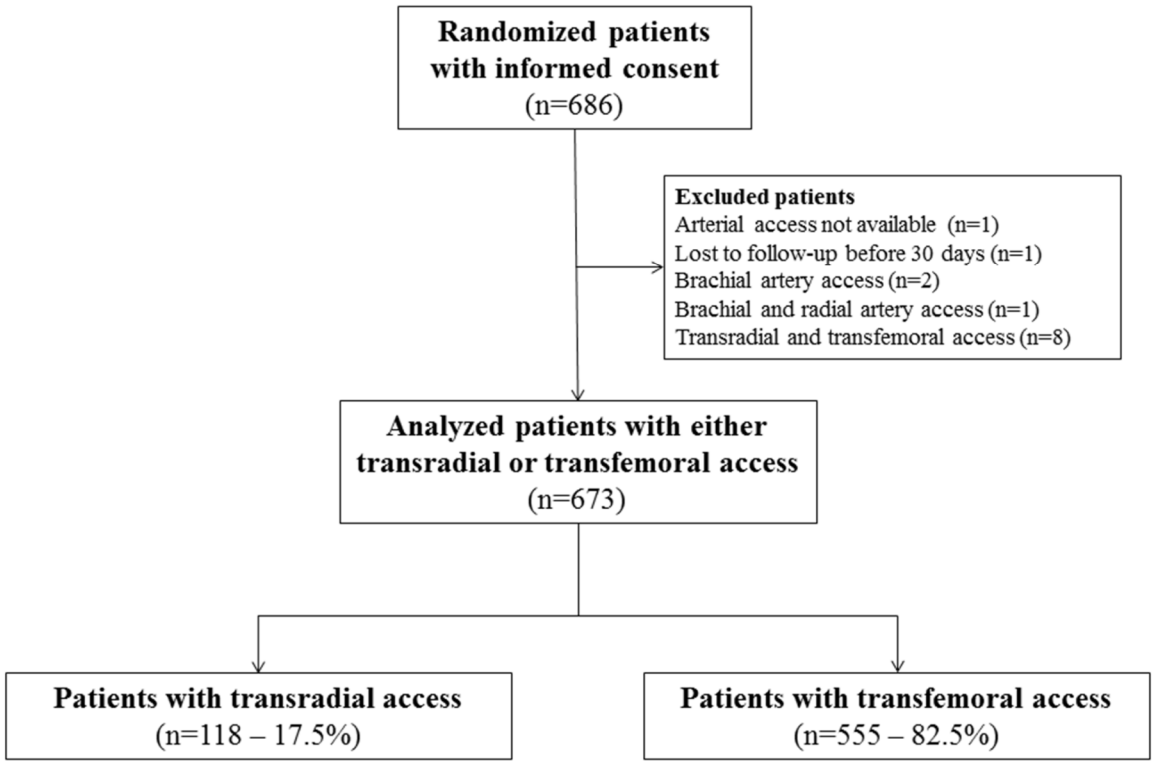
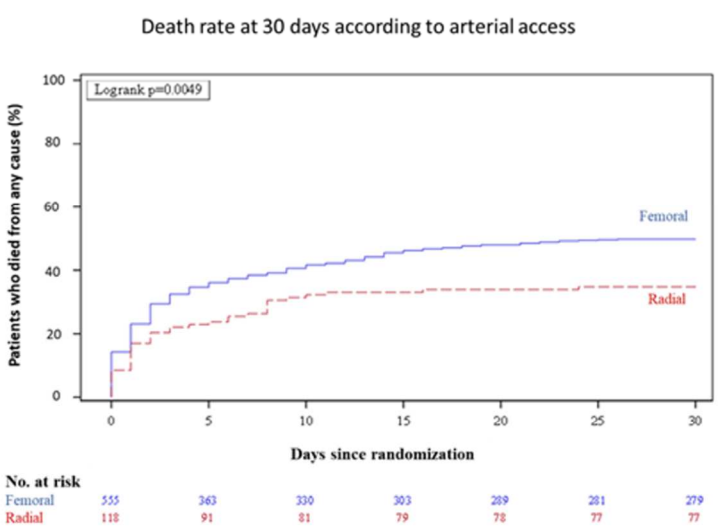
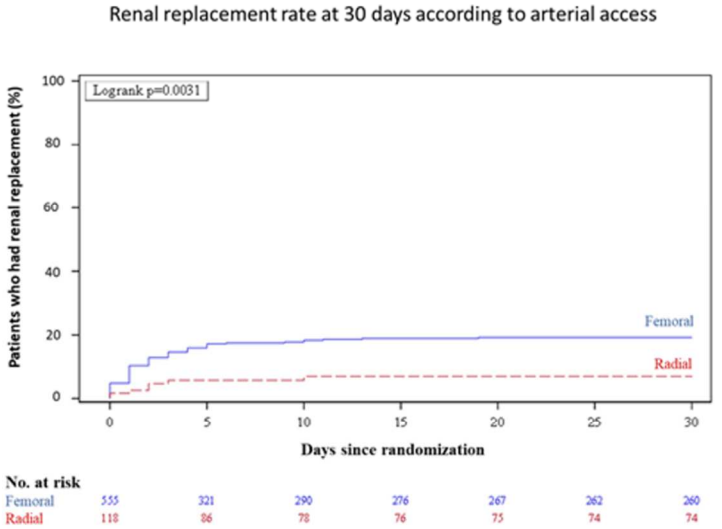
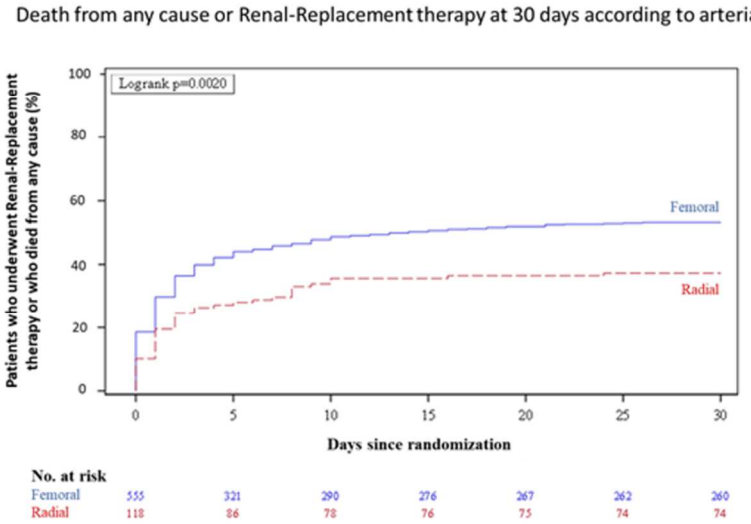
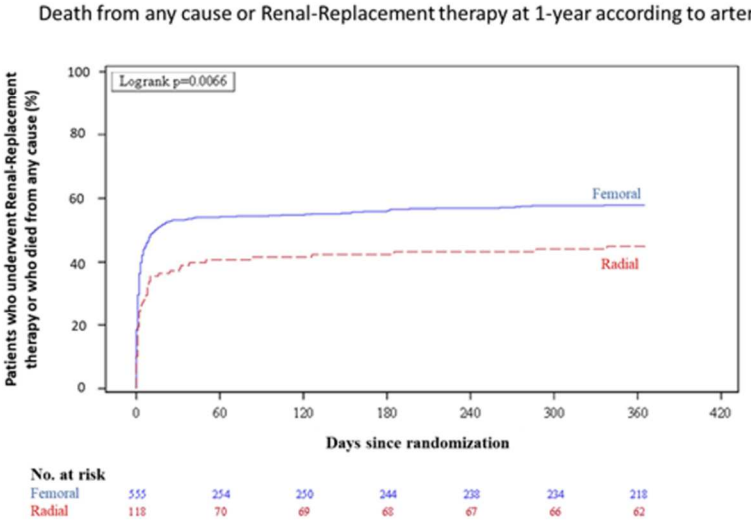


Figure 2 Unadjusted Kaplan Meier curves of 30-day and one-year outcomes









Graphical abstract