**Vascular access site and outcomes in 58,870 patients undergoing PCI with a previous history of coronary bypass surgery: results from the British Cardiovascular Interventions Society National database**

Tim Kinnaird1,9 MD, Richard Anderson1, MD, Sean Gallagher1, MD, James Cockburn2 MD, Alex Sirker3 MD, Peter Ludman4 MD, Mark de Belder5 MD, Samuel Copt6 PhD, James Nolan8,9 MD, Azfar Zaman PhD7, and Mamas Mamas8,9, PhD. 1Department of Cardiology, University Hospital of Wales, Cardiff, UK; 2Department of Cardiology, Sussex Cardiac Centre, Brighton and Sussex University Hospitals, Brighton, UK; 3Department of Cardiology, University College Hospital, London, UK; 4Department of Cardiology, Queen Elizabeth Hospital, Edgbaston, Birmingham, UK; 5Department of Cardiology, The James Cook University Hospital, Middlesbrough, UK; 6Biosensors SA, Morges, Switzerland; 7Department of Cardiology, Freeman Hospital, Newcastle-upon-Tyne, Institute of Cellular Medicine, Newcastle University, UK; 8Department of Cardiology, Royal Stoke Hospital, UHNM, Stoke-on-Trent, UK; 9Keele Cardiovascular Research Group, Institute of Applied Clinical Sciences, University of Keele, Stoke-on-Trent, UK.

**Corresponding Author:**

Dr. Tim Kinnaird

Consultant Interventional Cardiologist

Department of Cardiology,

University Hospital of Wales,

Cardiff, UK

Email: tim.kinnaird2@wales.nhs.uk

Phone: +44 2920 743938

Fax: +44 2920 744473

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**Abstract**

**Objectives:** Using the British Cardiovascular Intervention Society PCI database, access site choice and outcomes of patients undergoing PCI with previous CABG (PCI-CABG) were studied. **Background:** Given the influence of access site on outcomes, use of radial access in PCI-CABG warrants further investigation. **Methods:** Data were analysed from 58,870 PCI-CABG procedures performed between 2005 and 2014. Multivariate logistic regression was used to identify predictors of access site choice and its association with outcomes. **Results:** The number of PCI-CABG cases and the percentage of total PCI increased significantly during the study period. Femoral artery (FA) utilisation fell from 90.8% in 2005 to 57.6% in 2014 (p<0.001) with no differences in the rate of change of left vs. right radial use. In contemporary study years (2012-14), female sex, ACS presentation, CTO intervention, and lower operator volume were independently associated with FA access. Length of stay was shortened in the radial cohort. Unadjusted outcomes including an access site complication (1.1 vs. 0.3%, p<0.001), blood transfusion (0.2% vs. 0.04%, p<0.001), major bleeding (1.3 vs. 0.4%, p<0.001) and in-hospital death (1.1 vs. 0,6%, p=0.001) were more likely to occur with FA access compared to radial access. After adjustment, whilst arterial complications, transfusion and major bleeding remained more common with FA use, short and longer-term mortality, and MACE rates were similar. **Conclusions:** In contemporary practice, FA access remains predominant during PCI-CABG with case complexity associated with it use. FA use was associated with longer length of stay, and higher rates of vascular complications, major bleeding and transfusion.

**Condensed abstract**

Using a national PCI database, access site choice and outcomes of 58,870 PCI procedures in patients with prior CABG were assessed. Femoral artery (FA) utilisation fell from 90.8% in 2005 to 57.6% in 2014 (p<0.001). Covariates independently associated with FA access for native vessel PCI included CTO PCI, female gender, and ACS presentation. After adjustment for baseline differences, an access site complication, blood transfusion, and major bleeding were more likely to occur with FA access compared to radial access although mortality rates were similar between the two cohorts.

**Keywords**

Access choice, coronary artery bypass surgery, percutaneous coronary intervention, complications, national database

**Abbreviations**

BCIS - British Cardiovascular Intervention Society

CABG – Coronary artery bypass surgery

CCS- Canadian Cardiovascular Society

CTO - Chronic total occlusion

MI - Myocardial infarction

NICOR - The National Institute of Cardiovascular Outcomes Research

NYHA – New York Heart Association

OR - Odds ratio

PCI - Percutaneous coronary intervention

**Introduction**

Radial arterial access is increasingly used for percutaneous coronary intervention (PCI) worldwide.1-2 Many factors have driven this change in practice over the last decade including a reduction in major bleeding, transfusion and access site complications, an improvement in patient experience, a reduction in length of stay, and a reduction in mortality in certain sub-groups.3-10 Although there remains a significant variation in radial rates by country, centre and operator, many default radial centers now perform over 90% of procedures using radial access.11

Access site choice is defined by a number of factors including physician practice and preference, patient variables, coronary anatomy, radial occlusion and arterial spasm.12,13 However, particularly complex case sub-groups such those patients with a history of CABG and those with chronic occlusive disease may still be undertaken using femoral arterial access. In particular, patients with a history of prior coronary artery bypass surgery (CABG) undergoing PCI (PCI-CABG) may be more difficult to treat using radial access because of uncertain graft location, left radial or bilateral mammary artery use, and a propensity for chronic occlusive disease (CTO). .14,15 Problems include difficulties in seating the guide catheter adequately in a stable position, achieving adequate guide support, and/or reaching the ostia of venous grafts, and even following graft cannulation catheter support from the aortic sinus or opposite aortic wall may sub-optimal due to the position of the graft ostia.

We have previously demonstrated successful treatment of saphenous vein graft disease via radial access in a two centre UK study.16 However, access site outcomes in general for patients with prior CABG are poorly defined with only 1 randomised and 8 nonrandomized studies, and a total of 2,763 patients’ data published.17 Therefore, the aim of the present study was to use the British Cardiovascular Intervention Society (BCIS) National PCI Audit data from 2005 to 2014, to explore changes in national arterial access site practice in patients with prior CABG by examining the baseline demographics, procedural characteristics and predictors, and the outcomes of patients undergoing PCI from the femoral artery compared to the radial artery.

**Methods**

*Study design, setting and participants*

We analysed national data from all patients undergoing PCI with a previous history of CABG and without cardiogenic shock in England and Wales between January 2005 and December 2014. Participants with missing information on access site or CABG status were excluded.

*Setting, data source, and study size*

Data on PCI practice in the United Kingdom were obtained from the British Cardiovascular Intervention Society (BCIS) dataset that records this information prospectively and publishes this information in the public domain as part of the national transparency agenda.18 In 2014, 98.6% of all PCI procedures performed in the National Health Service (NHS) hospitals in England and Wales (www.bcis.org.uk/) were recorded on the database. The BCIS-NICOR database contains 113 clinical, procedural and outcomes variables with approximately 80,000 new records added each year. The participants of the database are tracked by the Medical Research Information Services for subsequent mortality using the patients' NHS number (a unique identifier for any person registered within the NHS in England and Wales). All data were collected as part of a national audit and were anonymized and therefore institutional review board approval was not required for this study.

*Study definitions*

Using the BCIS dataset, patients were categorised into either radial or femoral access during PCI-CABG. Multiple arterial access and unlisted access site were excluded from the analysis. Study definitions were used as in the BCIS-NICOR database.18 Specifically, pre-procedural renal failure is defined as any one of the following: creatinine >200µmol/l, and acute or chronic dialysis. An access site complication is defined as either a false aneurysm, haemorrhage (without haematoma). haemorrhage with delayed discharge, retroperitoneal haematoma, femoral arterial dissection, or any access site complication requiring surgical repair. In-hospital major bleeding was defined as either gastrointestinal bleed, intra-cerebral bleed, retroperitoneal hematoma, blood or platelet transfusion, or an arterial access site complication requiring surgery.

*Data analyses*

All study years (2005-2014) are presented initially to study temporal changes in access site. However, for the purposes of examining the predictors of access site for CABG-PCI, analysis was restricted to the final three years of data (2012 to 2014) to encompass more contemporary interventional practice and when changes in access choice rates were minimal. For these years, we examined the baseline characteristics of participants, the procedural details, individual operator CABG-PCI volumes, individual centre CABG-PCI volumes and clinical outcomes by femoral access vs. radial access. Data are presented by native vessel or graft vessel. We tested for associations between each categorical variable and access site using a Chi-squared test, and for continuous variables we used one-way analysis of variance. We then performed an analysis of the predictors of access site for the overall cohort, and then by sub-groups of native vessel, graft PCI, ad-hoc PCI and CTO PCI for the period 2012-2014. We used multivariate logistic regression to investigate the influence of variables that have the potential for being included in the linear component of a proportional hazard model. Variables included in the model were age, gender, presentation, NHYA class, previous MI, previous PCI, diabetes, BMI, hypertension, ejection fraction, lesion location, number of vessels diseased, CTO attempt, rotational and laser atherectomy use, micro-catheter use, penetration catheter use and renal failure. To correct for missing values, we first imputed missing data on baseline covariates using multiple imputations with chained equations to adjust for missing data. We then ran a stepwise forward selection with a proportional hazard model with p < 0.1 as entry criteria.

The outcomes of interest were in-hospital mortality, 30-day mortality, 1-year mortality, in-hospital bleeding, re-infarction, emergency CABG, stroke, cardiac tamponade, side branch occlusion and coronary dissection for which we initially calculated the crude rates by access site. Mortality outcome data were available for 94.5% of patients at 30-days and 92.3% as 12-months. Individual logistic regressions were done on the imputed data set for each of the MACE events according to the access site to quantify the independent association between access site and outcomes. In order to take into account baseline characteristics that might influence outcomes, we performed a propensity score analysis using the inverse probability of treatment weights. The weights were derived from a logistic regression with the following variables: age, gender, clinical presentation, NYHA class, previous MI, previous PCI, previous CABG, diabetes, hypertension, peripheral vascular disease, cerebrovascular disease, renal failure, left main and CTO attempt. A time to event analysis was performed using Kaplan-Meier curves, log-rank tests and Cox proportional hazard model to estimate the corresponding hazard ratio for mortality.

**Results**

*Temporal changes in access site choice and vessel type for PCI-CABG between 2005 and 2015*

Between 2005 and 2014, 58,870 PCI’s were undertaken in patients with prior CABG in England and Wales with significant increases in overall PCI (p<0.001) and PCI-CABG (p<0.001) numbers (Figure 1). PCI-CABG as a percentage of total PCI rose from 7.7% in 2005 to 10.5% in 2014 (p=0.0485, Figure 1 grey circles). Overall, femoral artery utilisation fell from 90.8% in 2005 to 57.6% in 2014 (Figure 2A, p<0.001 for trend). During the study period, there was a temporal change in the vessel treated with a significant relative reduction in graft PCI compared to native vessel PCI (p=0.0125, Figure 3A) although the absolute numbers of both increased significantly as the proportion of patients with a CABG history undergoing PCI increased. Femoral access use for PCI in graft vs. native vessel PCI fell in a parallel fashion although femoral access rates for native vessel PCI were consistently lower for all years apart from 2005 (Figure 3B). Patients with a history of CABG were older and had a significantly greater burden of comorbidity such as hypertension, renal failure, previous PCI, anti-coagulation, and diabetes than patients without previous CABG (Supplementary table 1).

*Baseline demographics by vessel type and access site choice for PCI-CABG from 2012 to 2014*

The baseline demographics by vessel type and access site for patients undergoing PCI-CABG between 2012 and 2014 are presented in Table 1. Patients undergoing native vessel PCI-CABG via the femoral artery were older, more likely to be female, present with an acute coronary syndrome and have more comorbid conditions than patients treated via the radial artery. Although there were fewer differences between the two access site cohorts for graft PCI patients undergoing graft PCI were in general older with a much greater burden of comorbidity than native vessel PCI patients (Table 1).

*Procedural variables by vessel type and access site choice for PCI-CABG from 2012 to 2014*

The procedural variables for PCI-CABG by vessel type and access site are presented in Table 2. In patients undergoing native vessel PCI, femoral access was more commonly used for right coronary PCI, whilst radial access was more commonly for left main and LAD PCI. Additionally, the complexity of the intervention was closely associated with access choice in native vessel PCI with a primary consultant operator, CTO-PCI, intra-vascular ultrasound, penetration catheter, micro-catheter, and Crossboss/Stingray use all more frequently utilised when femoral artery access was chosen. Differences in access site for graft PCI were fewer with intra-vascular ultrasound, laser atherectomy and distal protection more frequently used in the radial cohort.

*Baseline demographics and procedural variables by left or right radial access from 2012 to 2014*

Although the left radial was used left frequently than the right radial, both increased at a highly significant rate over time (p<0.001for both trends), with no significant difference in the rate of change between the two access sites (Figure 2B). An analysis of left or right radial access site use is presented in Supplementary table 2. This illustrates that when radial access is utilised, the left radial is more likely to be selected for acute coronary syndrome cases, ad-hoc PCI, graft intervention and for distal protection (p<0.001 for all comparisons). Conversely, the right radial artery is more likely to be used in native vessel PCI, with rotational atherectomy and in CTO intervention (p<0.001 for all comparisons).

*Operator and centre volume and access site choice for PCI-CABG from 2012 to 2014*

There was a negatively skewed distribution of operator volume of CABG-PCI cases with a significant number of low volume operators and a median during the study years 2012-2014 of 20 cases in total. There was also negatively skewed distribution of centre volume of CABG-PCI cases with a significant number of low volume centres and a median of 120 cases. There was a correlation between tertiles of operator volume and the likelihood of femoral access and between tertiles of operator volume and femoral access (p<0.001 for both comparisons, Table 3). There was a weak correlation between individual operator volume (r2=0.1006, p=0.016), but not individual centre volume (r2=0.1373, p=0.117, Supplementary figure 1). However, there was a very wide variation in access site choice for a particular decile, with femoral access use ranging from <20% and >80% within all operator volume categories below 50 cases.

*Predictors of access site choice for PCI-CABG by vessel type from 2012 to 2014*

Using multivariate analyses, covariates associated with access site choice in patients with previous CABG between 2012 and 2014 were identified and are presented in Table 4. Clinical factors associated with higher rates of femoral access use were female sex, ACS presentation, and chronic renal disease whilst chronic anticoagulation was associated with lower rates of femoral access use. Procedural complexity factors such as chronic occlusive disease intervention, CrossBoss use, graft intervention and previous PCI were all independently associated with femoral artery access. Additionally, higher operator volume was independently associated with a lower rate of femoral access with an odds ratio of 0.81 (95% CI [0.74-0.88], p<0.001) for the comparison of the intermediate tertile vs. the lowest tertile, and an odds ratio of 0.68 (95% CI [0.56-0.82], p<0.001) for the comparison of the highest tertile vs. the lowest tertile. Further analyses of covariates associated with access site choice in important sub-groups including native vessel by presentation type, native vessel by CTO status and graft vessel by presentation type were performed, and the results presented in Supplementary Tables 3-5.

*Clinical outcomes by access site choice for PCI-CABG from 2012 to 2014*

The number of successful lesions was similar for radial and femoral access although post-procedural TIMI 3 flow was more frequent in radial access cases (Supplementary Table 6). Immediate coronary complications including coronary perforation, coronary dissection and major side-branch loss occurred with similar frequency between the two access sties. However, an access site complication (1.1 vs. 0.3%, p<0.001) was significantly more likely to occur with femoral access. The crude unadjusted clinical outcomes including blood transfusion (0.2% vs. 0.04%, p<0.001), in-hospital major bleeding rates (1.3 vs. 0.4%, p<0.001, and mortality at 30-days and 1-year were significantly higher in the femoral cohort (Supplementary Table 6). After propensity score analysis to adjust for differences in baseline demographics that might influence patient outcomes, only arterial complications, transfusion and in-hospital major bleeding were more common in the femoral cohort (Table 5). The adjusted Kaplan Meier curves for 12-month survival by access site are displayed in Figure 4.

Length of stay for the whole study population was significantly lower in the radial cohort with same-day discharge also more likely (Supplementary Table 7). These differences were mainly driven by greater reduction in LOS with the elective cohort compared to the ACS cohort (Supplementary figure 2).

**Discussion**

In the United Kingdom, radial artery access for angiography and PCI has risen steadily year on year. It is noteworthy therefore, that despite the major change in overall practice, several sub-groups of PCI procedures such as CTO-PCI continue to be undertaken more often from the femoral artery.19 In the current study, more than half of all PCI procedures in patients with a history of CABG performed in the most recent year of analysis (2014) were performed via femoral arterial access. This contrasts with the most recent BCIS National Angioplasty Audit in which for the same year, 75.3% of all PCI procedures were performed using the radial artery.11 These data are all the more relevant given the significant increase in the overall numbers of PCI-CABG procedures from 3,092 in 2005 to 8,757 in 2014. Although there may be a lag-effect in operators’ skills to undertake PCI-CABG radially, the flattening of the radial uptake curve illustrated in our data make it unlikely that the radial rates observed across all PCI in the UK will be translated into PCI-CABG practice in the near future. It is also interesting to note that the baseline features of the PCI-CABG cohort were very different compared to a general PCI cohort i.e. advanced age, increased comorbidity and more frequent chronic anti-coagulation. Therefore, paradoxically this cohort of patients with characteristics of increased bleeding risk paradoxically are less likely to undergo PCI using radial access than a lower bleeding risk generalised PCI population.

In the current study, there were several baseline and procedural factors that were associated with access site choice for PCI-CABG for PCI. Clinical factors such as female sex and chronic renal impairment presumably reflect difficulties in adequate arterial cannulation due to radial artery caliber or calcification. The association between an ACS presentation and femoral artery use might be explained by a lack of information on the previous CABG available in the acute setting and therefore operators defaulting to the femoral artery to facilitate imaging of both mammary arteries. Additionally, although operator volume was associated with access site choice, it was a striking to observe a very wide range in femoral access use for all deciles of procedure volume and it seems unlikely that this variation is explained by a differential case mix between operators. These data therefore suggest that operator comfort and personal choice, rather than patient and procedural factors significantly influence access site choice for PCI in patients with previous CABG. Therefore, entrenched practice is potentially leading to avoidable adverse patient outcomes.14 Our data also illustrate that patients with a history of CABG are more likely to present with factors associated with higher rates of femoral access such as advanced age, hypertension, diabetes, previous PCI and renal failure than patients without prior CABG.20 Despite these concerns and technical challenges, there are published series of high radial success rates and novel interventional techniques for PCI-CABG.15,16,21-26 Indeed a recent meta-analysis of 2,763 patients derived from 1 randomised and 8 non-randomised studies of patients with previous CABG undergoing PCI, demonstrated similar procedure times, contrast volumes and success rates between radial and femoral access.17

Evolving CTO strategies have provided alterative native vessel interventional targets in patients with previous CABG who frequently have chronic occlusive disease. Several recent publications of CTO-PCI in patients with a history of CABG have demonstrated high procedural success rates confirming the validity of this as a viable strategy.27-29 However, our group recently demonstrated that in contemporary UK practice, the femoral artery remained the predominant access site for CTO intervention (with or without a history of CABG).19 Therefore, the propensity for chronic occlusive disease in patients with previous CABG, and the close association between femoral access and CTO intervention are likely to result in continuing high femoral artery use in for PCI-CABG procedures.

Although acute coronary complications were similar between the femoral and radial cohorts, there was a significant increase in access site complications in the femoral cohort. This was associated with increases in transfusion, and major bleeding which persisted after correction for baseline imbalances in the two cohorts. Although the crude unadjusted data suggest an association between mortality and access site choice, these differences were lost after use of propensity adjustment to correct for baseline imbalances between the radial and femoral cohorts. These data are consistent with previous data suggesting that although in certain subgroups such as those undergoing primary PCI, radial access is associated with a survival benefit,30 mortality is not necessarily lower in unselected patient cohorts. The adverse vascular access site outcomes are likely to be a contributor to the longer length of stay seen in the femoral cohort, although the major driver of shortened length of stay may simply be earlier ambulation and patient self-caring. Additionally, radial access for elective PCI appeared to significantly enhance the day-case procedures. This in itself is an important observation, with a recent US study suggesting that modest changes in access site choice might lead to annual savings nationally of $300 million.31

In considering the possible disadvantages of the radial approach, excess contrast and radiation doses have been suggested as a potential barrier to its widespread adoption. Although the BCIS dataset does not record contrast use, it is reassuring to observe that the rate of acute kidney injury is numerically lower in the radial cohort. Additionally, two previous meta-analyses have concluded that in patients undergoing PCI with a history of CABG, radial access is not associated with an increase in contrast usage.32-33 There is also no consistency in the data examining radiation dose and access site in a general PCI cohort.34-35 In addition, sub-analysis of the RIVAL trial demonstrated that excess radiation was only observed in the low volume radial centres with no difference in higher volume centres.36 recent meta-analysis of 24 published RCTs of 19 328 patients suggested that differences in screening time by access site also appear to have narrowed over time, with only a 30 second difference between radial and femoral access site reported in 2014.37 In considering radiation dose in specifically in post-CABG patients, in a recent meta-analysis of 2,763 patients undergoing PCI with a previous history of CABG, no differences in radiation dose were observed.33

As with any database, the robustness of the conclusions is directly related to the quality of data entered. Although there are high levels of case ascertainment and field completion within the database, the accuracy of field completion for individual centers cannot be validated. Finally, as this data is registry-derived, any conclusions are potentially influenced by unmeasured confounders inherent in observational studies of this nature such as comorbidity and frailty.

In conclusion, femoral artery access remains predominant during PCI-CABG and despite these patients being at risk of bleeding complications, radial access than was much lower than in a general PCI population. Access site complications were more frequent with femoral artery access and strongly correlated with adverse outcomes.

**Clinical perspective**

**What is known?**

Access site choice for PCI is a vital part of procedure planning and completion and in unselected populations, radial access is associated with lower rates of vascular complications.

**What's new?**

In the current study, we demonstrate that the femoral artery remains the default access site of choice even in the United Kingdom where the majority of all PCI procedures are undertaken radially. Femoral artery use was associated with more complicated procedures but also associated with more access site complications, major bleeding and transfusion.

**What's next?**

As the femoral artery still remains the most frequently used access site, further development of interventional practice may allow increased adoption of radial artery access to optimise the outcomes of patients undergoing PCI with a previous CABG.

**References**

1. [Bradley SM](http://www.ncbi.nlm.nih.gov/pubmed?term=Bradley%20SM%5BAuthor%5D&cauthor=true&cauthor_uid=24899678), [Rao SV](http://www.ncbi.nlm.nih.gov/pubmed?term=Rao%20SV%5BAuthor%5D&cauthor=true&cauthor_uid=24899678), [Curtis JP](http://www.ncbi.nlm.nih.gov/pubmed?term=Curtis%20JP%5BAuthor%5D&cauthor=true&cauthor_uid=24899678), et al. Change in hospital-level use of trans-radial percutaneous coronary intervention and peri-procedural outcomes: insights from the national cardiovascular data registry. Circ Cardiovasc Qual Outcomes. 2014;7:550-9.
2. [Feldman DN](http://www.ncbi.nlm.nih.gov/pubmed?term=Feldman%20DN%5BAuthor%5D&cauthor=true&cauthor_uid=23753843), [Swaminathan RV](http://www.ncbi.nlm.nih.gov/pubmed?term=Swaminathan%20RV%5BAuthor%5D&cauthor=true&cauthor_uid=23753843), [Kaltenbach LA](http://www.ncbi.nlm.nih.gov/pubmed?term=Kaltenbach%20LA%5BAuthor%5D&cauthor=true&cauthor_uid=23753843), 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(23):2295-306.
3. Cooper CJ, El-Shiekh RA, Cohen DJ et al. Effect of trans-radial access on quality of life and cost of cardiac catheterization: A randomized comparison. Am Heart J. 1999;138(3):430-6.
4. Mann JT,3rd, Cubeddu MG, Schneider JE, et al. Right radial access for PTCA: A prospective study demonstrates reduced complications and hospital charges. J Invasive Cardiol. 1996;8 Suppl D:40D-4D.
5. Hulme W, Sperrin M, Kontopantelis E, et al; British Cardiovascular Intervention Society and the National Institute of Cardiovascular Outcomes Research. Increased Radial Access Is Not Associated With Worse Femoral Outcomes for Percutaneous Coronary Intervention in the United Kingdom. Circ Cardiovasc Interv. 2017 Feb;10(2):e004279.
6. Hulme W, Sperrin M, Rushton H, et al. Is There a Relationship of Operator and Center Volume With Access Site-Related Outcomes? An Analysis from the British Cardiovascular Intervention Society. Circ Cardiovasc Interv. 2016;9(5):e003333.
7. Mamas MA, Nolan J, de Belder MA, et al ; British Cardiovascular Intervention Society (BCIS) and the National Institute for Clinical Outcomes Research (NICOR). Changes in Arterial Access Site and Association With Mortality in the United Kingdom: Observations From a National Percutaneous Coronary Intervention Database. Circulation. 2016;133(17):1655-67.
8. Kwok CS, Kontopantelis E, Kunadian V, et al; British Cardiovascular Intervention Society; National Institute for Cardiovascular Outcomes Research. Effect of access site, gender, and indication on clinical outcomes after percutaneous coronary intervention: Insights from the British Cardiovascular Intervention Society (BCIS). Am Heart J. 2015;170(1):164-72.
9. Kwok CS, Khan MA, Rao SV, et al. Access and non-access site bleeding after percutaneous coronary intervention and risk of subsequent mortality and major adverse cardiovascular events: systematic review and meta-analysis. Circ Cardiovasc Interv. 2015;8(4) pii: e001645.
10. Kinnaird TD, Stabile E, Mintz GS, et al. Incidence, predictors, and prognostic implications of bleeding and blood transfusion following percutaneous coronary interventions. Am J Cardiol. 2003 Oct 15;92(8):930-5.
11. BCIS Audit Returns for Adult Interventional Procedures Jan 2015–Dec 2015. <http://www.bcis.org.uk/documents/39F_BCIS_Audit_2014_23022016_for_web.pdf>
12. Pancholy SB, Ahmed I, Bertrand OF, et al. Frequency of radial artery occlusion after transradial access in patients receiving warfarin therapy and undergoing coronary angiography. Am J Cardiol. 2014;113(2):211-4.
13. Abdelaal E, Molin P, Plourde G, et al. Successive transradial access for coronary procedures: experience of Quebec Heart-Lung Institute. Am Heart J. 2013;165(3):325-31.
14. Gaudino M, Puskas JD, Di Franco A, et al. Three Arterial Grafts Improve Late Survival: A Meta-Analysis of Propensity Matched Studies. Circulation. 2017 Jan 24. pii: CIRCULATIONAHA.116.025453.
15. Dautov R, Manh Nguyen C, et al. Recanalization of Chronic Total Occlusions in Patients With Previous Coronary Bypass Surgery and Consideration of Retrograde Access via Saphenous Vein Grafts. Circ Cardiovasc Interv. 2016 Jul;9(7)
16. Bundhoo SS, Earp E, Ivanauskiene T et al. [Saphenous vein graft percutaneous coronary intervention via radial artery access: safe and effective with reduced hospital length of stay.](http://www.ncbi.nlm.nih.gov/pubmed/23067903) Am Heart J. 2012;164(4):468-72.
17. Rigattieri S, Sciahbasi A, Brilakis ES, et al. Meta-Analysis of Radial Versus Femoral Artery Approach for Coronary Procedures in Patients With Previous Coronary Artery Bypass Grafting. Am J Cardiol. 2016 Apr 15;117(8):1248-55.
18. Ludman PF, British Cardiovascular Intervention S. British Cardiovascular Intervention Society Registry for audit and quality assessment of percutaneous coronary interventions in the United Kingdom. Heart 2011;97:1293-7.
19. Kinnaird T, Anderson R, Ossei-Gerning N, et al; British Cardiovascular Intervention Society and the National Institute for Cardiovascular Outcomes Research. Legacy Effect of Coronary Perforation Complicating Percutaneous Coronary Intervention for Chronic Total Occlusive Disease: An Analysis of 26 807 Cases From the British Cardiovascular Intervention Society Database. Circ Cardiovasc Interv. 2017;10(5). pii: e004642. doi: 10.1161/CIRCINTERVENTIONS.116.004642.
20. Hamon M, Rasmussen LH, Manoukian SV, et al. Choice of arterial access site and outcomes in patients with acute coronary syndromes managed with an early invasive strategy: the ACUITY trial. EuroIntervention 2009;5(1):115-120.
21. Kim MH, Cha KS, Kim HJ, et al. Bilateral selective internal mammary artery angiography via right radial approach: clinical experience with newly designed Yumiko catheter. Catheter Cardiovasc Interv 2001;54(1):19-24.
22. Ierna S, Belli R, Giammaria M, et al. Successful angioplasty and stenting of bilateral internal mammary artery grafts from the left radial approach. Case report and review of the literature. J Cardiovasc Med 2007;8(7):531-534. Review.
23. Alaswad K, Menon RV, Christopoulos G, et al. [Transradial approach for coronary chronic total occlusion interventions: Insights from a contemporary multicenter registry.](http://www.ncbi.nlm.nih.gov/pubmed/25640902) Catheter Cardiovasc Interv 2015;85(7):1123-1129.
24. Burzotta F, De Vita M, Lefevre T, et al. Radial approach for percutaneous coronary interventions on chronic total occlusions: technical issues and data review. Catheter Cardiovasc Interv 2014;83(1):47-57.
25. Rathore S, Hakeem A, Pauriah M, et al. A comparison of the transradial and the transfemoral approach in chronic total occlusion percutaneous coronary intervention. Catheter Cardiovasc Interv 2009;73(7):883-887.
26. Farooq V, Mamas MA, Fath-Ordoubadi F, et al. The use of a guide catheter extension system as an aid during transradial percutaneous coronary intervention of coronary artery bypass grafts. Catheter Cardiovasc Interv. 2011;78(6):847-63.
27. Dautov R, Manh Nguyen C, et al. Recanalization of Chronic Total Occlusions in Patients With Previous Coronary Bypass Surgery and Consideration of Retrograde Access via Saphenous Vein Grafts. Circ Cardiovasc Interv. 2016l;9(7). pii: e003515.
28. Teramoto T, Tsuchikane E, Matsuo H, et al. Initial success rate of percutaneous coronary intervention for chronic total occlusion in a native coronary artery is decreased in patients who underwent previous coronary artery bypass graft surgery. JACC Cardiovasc Interv 2014;7(1):39-46.
29. Christopoulos G, Menon RV, Karmpaliotis D, et al. Application of the "hybrid approach" to chronic total occlusions in patients with previous coronary artery bypass graft surgery (from a Contemporary Multicenter US registry). Am J Cardiol 2014;113(12):1990-4.
30. Mamas MA, Ratib K, Routledge H, et al. Influence of access site selection on PCI-related adverse events in patients with STEMI: meta-analysis of randomised controlled trials. Heart. 2012;98(4):303-11.
31. Amin AP, Patterson M, House JA, et al. Costs Associated With Access Site and Same-Day Discharge Among Medicare Beneficiaries Undergoing Percutaneous Coronary Intervention: An Evaluation of the Current Percutaneous Coronary Intervention Care Pathways in the United States. JACC Cardiovasc Interv 2017;10(4):342-351.
32. [Shah R](https://www.ncbi.nlm.nih.gov/pubmed/?term=Shah%20R%5BAuthor%5D&cauthor=true&cauthor_uid=28515857), [Mattox A](https://www.ncbi.nlm.nih.gov/pubmed/?term=Mattox%20A%5BAuthor%5D&cauthor=true&cauthor_uid=28515857), [Khan MR](https://www.ncbi.nlm.nih.gov/pubmed/?term=Khan%20MR%5BAuthor%5D&cauthor=true&cauthor_uid=28515857), et al. Contrast use in relation to the arterial access site for percutaneous coronary intervention: A comprehensive meta-analysis of randomized trials. [World J Cardiol.](https://www.ncbi.nlm.nih.gov/pubmed/28515857) 2017;9(4):378-383.
33. [Rigattieri S](https://www.ncbi.nlm.nih.gov/pubmed/?term=Rigattieri%20S%5BAuthor%5D&cauthor=true&cauthor_uid=26892452), [Sciahbasi A](https://www.ncbi.nlm.nih.gov/pubmed/?term=Sciahbasi%20A%5BAuthor%5D&cauthor=true&cauthor_uid=26892452), [Brilakis ES](https://www.ncbi.nlm.nih.gov/pubmed/?term=Brilakis%20ES%5BAuthor%5D&cauthor=true&cauthor_uid=26892452), et al. Meta-Analysis of Radial Versus Femoral Artery Approach for Coronary Procedures in Patients With Previous Coronary Artery Bypass Grafting. [Am J Cardiol.](https://www.ncbi.nlm.nih.gov/pubmed/26892452) 2016;117(8):1248-55.
34. Sciahbasi A, Frigoli E, Sarandrea A, et al. Radiation Exposure and Vascular Access in Acute Coronary Syndromes: The RAD-Matrix Trial. J Am Coll Cardiol. 2017;69(20):2530-2537
35. Bakker EJ, Maeremans J, Zivelonghi C, et al. Fully Transradial Versus Transfemoral Approach for Percutaneous Intervention of Coronary Chronic Total Occlusions Applying the Hybrid Algorithm: Insights From RECHARGE Registry. Circ Cardiovasc Interv. 2017;10(9). pii: e005255. doi:10.1161/CIRCINTERVENTIONS.117.005255.
36. Jolly SS, Cairns J, Niemela K, et al; RIVAL Investigators. Effect of radial versus femoral access on radiation dose and the importance of procedural volume: a substudy of the multicenter randomized RIVAL trial. JACC Cardiovasc Interv. 2013;6(3):258-66.
37. Plourde G, Pancholy SB, Nolan J, Jolly S, Rao SV, Amhed I, Bangalore S, Patel T, Dahm JB, Bertrand OF. Radiation exposure in relation to the arterial access site used for diagnostic coronary angiography and percutaneous coronary intervention: a systematic review and meta-analysis. Lancet. 2015;386(10009):2192-20.

**Figure Legends**

**Figure 1 Crude numbers of total PCI and CABG-PCI cases:** Annual numbers of total PCI (light grey bars), annual numbers of PCI in patients with a CABG history (dark grey bars), p<0.001 for both trends, and percentage of total PCI represented by patients with a CABG history (grey circles), p=0.0485 for trend in England and Wales 2005-2014.

**Figure 2 Arterial use for PCI-CABG between 2005 and 2014:** A) Temporal change in femoral access use for PCI in patients with prior CABG in England and Wales 2005-2014 (P<0.001 for trend); B) Temporal change in left (closed circles) and right radial (open circles) use for PCI in patients with prior CABG in England and Wales 2005-2014 (P<0.001 for both trends, with no significant difference in the comparison between trends).

**Figure 3 Changes in vessel type and access site over time:** A) Temporal change in vessel treated in patients with previous CABG (p=0.0125 for trend) in England and Wales 2005-2014; B) Femoral access use for PCI in graft PCI vs. native vessel PCI over time (p<0.001 for both trends, p<0.001 for graft vs. native PCI for each yearly time point except 2005) in England and Wales 2005-2014.

**Figure 4 Survival by access site for PCI-CABG:** Kaplan Meier plots for 12-month adjusted mortality by access site in 2012-14 procedure years.