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Complex high-risk percutaneous coronary intervention types, trends, and outcomes according to vascular access site

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Abstract

Background: Radial access is associated with improved outcomes following percutaneous coronary intervention (PCI); however, its role in complex, high-risk percutaneous coronary intervention (CHiP) remains poorly studied.

Methods: We studied retrospectively all registered patients's records from the British Cardiovascular Intervention Society dataset and compared the baseline characteristics, trends and outcomes of CHiP procedures performed electively between January 2006 and December 2017 according to the access site.

Results: Out of 137,785 CHiP procedures, 61,825 (44.9%) were undertaken via transradial access (TRA). TRA use increased over time (14.6% in 2006 to 67% in 2017). The TRA patients were older, with a greater prevalence of previous stroke, hypertension, peripheral vascular disease, and smokers. TRA was used more frequently in most CHiP procedures (elderly (51.6%), chronic renal failure (52.6%), poor left ventricular (LV) function (47.6%), left main PCI (48.0%), treatment for severe vascular calcification (50.3%); although transfemoral access (TFA) was used more commonly in those with prior history of coronary artery bypass graft surgery, and PCI to a chronic total occlusion and LV support patients. Following adjustment for differences in clinical and procedural characteristics, TFA was independently associated with higher odds for mortality [adjusted odds ratio (aOR): 1.3 (1.1–1.7)], major bleeding [aOR: 2.9 (2.3–3.4)], and MACCE (following propensity score matching) [aOR: 1.2 (1.1–1.4)]. The same was found with multiple accesses: mortality [aOR: 2.1 (1.5–2.8)], major bleeding [aOR: 5.5 (4.3–6.9)], and MACCE [aOR: 1.4 (1.2–1.7)].

Conclusion: TRA has become the predominant access site for CHiP procedures and is associated with significantly lower mortality, major bleeding and MACCE odds than TFA.

KEYWORDS
complex PCI, high-risk PCI, radial access, stable angina

Abbreviations: BCIS, British Cardiovascular Intervention Society; CABG, coronary artery bypass graft surgery; CHiP, complex high-risk but indicated percutaneous coronary interventions; MACCE, major adverse cardiovascular and cerebral events; NICOR, National Institute of Cardiovascular Outcomes and Research; TFA, transfemoral access; TRA, transradial access.

1 | INTRODUCTION

The first reports on the use of transradial access (TRA) in percutaneous coronary procedures emerged more than three decades ago.[1,2] Since then, the adoption of the TRA for percutaneous coronary interventions (PCI) has been shown to reduce death, major bleeding, and major cardiovascular and cerebral events (MACCE) in several randomized controlled trials (RCT).[3–5] There has been increased adoption of TRA for PCI in the United Kingdom, Europe, and worldwide not only due to proven benefits around bleeding and mortality events compared to transfemoral access (TFA) but also due to factors such as patient preference, comfort and reduced health care costs.[6] Consequently, a "radial first" strategy has been endorsed by the European and North American guidelines[7,8] which has paved the way toward considering TRA for more complex, high-risk PCIs (CHiP).

In recent years, much has been made of the concept of CHiP; it may refer to a group subset with specific patients' and procedural's characteristics that increase procedural complexity and patient risk.[9–12] However, studies around CHiP outcomes according to access site are limited to nonrandomized or small RCT,[5,13–16] highly selected cohorts (specific types of CHiP only),[17–19] certain geographical areas,[20,21] or international surveys.[6] Hence, the question of whether "radial first" can achieve similar benefits in PCI outcomes in a CHiP procedure remains unanswered.

This analysis sought to study the baseline characteristics and clinical outcomes of CHiP undertaken in patients with stable angina over 12 years according to the access site, using data from a national PCI registry.

2 | METHODS

2.1 | Data source

We used data from the British Cardiovascular Intervention Society (BCIS) registry. The BCIS is managed by the National Institute of Cardiovascular Outcomes and Research (NICOR). Annually, data on over 95% (112 out of the 117 PCI centers in the United Kingdom) of PCI procedures undertaken in England and Wales are collected. The BCIS dataset collects important cardiovascular comorbidities, clinical characteristics, interventional and pharmacological treatments, in-hospital procedural complications and mortality.[22] All data are collected prospectively and encrypted before transferring to central NICOR servers. We did not require ethical approval as all data have section 251 approval of NHS Act 2006, which allows the dataset to be used for audit purposes and research without seeking patients' consent.[23] The BCIS data entry is required for professional revalidation.[22] BCIS dataset quality and accuracy have been previously ascertained.[24]

2.2 | Study design and definitions

This is a retrospective study of prospectively collected data on patients who underwent a CHiP for stable angina in England and Wales between 1st January 2006 and 31st December 2017 on the BCIS registry. We defined CHiP, based on our previous work[12,25,26] as any PCI case that has met at least one of the following patients' characteristics (age ≥80 years, left ventricular function [LV] impairment, previous coronary artery bypass graft [CABG], and chronic renal failure [CRF]) or the following procedural's characteristics: PCI into a left main (LM) or chronic total occlusion (CTO), severe vascular calcifications, or the need for LV support. The collected data were categorized into Radial Access, Femoral Access, and Multiple Access groups.

We defined LV support use as cases where Impella or intra-aortic balloon pump (IABP) was used; severe LV impairment as LV function with an estimated ejection fraction of 30% or less; and extensive vascular calcification as any PCI that required cutting balloons, rotational or laser atherectomy. Finally, CRF was defined as any patient with chronic creatinine elevation of more than 200 µmol/L, a history of renal transplant, or chronic dialysis, which is predefined in the dataset.

2.3 | Study endpoints

We divided the outcome of interests into (a) primary: in-hospital all-cause mortality; (b) secondary: In-hospital major bleeding events and in-hospital MACCE.

Major bleeding events were defined any case that met the Bleeding Academic Research Consortium's definition for Bleeding Type 2 and above. This included access site complication (defined as any of the following: arterial dissection, false aneurysm, retroperitoneal hematoma, or hemorrhage), access site bleeding requiring surgery or intervention, any transfusion of blood or blood products, clinically evident gastrointestinal tract bleeding, radiological evidence of intracranial bleed, retroperitoneal bleed/hematoma.

MACCE was defined as the cumulative incidence of in-hospital death, peri-procedural myocardial infarction (MI) or periprocedural stroke. We defined periprocedural MI as a composite of Q-wave or non-Q-wave MI, repeat revascularization/reintervention (emergency PCI or CABG), and reinfarction, all predefined within the BCIS registry.

2.4 | Statistical analysis

After the initial selection process detailed earlier, the study population was divided into transradial (TRA), transfemoral (TFA), and multiple access groups. All cases where there was missing data in the access, age, sex, and outcomes variables were excluded from the analysis. We then summarized patients' variables as median (interquartile range) for continuous, nonparametric data and frequencies (percentages) for categorical data. We compared the patients' baseline characteristics and procedural details using Pearson's Chi-squared test for categorical and the Kruskal Wallis test for continuous data. Table S1 details the missing data for each variable

included in the study. We used multiple imputations with chained equations to impute missing data to create 10 datasets, assuming that data were missing at random.[27] Logistic regression was used for binary variables, multinomial for nominal, ordinal for ordered, and linear regression for continuous variables in our multiple imputation framework. Age, sex, access, year, and outcomes variables were registered as complete variables in the imputation models. The following variables were imputed: ethnicity, history of dyslipidaemia, previous MI, previous CABG, previous PCI, previous stroke, hypertension, diabetes mellitus, CRF, LV function, peripheral vascular disease (PVD), clopidogrel, family history of coronary artery disease (CAD), intracoronary imaging, LM and CTO PCI, Use of LV support, Use of calcium modification devices, number of treated lesions, stent size and length, number of stents used, and body mass index (BMI). Variables with significant missing observations (such as ethnicity and LV function) were also included in the multiple imputation models; studies have confirmed the robustness of the multiple imputation frameworks even at an extremely high level of missingness, although they can offer some protection when data are missing not at random.[28] Subsequent analyses on the imputed dataset were performed, and results were pooled using Rubin's rule.[29] We used multivariable logistic regression analyses to determine the adjusted odds ratios (aOR), 95% confidence interval (CI), and the p value of outcomes between the three groups. We used forward stepwise selection of the variables with an inclusion criterion of $p < 0.1$ to help select predictors into the final multivariate model. All models included the same variables used in the multiple imputation framework. Finally, to control differences and imbalances in the baseline clinical and procedural characteristics between the TRA and TFA groups, we used multiple imputations with propensity scores matching PSM (mi estimate:teffects psmatch). We matched the following variables: sex, age, ethnicity, dyslipidaemia, previous MI, previous CABG, previous stroke, previous PCI, hypertension, diabetes mellitus, smokers, LV function, CRF, PVD, clopidogrel, family history of CAD, intracoronary imaging, IABP, severe vascular calcifications, LM and CTO PCI, number of treated lesions, number of stents used, stent length and size, and BMI. This was followed by performing logistic regression to estimate the propensity score and matching to the nearest algorithm (Figure S1). To help with a better interpretation of the results, we converted the coefficients to odds ratios. We also performed a sensitivity analysis on the nonimputed dataset to better assess the consistency of the results obtained. Stata version 14.1 was used to conduct the analyses (StataCorp). Statistical significance was evaluated at a type I error rate of 0.05.

3 | RESULTS

The study cohort consisted of 137,785 CHiP (29.6%) out of 424,290 procedure records performed for stable angina patients in England and Wales (1st January 2006–30th December 2017). Figure 1 details the patients' inclusion and exclusion process for this analysis. Figure 2 demonstrates the temporal changes in the prevalence of CHiP procedures stratified by access site; TFA use was predominant in 2006 which gradually declined throughout the study years (2006: TRA 14% vs. TFA 84%; 2017: TRA 67% vs. TFA 18%). Multiple access use increased over time (2006: 2% vs. 2017: 15%). Figure 3 shows the prevalence and percent change of each CHiP factor in the use of TRA and TFA access sites over time with similar findings to those seen in the overall cohort (Figure 2).

3.1 | Baseline characteristics

Overall, 61,825 (44.9%) of the CHiP procedures were performed via the TRA, 63,837 (46.3%) were performed via TFA, and 12,123 (8.8%) needed more than one access. The TRA patients were, on average, older [TRA: 71.2 (62.4–80.3); TFA: 70.2 (61.6–78.6); Multiple: 66.8 (58.3–75)]. Patients who had their CHiP procedure undertaken through TFA had a higher prevalence of diabetes, previous history of MI or PCI, and severe LV dysfunction than the TRA patients. In contrast, TRA patients had a higher prevalence of hypertension, previous stroke and PVD. Also, a higher prevalence of previous MI or PCI and current smokers were observed in those patients who needed more than one access site than in the other groups (Table 1).

3.2 | CHiP factors (types)

TRA was more commonly used in the different types of CHiP compared to TFA including age >80 (51.6% vs. 43.7%), CRF (52.6% vs. 42.0%), LM PCI (48.0% vs. 45.6%), severe vascular calcification (50.3% vs. 44.4%), and poor LV function (47.6% vs. 45.1%), respectively; $p < 0.001$. In contrast, TFA was used more commonly in those patients with previous CABG (56.3% vs. 37.0%), had a PCI to a CTO vessel (42.1% vs. 36.2%), or used an LV support device (46.5% vs. 27.1%), respectively, $p < 0.001$ for all (Table 1).

3.3 | Procedural characteristics

Procedural characteristics varied among the groups (Table 1). TRA group, compared to TFA, had higher rates for intravascular imaging (14.5% vs. 8.5%, respectively; $p < 0.001$) and received treatment for more extensive coronary diseases than TFA; for example, 36.2% of TRA patients received treatment for two or more vessels versus 35.7% in the TFA group. Also, the TRA group required the use of bigger size stents [TRA, 3.5 mm (3.0–4.0) vs. TFA, 3.0 (3.0–3.5)], and longer stents [TRA, 24 mm (18–38) vs. TFA, 23 mm (16–30)], and received two or more stents (45.3% vs. 43.6%), respectively; $p < 0.001$ for all. Similarly, cutting balloons were used more frequently in the TRA group (TRA, 15.9% vs. TFA, 11.9%, $p < 0.001$) as well as laser atherectomy, suggestive of more extensive calcification in the TRA group. Those who required multiple access had the highest rates for use of intracoronary imaging (17.7%), LV support devices (1.7%), needed longer stents [38 mm (24–60)], and had three

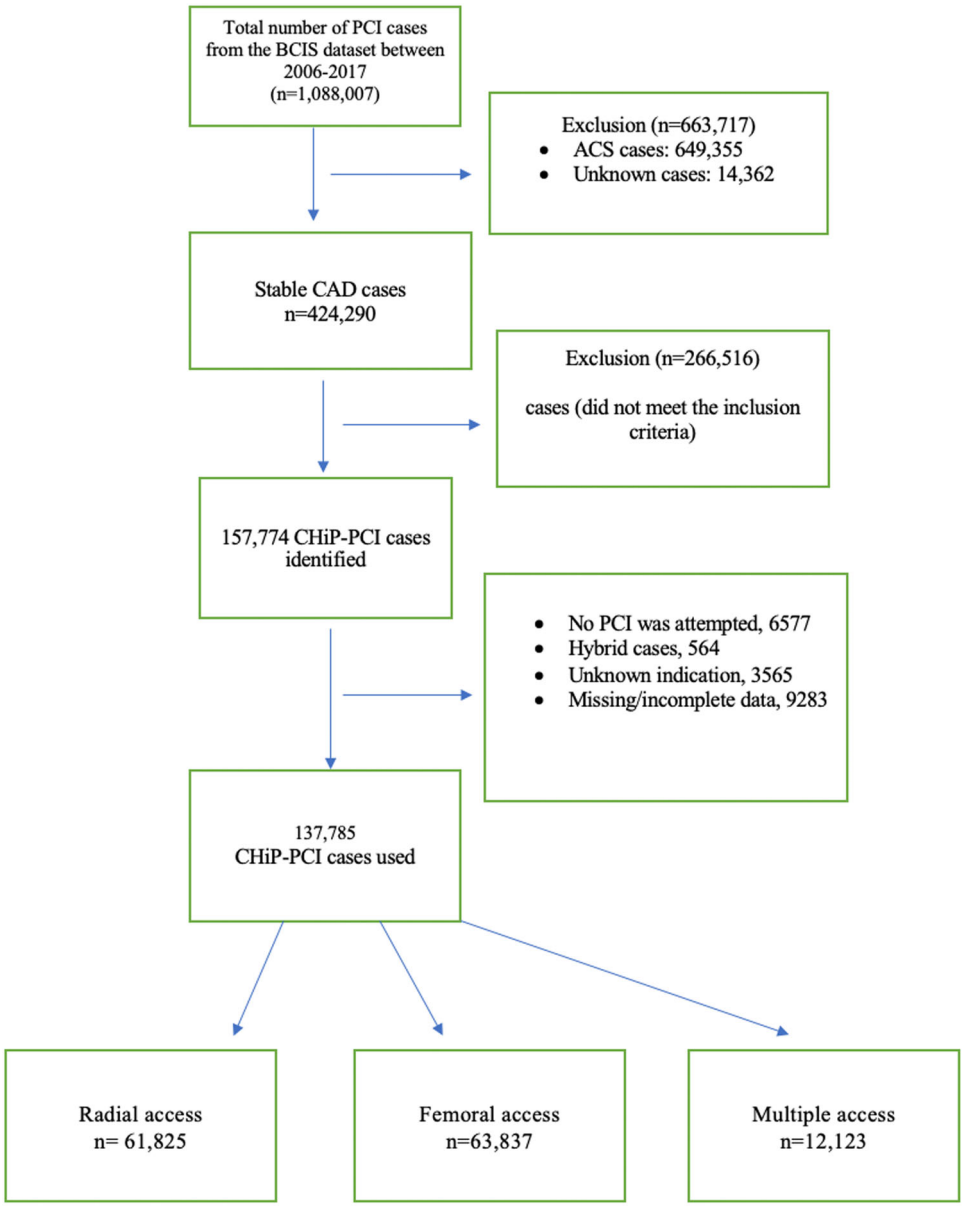

FIGURE 1 Flow diagram illustrating the process of patients' inclusion and exclusion for the CHiP analysis. BCIS, British Cardiovascular Intervention Society; CHiP, complex, high-risk, but indicated percutaneous coronary intervention; PCI, percutaneous coronary interventions. *Inclusion criteria: left main PCI, PCI to chronic total occlusion vessel, chronic renal failure, poor left ventricle function, severe vessel calcifications, previous coronary artery bypass graft, age ≥80 years. [Color figure can be viewed at wileyonlinelibrary.com]

or more stents (32.9%) compared to the other groups. Moreover, the TRA was associated with less failed PCI attempts compared to TFA (8.6% vs. 13.2%, respectively; $p < 0.001$.

3.4 | Clinical outcomes

Table 2 details the crude and adjusted outcomes stratified by access site. Overall, the crude mortality, major bleeding and MACCE were worse in the TFA group than TRA [Mortality: 0.3% vs. 0.2% ($p < 0.001$); Bleeding: 0.6% vs. 0.2% ($p < 0.001$); MACCE: 1.5% vs. 1.3% ($p = 0.002$), respectively]. Following adjustment for differences in baseline covariates the TFA group, compared to TRA, had worse odds for Mortality [aOR: 1.3 (95% CI: 1.1–1.7); $p = 0.008$] and major bleeding [aOR: 2.9 (95% CI: 2.3–3.4); $p < 0.001$]. Adjusted odds for MACCE was: 1.1 (95% CI: 0.9–1.1). However, following PSM, adjusted odds for major bleeding events in the TFA were down to 1.2 (1.1–1.2), $p < 0.001$, whereas MACCE odds were significant [aOR: 1.2 (95% CI 1.1-1.2); $p < 0.001$] (Table S2). Table 3 depicts the overall number of radial access procedures needed to potentially avoid one death, major bleeding event, or MACCE and the number needed in those cases performed in the last 4 years of the study (2014–2017, NNT: mortality, 579; major bleeding events, 244; MACCE, 403).

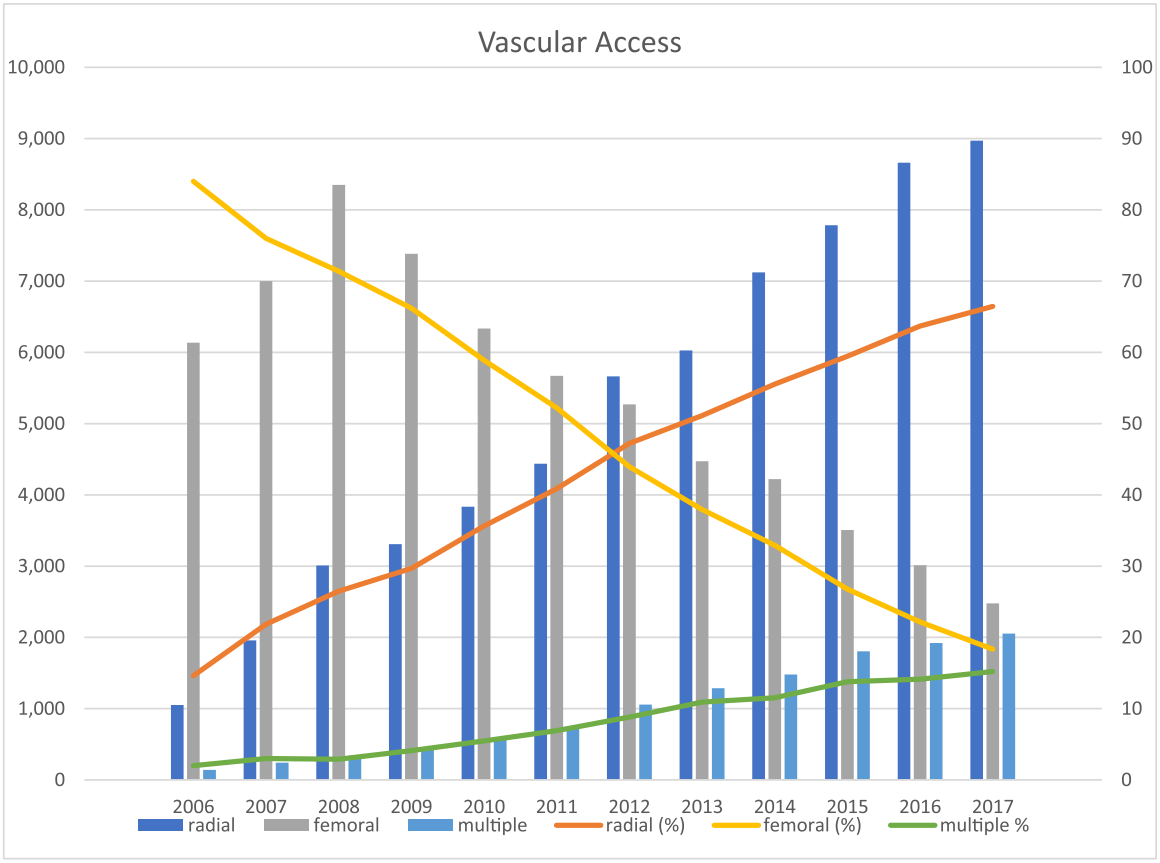

FIGURE 2 Temporal changes in CHiP procedures' prevalence and percent changes over time, stratified by access site. CHiP, complex high-risk but indicated percutaneous coronary interventions. [Color figure can be viewed at wileyonlinelibrary.com]

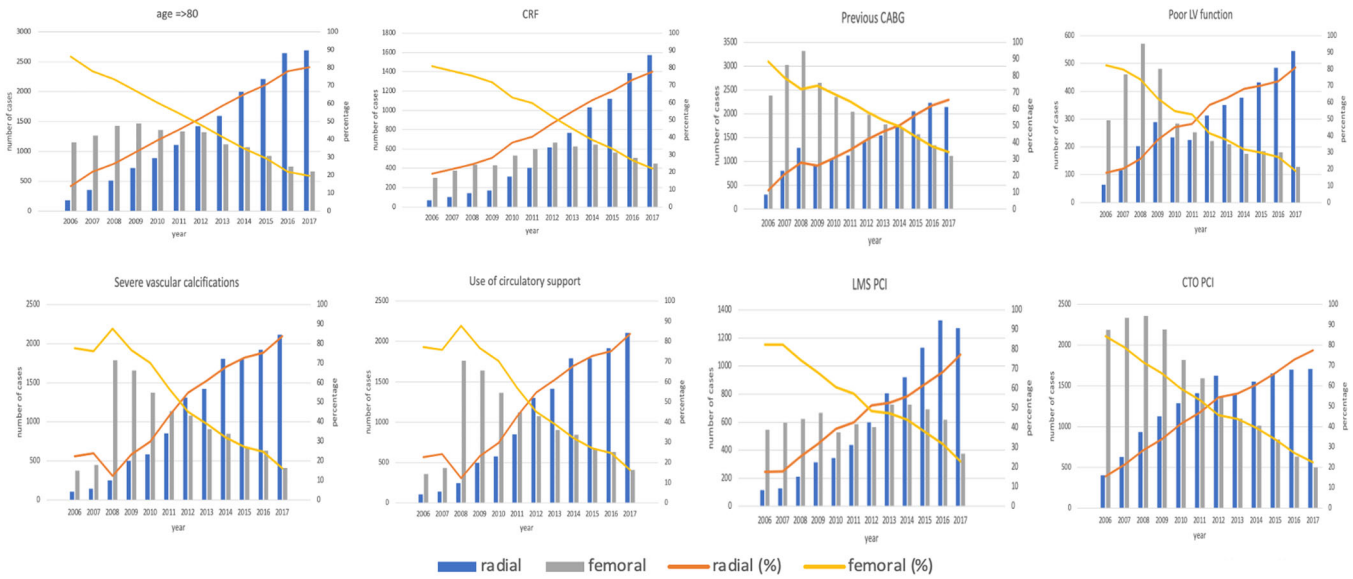

FIGURE 3 Temporal changes in prevalence of each CHiP factor among patients with stable angina and percent change over time, stratified by access site (radial vs. femoral access). CABG, coronary artery bypass graft; CHiP, complex high risk percutaneous coronary interventions; CRF, chronic renal failure; CTO, chronic total occlusion; LMS, left main stem; LV, left ventricle; PCI, percutaneous coronary intervention. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Baseline clinical and procedural characteristics of patients with stable angina undergoing CHiP, stratified by access site.

	Total, *n*	Radial, *n* (%)	Femoral, *n* (%)	Multiple, *n* (%)	*p* value
Number of participants	137,785	61,825 (44.9)	63,837 (46.3)	12,123 (8.8)	
Age median (IQR)	70.7 (62–79.6)	71.2 (62.4–80.3)	70.2 (61.6–78.6)	66.8 (58.3–75)	<0.001
BMI median (IQR)	28.0 (25.2–31.4)	28.1 (25.3–31.6)	27.8 (25.1–31.2)	28.9 (25.9–32.4)	<0.001
Weight <60 kg) *n* (%)	6592 (5.3)	3069 (4.9)	3523 (5.5)	493 (4.1)	<0.001
CHiP risk factors					
(a) Patients' factors					
• Age >80	31,659 (23)	16,330 (51.6)	13,834 (43.7)	1495 (4.7)	<0.001
• Prior CABG	44,970 (33)	16,635 (37.0)	25,319 (56.3)	3016 (6.7)	<0.001
• Chronic renal failure	14,650 (11.1)	7702 (52.6)	6138 (42.0)	810 (5.5)	<0.001
• Poor LV function	7640 (9.4)	3637 (47.6)	3446 (45.1)	557 (7.3)	<0.001
(b) Procedural factors					
• LM PCI	15,863 (11.7)	7605 (48.0)	7247 (45.6)	1011 (6.4)	<0.001
• CTO PCI	42,576 (32.7)	15,424 (36.2)	17,935 (42.1)	9217 (21.7)	<0.001
• Severe coronary calcifications	25,464 (22.5)	12,812 (50.3)	11,315 (44.4)	1337 (5.3)	<0.001
• Use of LV support	746 (0.6)	202 (27.1)	347 (46.5)	197 (26.4)	<0.001
Cardiovascular risk factors					
• Hypertension	85,348 (65.3)	39,314 (67.4)	38,461 (64.4)	7573 (65.6)	<0.001
• Dyslipidaemia	84,112 (64.9)	37,260 (63.9)	38,974 (65.2)	7878 (68.2)	<0.001
• Diabetes mellitus	34,250 (26.1)	15,335 (25.8)	15,980 (26.6)	2935 (25.0)	<0.001
• Smoking					<0.001
Never	49,769 (41.5)	22,982 (41.8)	22,764 (42.1)	4023 (36.7)	
Ex-smokers	58,659 (48.9)	26,652 (48.6)	26,476 (49)	5531 (50.4)	
Current smokers	11,484 (9.6)	5257 (9.6)	4814 (8.9)	1413 (12.9)	
• Family history of CAD	55,473 (46.8)	25,010 (45.3)	25,120 (47.8)	5343 (49.4)	<0.001
• History of MI	54,780 (42.6)	23,757 (40.2)	25,491 (44.2)	5532 (46.7)	<0.001
• Previous PCI	51,735 (38.6)	22,522 (37.1)	23,798 (38.7)	5415 (45.3)	<0.001
• Previous stroke	6182 (4.8)	3097 (5.3)	2593 (4.3)	492 (4.2)	<0.001
• History of PVD	8994 (6.9)	4174 (7.2)	3972 (6.7)	848 (7.3)	0.001
• LV systolic function					<0.001
Normal (EF > 50)	57,077 (70.1)	27,548 (70.9)	23,518 (68.3)	6011 (73.4)	
Impaired (EF 30–50)	16,666 (20.5)	7646 (19.8)	7402 (21.4)	1618 (19.8)	
Severe (EF < 30)	7,640 (9.4)	3637 (9.4)	3446 (10.0)	557 (6.8)	
Pharmacology					
• Warfarin	2689 (2.2)	1487 (2.7)	1042 (1.8)	160 (1.4)	<0.001
• GPIIb IIIa inhibitors	9731 (7.6)	3658 (6.4)	5640 (9.6)	433 (3.7)	<0.001
• Clopidogrel	102,388 (82.0)	45,734 (81.6)	47,076 (82.1)	9578 (83.7)	<0.001
• Prasugrel	1132 (0.9)	645 (1.2)	346 (0.6)	141 (1.2)	<0.001
• Ticagrelor	4452 (3.7)	2940 (5.2)	917 (1.6)	595 (5.2)	<0.001

TABLE 1 (Continued)

	Total, *n*	Radial, *n* (%)	Femoral, *n* (%)	Multiple, *n* (%)	*p* value
Vascular imaging					<0.001
• None	92,495 (88.6)	44,051 (85.5)	48,444 (91.5)	8614 (82.3)	
• IVUS or OCT	13,811 (12.0)	7459 (14.5)	4494 (8.5)	1858 (17.7)	
Circulatory support					
• No support	130,960 (99.5)	59,379 (99.7)	60,049 (99.4)	11,532 (98.3)	<0.001
• IABP	694 (0.5)	184 (0.3)	335 (0.6)	175 (1.5)	<0.001
• Impella	55 (0.04)	18 (0.03)	15 (0.02)	22 (0.2)	<0.001
Number of treated lesions					<0.001
• One	87,576 (64.3)	38,452 (62.8)	40,642 (64.3)	8482 (71.2)	
• Two	34,279 (25.2)	16,084 (25.3)	15,865 (25.1)	2330 (19.6)	
• Three	14,421 (10.6)	6658 (10.9)	6663 (10.6)	1100 (9.2)	
Stent size median (IQR)	3.5 (3.0–3.75)	3.5 (3.0–4.0)	3.0 (3.0–3.5)	3.5 (3.0–4.0)	<0.001
Stent length median (IQR)	24 (18–38)	24 (18–38)	23 (16–30)	38 (24–60)	<0.001
Procedural devices					
• Cutting Balloon	15,174 (13.4)	8098 (15.9)	6305 (11.9)	771 (8.3)	<0.001
• Rotational atherectomy	10,358 (9.2)	4780 (9.4)	5049 (9.5)	529 (5.7)	<0.001
• Laser atherectomy	861 (0.8)	389 (0.8)	377 (0.7)	95 (1.0)	0.006
Number of stents used					<0.001
• One stent	55,607 (40.6)	25,818 (41.9)	27,417 (43.2)	2372 (19.7)	
• Two stents	34,929 (25.5)	16,120 (26.2)	16,103 (25.3)	2706 (22.5)	
• Three or more stents	27,280 (19.9)	11,718 (19.1)	11,600 (18.3)	3962 (32.9)	
Target vessel PCI					
• LM PCI	15,863 (11.7)	7605 (48.0)	7247 (45.6)	1011 (6.4)	<0.001
• LAD	55,510 (41.0)	27,763 (45.6)	23,794 (38.1)	3953 (32.9)	<0.001
• LCX	34,710 (25.6)	16,460 (27.0)	16,376 (26.2)	1874 (15.6)	<0.001
• RCA	48,135 (33.6)	20,123 (33.0)	21,250 (34.0)	6762 (56.3)	<0.001
• Graft	12,917 (9.5)	4494 (7.3)	7839 (12.6)	584 (4.9)	<0.001
Failed PCI attempts	12,575 (11.8)	4574 (8.6)	5587 (13.2)	2414 (22.1)	
Number of target vessel PCI					<0.001
• One	100,000 (74.7)	43,660 (72.7)	46,994 (75.9)	9346 (78.4)	
• Two	26,853 (20.1)	12,804 (21.3)	12,065 (19.5)	1984 (16.6)	
• Three	7033 (5.3)	3560 (5.9)	2883 (4.7)	590 (4.9)	

Abbreviations: CABG, coronary artery bypass graft; CAD, coronary artery disease; CHiP, complex high-risk percutaneous coronary intervention; CTO, chronic total occlusion; GPIIbIIIa, glycoprotein IIaIIIb; IQR, interquartile range; LCX, left circumflex; LMS, left main stem; LV, left ventricle; MI, myocardial infarction; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; RCA, right coronary artery.

TABLE 2 Crude and adjusted outcomes of patients with stable angina undergoing CHiP, stratified by access site. (reference, radial access).

Variables	Total, *n* (%)	Radial, *n* (%)	Femoral, *n* (%)	Multiple, *n* (%)	aOR (CI), *p* value (Femoral)	aOR (CI), *p* value (Multiple)
Mortality	410 (0.3)	129 (0.2)	202 (0.3)	79 (0.7)	1.3 (1.1–1.7), 0.008	2.1 (1.5–2.8), <0.001
Major bleeding	716 (0.5)	140 (0.2)	387 (0.6)	189 (1.6)	2.9 (2.3–3.4), >0.001	5.5 (4.3–6.9), >0.001
MACCE	2011 (1.5)	796 (1.3)	952 (1.5)	263 (2.2)	1.1 (0.9–1.1), 0.69	1.4 (1.2–1.7), <0.001

Abbreviations: aOR, adjusted odd ratio; CHiP, complex high risk percutaneous coronary intervention; MACCE, major cardiovascular and cerebral events.

3.5 | Outcomes trends

Table S3 and Figure 4 detail the temporal changes in outcomes according to the access site used. The mortality trends in the TFA and multiple access groups suggest a gradual increase [(2006–2009) vs. (2011–2017): TFA, 0.3% vs. 0.4%; Multiple access, 0.6% vs. 0.8%]. However, MACCE rates declined across the three groups [(2006–2009) vs. (2011–2017): TRA, 1.6% vs. 1.0%; TFA, 1.7% vs. 1.3%; Multiple access, 2.7% vs. 1.9%, respectively].

4 | DISCUSSION

This analysis of a national cohort of 137,785 patients' records is the first to examine differences in the clinical characteristics and outcomes of CHiP procedures undertaken in patients with stable angina according to the access site. We demonstrate that TRA has grown to be the most commonly used access site over the 12 years, from 14.6% in 2006 to 67% in 2017. The study findings can be summarized as follows: (1) CHiP patients who had their PCI undertaken using the TRA were older and had a higher prevalence of hypertension, stroke, and current smokers than those undertaken via TFA (2) TRA was more commonly used in patients with CRF, aged 80 years or above, treatment of severe vascular calcification, poor LV function, and LM PCI; whilst TFA was more commonly used in patients with previous CABG, had PCI to a CTO vessel, or in cases where LV support was needed. (3) Close to 9% of CHiP cases require multiple access site utilization, the majority of which were undertaken in CTO procedures highlighting the complex nature of these cases. (4) Finally, despite more frequent treatment of extensive coronary disease amongst the TRA group than in TFA, the adjusted in-hospital odds for mortality, major bleeding events and MACCE were significantly higher in the TFA.

TRA has been examined in several RCT and observational studies and found to be consistently associated with better outcomes in patients undergoing PCI; this study extends this benefit to those high-risk, complex patients undergoing a CHiP procedure.[3,5,15,30–33] The most recent ESC/EACTS guidelines on myocardial revascularisation recommend TRA over TFA as class Ia in patients with acute coronary syndromes,[34] and class Ib in elderly patients with stable CAD to reduce access site bleeding complications.[35] However, in stable CAD, the RCT trials looking at TRA versus TFA outcomes were relatively small and failed to include/specifically describe those patients with complex CAD.[36–38] Historically, complex PCI required the TFA to accommodate larger catheters and devices.[39,40] However, technological advances have allowed the safe use of TRA in complex PCI; for example, the use of the slender technology when large-bore guiding catheters are required,[5] the CTO enabling strategies[41] as well as other advances.[42,43]

This study highlights differences in baseline characteristics amongst the groups. Established CAD was more prevalent amongst patients who had their procedure undertaken via TFA, whereas cardiovascular risks for CAD were more prevalent in patients who had their PCI undertaken via TRA. Patients in whom multiple access sites were adopted were on average 4 years younger than the other 2 groups of patients, but had worse CV risk factor profiles; 76% of procedures were CTO interventions. Utilization of the TFA and mixed access for CHiP procedures is probably related to the fact that these cases are more likely to have more complex CAD, requiring bigger devices that may not be accommodated if the TRA alone was chosen.

The uptake of the TRA site was more frequent in most of the CHiP factors except in those who had a previous CABG, needed LV support, or had PCI to a CTO where TFA was used more frequently—presumably reflecting challenging anatomy (CTO and

TABLE 3 The number of radial compared to Femoral access needed to potentially avoid one adverse outcome in the overall CHIP cohort and in those cases performed between 2010 and 2017.

	Overall NNT (2006–2017)	NNT (2014–2017)
Death	928	579
Major bleeding events	263	244
MACCE	491	403

Abbreviation: CHiP, complex,high-risk percutaneous coronary interventions.

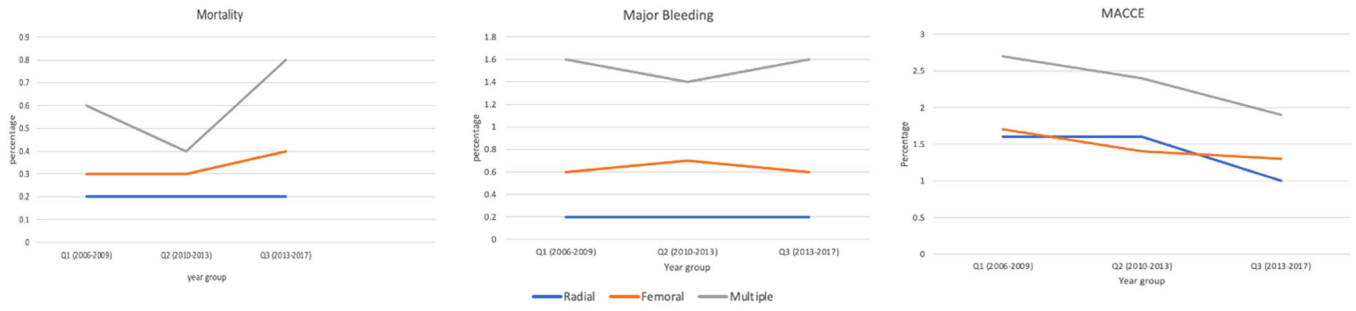

FIGURE 4 Temporal changes of CHiP outcomes among patients with stable angina (percent change over time), stratified by access site. CHiP, complex, high-risk percutaneous coronary intervention; MACCE, major adverse cardiovascular and cerebral events. [Color figure can be viewed at wileyonlinelibrary.com]

CABG) and or the need for larger bore guide catheters. However, the higher odds for worse outcomes in the overall population in this study with the TFA should encourage operators to adapt the TRA in those with CABG history, CTO PCI, and LV support cases. Indeed our previous work has shown a decrease in access site major bleeding complications associated with TRA in both PCI cases undertaken for CTO indications[44] and in patients with prior CABG.[45]

This analysis has demonstrated significantly higher odds of mortality, major bleeding, and MACCE outcomes associated with TFA or in cases requiring dual access, These findings are consistent with other studies that have reported access site related outcomes in individual CHiP factors. For example, studies amongst dialysis/chronic insufficiency patients found that mortality and major bleeding odds were significantly lower in the TRA group [OR: 0.19 (95% CI: 0.051–0.73); $p = 0.015$].[19] Most studies around access site related outcomes in the elderly showed benefits of TRA despite limitations[46]. However, a meta-analysis of 13 studies confirmed less major bleeding odds in the TRA groups [OR: 0.49 (95% CI: 0.33–072); $p = 0.0002$)].[47] Similarly, a meta-analysis of 8 nonrandomised trials examining LM PCI outcomes by access site found similar MACCE risks [PSM data; relative risk (RR): 0.97, 95% CI: 0.94–1.28; $p = 0.63$]; but with significantly lower major bleeding risk (RR: 0.28, 95% CI: 0.17–0.47; $p < 0.001$).[14] There are no RCTs comparing TRA versus TFA outcomes of PCI with rotational atherectomy. However, findings from limited observational studies concluded mortality benefits with the use of TRA which was mainly derived from lower rates of major bleeding events in the TRA group. (TFA, 13% vs. TRA, 1%; $p = 0.001$).[48]

The mortality odds were 30% (50% with PSM) higher in the TFA group, which is higher than the odds seen in noncomplex PCI studies (TRA vs. TFA: aOR: 0.70, 95% CI: 0.66–0.74).[32] This, in part, could be attributed to the higher baseline major bleeding risk in this population. Previous analyses have suggested that the benefit of the radial approach is related to baseline bleeding risk, with the greatest benefit seen in those at highest risk of major bleeding complications.[49,50] Studies from our group and others have proved access site complications and higher bleeding rates to be directly associated with significant morbidity and mortality.[51–53]

This analysis demonstrated that TRA site benefits are extended to CHiP populations. This was all made possible due to advances like the latest-generation lower-profile stents and delivery systems, which means many complex procedures such as bifurcation and calcium modification therapies are now performed using a 6-F guide. The limitations of the smaller calibre radial artery are mitigated using advanced technologies and techniques that allowed the safer use of larger guides such as sheathless guide catheters, 7-F thin-walled hydrophilic sheaths, and techniques like balloon tracking. TRA benefits were extended across all CHiP factors, including those where TFA was commonly used. The same was seen in a study from six centers in the United States comparing CTO outcomes demonstrated similar outcomes to TFA (major complications rate: TRA, 1.7% vs. TFA, 1.8%; $p = 0.99$).[54]

4.1 | Study strengths and limitations

To the best of our knowledge, this is the first study that has examined CHiP outcomes in a real-world, unselected setting at a national level, according to the access site. The statistical power was sufficient to determine real differences between the groups. The cohort represents the national practice in the United Kingdom, given that BCIS is a population-based registry with over 95% of the PCI cases performed in England and Wales recorded.

This study has limitations mainly related to the observational nature of the study, most commonly errors during reporting and coding, which could result in potential bias such as the under-reporting of comorbidities, complications are self-reported with no external validation.

Also, we cannot exclude the possibility of other confounders like frailty, anaemia, economic status, and the control of diseases like diabetes and hypertension, which may impact the outcome. However, we tried to adjust for as many variables as possible to overcome this issue. Additionally, despite the incidence of periprocedural MI is clearly defined in the BCIS dataset, the dataset fails to confirm whether this diagnosis was based on a specific definition (e.g., the fourth or third universal MI definition etc.). Last, the BCIS dataset only captures in-hospital outcomes, and we cannot rule out significant differences in the longer term.

5 | CONCLUSION

In summary, this large analysis has demonstrated the safe use of the TRA in CHiP where, despite treatment of more complex CAD in the TRA group, death, major bleeding, and MACCE odds were significantly lower than TFA. Wider adoption of TRA amongst higher-risk patients may potentially improve CHiP outcomes.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data is owned by a third party. The data underlying this article were provided by NICOR under license/by permission. Data will be shared on request to the corresponding author with permission of NICOR. The data that support the findings will be available in BCIS at https://www.bcis.org.uk/public-information/ following an embargo from the date of publication to allow for commercialization of research findings.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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