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Complex, high-risk percutaneous coronary intervention types, trends, and in-hospital outcomes among different age groups: An insight from a national registry

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Abstract

Background: Complex, high-risk percutaneous coronary intervention (PCI) (CHiP) is increasingly being undertaken in octogenarians. However, limited data exist on CHiP types, trends, and outcomes in the octogenarian.

Methods: This is a retrospective cohort study from a national registry dataset on CHiP undertaken in patients with stable angina in England and Wales (January 2006 and December 2017) according to three age groups (group 1 [G1]: < 65 years; group 2 [G2]: 65–79 years; and group 3 [G3]: ≥80 years).

Results: Of 424,290 elective PCI procedures, 138,831 (33.0%) were CHiP [G1: 46,832 (33.7%); G2: 59,544 (42.9%); G3: 32,455 (23.4%)]. Among CHiP types, chronic total occlusion (CTO) (49.2%), prior coronary artery bypass graft (CABG) (30.4%), and severe vascular calcification (21.8%) were common in G1; prior CABG (42.9%), CTO (32.9%), and severe vascular calcifications (27%) were common in G2; prior CABG (15.8%), severe vascular calcification (15.5%), and chronic renal failure (11.1%) were common CHiP among the octogenarians. The older age groups had higher adjusted odds (aOR) for adverse outcomes [G2: mortality, aOR 1.7, 95% confidence interval (CI): (1.3–2.3); major bleeding, aOR 1.3, 95% CI (1.1–1.5); MACCE, aOR 1.2, 95% CI (1.0–1.3); G3: mortality, aOR 2.6, 95%CI (1.9–3.6); major bleeding, aOR 1.4, 95% CI (1.1–1.7); MACCE, aOR 1.3, 95% CI (1.1–1.5)].

Conclusion: There were significant differences in the types of CHiP cases undertaken and clinical outcomes across age groups.

KEYWORDS

age disparity, complex PCI, high-risk PCI, stable angina

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1 | INTRODUCTION

The elderly population has steadily increased over the past few decades and is expected to grow further. With the aging population comes the increased prevalence of diseases such as coronary arter disease (CAD), which remains the second leading cause of disability among the elderly and accounts for more than half of all deaths related to cardiovascular disease.[1]

Complex, high-risk percutaneous coronary intervention (PCI) (CHiP) is increasingly undertaken in the older age groups; it refers to a subset of patients with specific criteria associated with increased procedural complexity and risks.[2] Age is one of the accepted criteria of how CHiP is defined, and is known to be an important predictor of worse PCI outcomes.[3] While there are no specific studies that have looked explicitly at CHiP outcomes according to age in the real-world setting, prior studies that have focused on individual CHiP components have suggested worse outcomes associated with older age in chronic renal failure (CRF),[4] PCI in chronic total occlusions (CTOs)[5,6] left main (LM) PCI,[7] or severe vascular calcification.[8]

There have been no previous studies focused on whether the type of CHiP cases undertaken in different age groups varies by age, and whether the growth of CHiP and the types of cases undertaken has changed differentially among different age groups. Furthermore, there is no previous data on whether there are differences in CHiP outcomes stratified by age. In this national analysis derived from the United Kingdom, we sought to study age-stratified baseline characteristics, trends, and clinical outcomes of CHiP's undertaken in patients with stable angina over 12 years, using data from a national PCI registry.

2 | METHODS

2.1 | Data source

We obtained the data from the British Cardiovascular Intervention Society (BCIS) registry. The BCIS is managed by the National Institute of Cardiovascular Outcomes and Research (NICOR). The BCIS data includes a wide range of clinical characteristics, interventional and pharmacological treatments, important cardiovascular comorbidities, and in-hospital procedural complications and mortality. Healthcare professionals collect data from over 95% (112 out of the 117 PCI centers in the United Kingdom) of PCI procedures undertaken in England and Wales. Data are collected prospectively and encrypted before transferring to database services as part of a NICOR national audit initiative. Also, 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. Hence, ethical approval was not required for this study.[9] The BCIS data entry is mandated as part of the professional revalidation. Data are entered by interventional operators performing the procedures, with almost 100,000 procedures records added to the BCIS registry every year.[10] The BCIS data accuracy and quality have been previously ascertained.[11]

2.2 | Study design and definitions

We retrospectively analyzed records of patients who underwent PCI for stable angina in England and Wales between January 1, 2006 to December 31, 2017 in the BCIS data set. Based on our previously published work,[12–16] CHiP was defined as any procedure with at least one clinical or procedural high-risk feature. Clinical high-risk features were defined as any patient with a previous history of coronary artery bypass graft (CABG), CRF, or severely impaired left ventricular (LV) function. The procedural (anatomical) high-risk factor was defined as cases including LM PCI, severe vascular calcification treatment, CTO PCI, or the need for LV support. All CHiP procedures were then categorized into three groups (group 1 [G1]: <65; group 2 [G2]: 65–79; group 3 [G3]: ≥80 years old).

CRF was defined as any case that met any of the following: renal transplant history, chronic dialysis, or chronic creatinine elevation of more than 200 μmol/L, all predefined in the BICS data. Severe vascular calcifications were defined as any PCI that required using rotational or laser atherectomy devices or cutting balloons. Severe LV impairment was defined as LV function with an estimated ejection fraction of 30% or less. The need for LV support was defined as the use of intraaortic balloon pump (IABP) or Impella.

2.3 | Study endpoints

In-hospital all-cause mortality was the primary outcome of interest. The secondary outcomes included (a) In-hospital major adverse cardiovascular and cerebral events (MACCE). (b) In-hospital major bleeding complications.

MACCE was defined as the cumulative incidence of in-hospital death, periprocedural stroke, or myocardial infarction (MI). Periprocedural myocardial infarction was defined as a composite of non-Q-wave and Q-wave myocardial infarctions, reinfarction, and reintervention (emergency PCI or CABG) defined within the BCIS registry.

Major bleeding events were defined as any case that meets the Bleeding Academic Research Consortium's definition for Bleeding Type 2 and above[17]; this may include clinically evident gastrointestinal bleeding, radiological evidence of intracranial bleed, retroperitoneal bleed/hematoma, any transfusion of blood or blood products, and access site bleeding complications requiring intervention. Access site complications are defined as a composite of a false aneurysm, arterial dissection, retroperitoneal hematoma, or hemorrhage.

2.4 | Data analysis

We expressed the data as median (interquartile range) for continuous data and whole numbers (percentages) for categorical data. Differences between the CHiP groups were assessed using Pearson's χ^2 test for categorical variables and the Kruskal–Wallis or

Wilcoxon–Mann–Whitney tests for continuous data depending on the number of groups being compared. Supporting Information: Table 1 provides information about missing data for each variable included in the study. Multiple imputations with chained equations were used to impute missing data to create 10 data sets, assuming that data were missing at random.[18] In the multiple imputation framework, we used logistic regression for binary variables, multinomial for nominal variables, ordinal logistic regression for ordered variables, and linear regression for continuous variables. We included the following variables in the model: sex, age, and outcomes variables (registered as regular), while we registered the following variables as imputed: ethnicity, history of dyslipidemia, smoking history, previous CABG, previous MI, previous PCI, previous stroke, diabetes mellitus, hypertension, CRF, LV function, peripheral vascular disease (PVD), family history of CAD, clopidogrel, vascular access, LM PCI, circulatory support, number of treated lesions, severe vascular calcification, number of stents used, and body mass index. All the subsequent analyses were performed on the imputed data set, and results were pooled using Rubin's rules.[19] For cases where event rates were low, findings from the multivariate analysis were interpreted after evaluating the assumptions implied by the model against both data and prior information obtained from the literature search.[20] Variables with extensive missing observations (>20% missing), for example, the LV function variable, were also included in the multiple imputation models. It has been shown that multiple imputation frameworks are robust even when levels of missingness are extremely high, although they can offer some protection when data are missing not at random.[21–23] Finally, multivariable logistic regression analyses were used to determine the adjusted odds ratios (aOR), 95% confidence interval (CI), and *p* values of outcomes between the age-stratified CHiP groups. All models included the same variables as used in the multiple imputation framework.[20] Stata

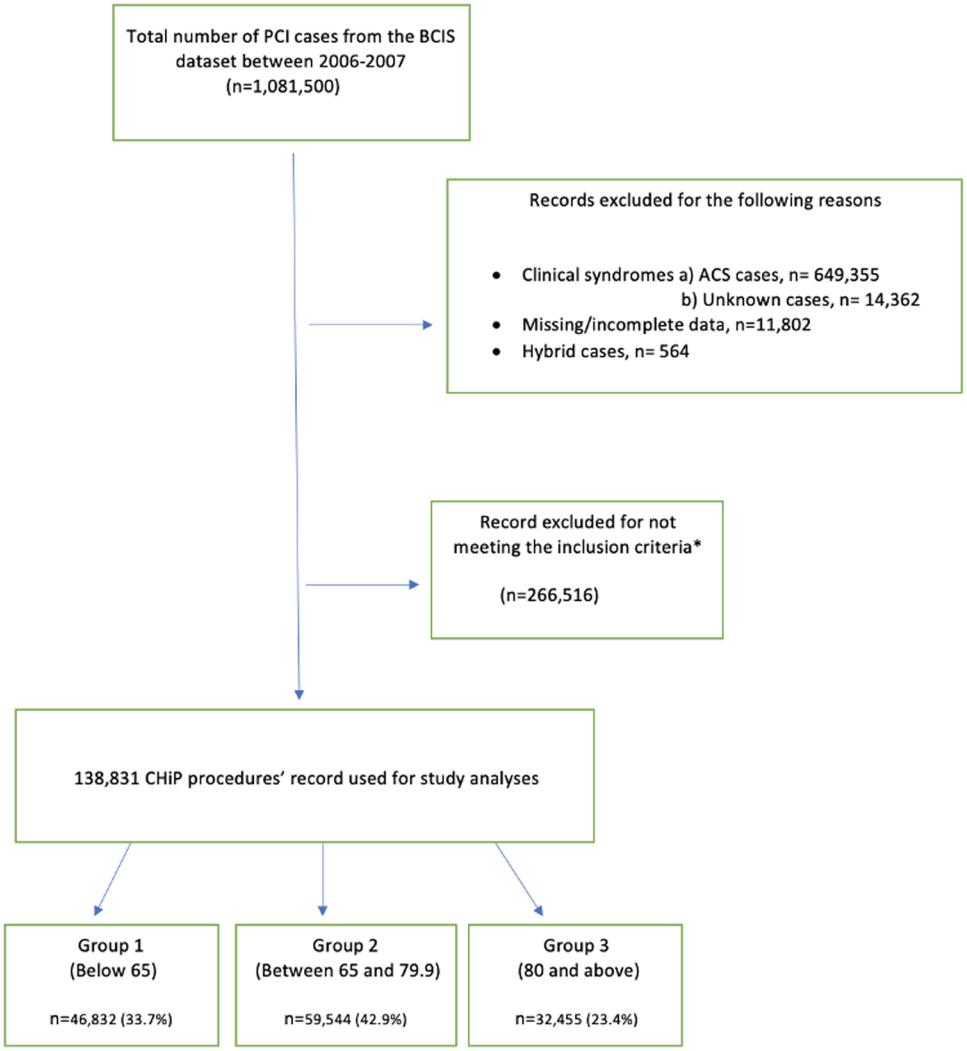

FIGURE 1 Flow diagram illustrating the process of patients' inclusion and exclusion for the CHiP analysis. ACS, acute coronary syndromes; BCIS, British Cardiovascular Intervention Society; CHiP, complex, high-risk percutaneous coronary intervention; PCI, percutaneous coronary intervention *Inclusion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

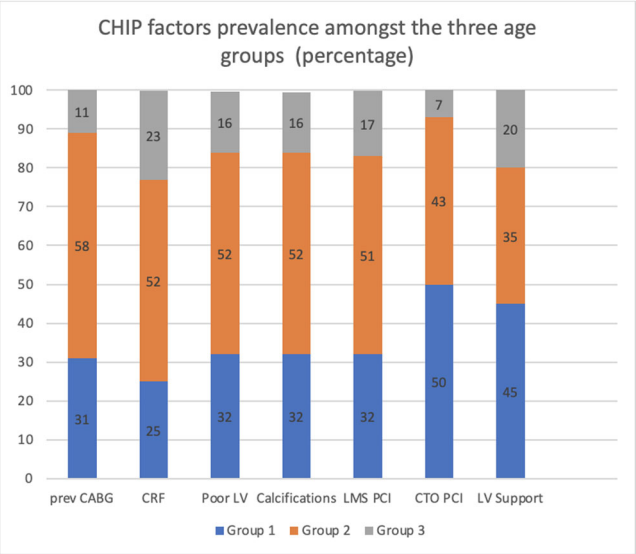

FIGURE 2 Prevalence of CHiP factors in patients with stable angina, stratified by three age groups (group 1, <65 years; group 2, 65–79 years; group 3, 80 and above years). CABG, coronary artery bypass graft; CHiP, complex high-risk percutaneous coronary intervention; CTO, chronic thrombus occlusion; LMS, left main stem; LV, left ventricle; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; RCA, right coronary artery. [Color figure can be viewed at wileyonlinelibrary.com]

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

3.1 | Study cohorts

The study cohort consisted of 138,831 (32.7%) out of 424,290 PCI procedure records undertaken for stable CAD between January 1, 2006 and December 31, 2017 in England and Wales. The process of patients' inclusion and exclusion for this analysis is presented in Figure 1. Figure 2 shows the prevalence of each CHiP factor in the CHiP cohort, stratified by age. CTO PCI was most common in the youngest age group, whereas the most common CHiP factor in the 65 years and above age group was prior CABG.

3.2 | Clinical characteristics

Table 1 provides an overview of CHiP factors distribution, cardiovascular risk factors' prevalence, pharmacology, and procedural characteristics according to three groups (G1: <65 years; G2: 65–79 years; G3, ≥80 years). Overall, most cases (42.9%) were undertaken in patients between 65 and 79 years old. Those aged 80 years and above represented 23.4% of the cases. Male sex represented 64.9% of the patients in G3, 78.5% of the cases in G2, and 84.6% of the cases in G1. Similarly, most patients were White (87.7% in G3 vs. 80.5% in G1).

3.3 | CHiP factors

The most common CHiP indication in G1 was PCI to a CTO vessel (49.2%), followed by prior CABG (30.4%) and severe vascular calcification (21.8%). In contrast, prior CABG was the most common indication in G2 (42.9%) and G3 (15.8%), followed by PCI to a CTO (32.9%) and severe vascular calcification (21.0%) in G2, and severe vascular calcification (15.5%) and chronic renal failure (11.1%) in G3. Except for PCI to a CTO vessel, all other CHiP factors were more prevalent in G2 than in the other groups.

3.4 | Cardiovascular risk factors

Hypertension was common in all groups, with the highest prevalence seen among the octogenarians (70%). A higher prevalence of current smokers (17.9%) and a family history of CAD (55.4%) was seen among G1 compared to other groups. In contrast, the octogenarians had the lowest prevalence of diabetes mellitus (19%), prior PCI (33.8%), and prior MI (36.2%).

3.5 | Procedural characteristics

There were no significant differences in the use of support devices among the groups (Impella, $p = 0.727$ and IABP, $p = 0.154$). Similarly, PCI to a single lesion was commonly observed across all groups (45.5%, 47.1%, 51.7% for G1, G2, and G3, respectively). Cutting balloons were most used in G1 (16%), whereas rotational atherectomy was mostly used in G2 (12%). Octogenarians had the lowest rates of use of calcium modification devices (none used in 84% in G3 compared to 73% in G2% and 78% in G1).

The most common target vessel revascularized in all the three groups was the LAD (G1: 39.4%; G2: 38.2%; G3: 50.9%); $p < 0.001$. PCI to a graft or LM vessel was more common among G2 (graft, 11%; LMS, 14%). Around (51.5%) of CHiP in the octogenarians was undertaken via radial access, which was more common compared to G1 (41.6%) and G2 (43.9%).

Warfarin prescription was more frequent among G3 (3.3%), while G1 had higher prescription rates of ticagrelor (4.0%) and prasugrel (1.3%); $p < 0.001$.

3.6 | Clinical outcomes

Table 2 details the crude outcomes according to three age groups. The octogenarians had the highest in-hospital mortality rates (0.5%)

TABLE 1 Baseline clinical and procedural characteristics of patients who underwent a CHiP procedure for stable angina stratified according to three age groups (group 1: <65 years; group 2: 65–79 years; group 3: 80 and above years)

	Age <65 (%)	Age 65–79 (%)	Age ≥80 (%)	*p* Value
Number of participants	46,832 (33.7)	59,544 (42.9)	32,455 (23.4)	
Age median, *n* (IQR)	58.1 (52.8–61.8)	72.1 (68.6–75.7)	82.9 (81.3–85.2)	<0.001
BMI, *n* (IQR)	29.3 (26.2–32.8)	28.1 (25.3–31.3)	26.5 (24–29.4)	<0.001
Males, *n* (%)	39,610 (84.6)	46,743 (78.5)	21,074 (64.9)	<0.001
Whites, *n* (%)	28,355 (80.5)	37,459 (84.4)	21,012 (87.7)	<0.001
CHiP factors (types)				
Patients' factors				
Prior CABG	13,902 (30.4)	25,094 (42.9)	4975 (15.8)	<0.001
Chronic renal failure	3729 (8.3)	7677 (13.5)	3404 (11.1)	<0.001
Poor LV function	2520 (9.1)	4053 (11.3)	1222 (6.3)	<0.001
Procedural factors				
LMS PCI	5214 (11.3)	8226 (14)	2716 (8.6)	<0.001
CTO PCI	22,103 (49.2)	18,611 (32.9)	3118 (10.5)	<0.001
Severe coronary (vascular) calcifications	8,405 (21.8)	13,273 (27)	3992 (15.5)	<0.001
Use of LV support	255 (0.6)	346 (0.6)	156 (0.5)	0.154
Cardiovascular risk factors				
Hypertension	26,346 (60)	38,341 (68.5)	21,421 (70)	<0.001
Dyslipidemia	29,059 (66.2)	37,081 (66.3)	18,703 (61.2)	<0.001
Diabetes melliti	11,762 (26.4)	16,645 (29.3)	6134 (19)	<0.001
Smoking				<0.001
Never	14,575 (35.6)	21,037 (40.7)	14,141 (50.8)	
Ex-smokers	19,002 (46.4)	27,432 (53.1)	12,954 (46.5)	
Current smokers	7354 (17.9)	3216 (6.2)	752 (2.7)	
Family history of CAD	22,458 (55.4)	24,081 (47.3)	9303 (33.8)	<0.001
History of MI	19,114 (43.8)	25,332 (45.6)	10,978 (36.2)	<0.001
Previous PCI	18,329 (40)	23,501 (40.5)	10,610 (33.8)	<0.001
Previous stroke	1366 (3.1)	2950 (5.3)	1914 (6.2)	<0.001
History of PVD	2260 (5.1)	4502 (8.1)	2324 (7.6)	<0.001
LV systolic function				<0.001
Normal (EF > 50)	20,414 (73.7)	24,070 (67)	13,760 (70.8)	
Impaired (EF 30–50)	4749 (17.2)	7783 (21.7)	4444 (22.9)	
Severely impaired (EF < 30)	2520 (9.1)	4053 (11.3)	1222 (6.3)	
Pharmacology				
Warfarin	411 (0.9)	1338 (2.5)	959 (3.3)	<0.001
GPIIbIIIa inhibitors	3924 (9.1)	3924 (7.8)	1466 (4.9)	<0.001
Clopidogrel	34,242 (81.6)	44,533 (82.9)	24,174 (83.0)	<0.001
Prasugrel	545 (1.3)	493 (0.9)	102 (0.4)	<0.001
Ticagrelor	1688 (4.0)	1805 (3.3)	977 (3.3)	<0.001

(Continues)

TABLE 1 (Continued)

	Age <65 (%)	Age 65–79 (%)	Age ≥80 (%)	*p* Value
Vascular access				<0.001
Radial	18,954 (41.6)	25,500 (43.9)	16,349 (51.5)	
Femoral	21,221 (46.7)	27,361 (47.2)	13,851 (43.7)	
Multiple accesses	5315 (11.7)	5168 (8.9)	1510 (4.8)	
Circulatory support				
No support	44,258 (98.9)	56,560 (99.36)	30,744 (99.46)	0.154
IABP	255 (0.6)	346 (0.6)	156 (0.5)	0.154
Impella	22 (0.5)	23 (0.04)	12 (0.04)	0.727
Number of successfully treated lesions				<0.001
None	5294 (14.8)	5616 (12)	1682 (6.5)	
One	16,193 (45.5)	21,972 (47.1)	13,297 (51.7)	
Two	9921 (27.8)	13,325 (28.6)	7757 (30.2)	
Three or more	4224 (11.9)	5733 (12.3)	2989 (11.6)	
Procedural devices				
None	30,142 (78.0)	35,969 (73.0)	21,766 (84.0)	<0.001
Cutting balloon	6277 (16.0)	7315 (14.1)	1650 (6.2)	<0.001
Rotational atherectomy	2037 (5.3)	6035 (12.0)	2427 (9.3)	<0.001
Laser atherectomy	258 (0.7)	479 (0.9)	128 (0.5)	<0.001
Number of stents used				<0.001
None	7437 (16)	8466 (14.5)	3260 (10.1)	
One stent	17,306 (37.3)	23,473 (39.7)	15,107 (46.9)	
Two stents	11,481 (24.8)	15,116 (25.5)	8533 (26.5)	
Three or more stents	10,165 (21.9)	11,960 (20.3)	5297 (16.5)	
Target vessel PCI				
Left main stem (LMS)	5214 (11.3)	8226 (14)	2716 (8.6)	<0.001
LAD	18,199 (39.4)	22,373 (38.2)	16,152 (50.9)	<0.001
LCX	12,022 (26.0)	15,525 (26.5)	7935 (25)	<0.001
RCA	18,045 (39.1)	20,706 (35.3)	10,626 (33.5)	<0.001
Graft	3406 (7.4)	6446 (11)	1429 (4.5)	<0.001
Number of target vessel PCI				<0.001
One	35,040 (75)	43,869 (74.1)	23,674 (74.1)	
Two	8983 (19)	11,890 (20)	6709 (20.9)	
Three or more	2361 (5.1)	3240 (5.9)	1604 (5.0)	

Abbreviations: BMI, body mass index; CABG, coronary artery bypass graft; CAD, coronary artery disease; CHiP, complex high-risk percutaneous coronary intervention; CTO, chronic thrombus occlusion; EF, ejection fraction; GPIIbIIIa, glycoprotein IIaIIIb; IABP, intraaortic balloon pump; IQR, interquartile range; LAD, left anterior descending coronary artery; 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.

compared to the other groups studied (G2, 0.3%; G1, 0.2%); $p < 0.001$. Similarly, major bleeding and MACCE rates were highest in G3 (major bleeding: 1.0%; MACCE: 1.7%) and lowest in G1 (major bleeding: 0.7%; MACCE: 1.3%); $p < 0.001$. Following adjustment for baseline covariates, the odds for mortality increased with increasing age [G2: aOR 1.7, 95% CI (1.3–2.3); G3: aOR 2.6, 95% CI (1.9–3.6) compared to G1]. Similarly, the odds of both major bleeding [G2: aOR 1.3, 95% CI (1.1–1.5), G3: aOR 1.4, 95% CI (1.1–1.7)] and MACCE

TABLE 2 Crude outcomes of CHiP procedures undertaken among patients with stable angina stratified into three age groups (group 1, <65 years; group 2, 65–79 years; group 3, 80, and above years)

Variables	>65, *n* (%)	65–79, *n* (%)	≥80, *n* (%)	*p* Value
Mortality	76 (0.2)	194 (0.3)	147 (0.5)	<0.001
Bleeding	312 (0.7)	519 (0.9)	297 (1.0)	<0.001
MACCE	602 (1.3)	921 (1.6)	556 (1.7)	<0.001

Abbreviations: CHiP, complex high-risk percutaneous coronary intervention; MACCE, major cardiovascular and cerebral events.

TABLE 3 Adjusted odds of adverse outcomes post CHiP in patients with stable angina according to three age groups (group 1, <65 years; group 2, 65–79 years; group 3, 80 and above years) (comparable, group 1)

Variables	Group 2 aOR	95% CI	*p* Value	Group 3 aOR	95% CI	*p* Value
Mortality	1.7	1.3–2.3	>0.001	2.6	1.9–3.6	>0.001
Bleeding	1.3	1.1–1.5	>0.001	1.4	1.1–1.7	>0.002
MACCE	1.2	1.0–1.3	0.006	1.3	1.1–1.5	>0.001

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

[G2: aOR 1.2, 95% CI (1.0–1.3), G3: aOR 1.3, 95% CI (1.1–1.5)] increased across the age groups (Table 3).

3.7 | Temporal trends

Figure 3 shows the temporal changes in the prevalence of each CHiP factor stratified by age. Over time, there was an expansion of the different types of CHiP cases across all age groups. The greatest increase in the prevalence of prior CABG occurred in octogenarians. Similarly, the greatest expansion of PCI for LM, CTO, and calcific vascular disease occurred in this group.

Supporting Information: Table 2 further details the temporal changes in baseline characteristics and clinical outcomes across three age groups. Overall, the prevalence of cardiovascular risk factors increased across all age groups, except for current smokers in those ≥65 years [G2: 6.5% (≤2011) vs. 6% (>2011); G3: 3% (≤2011) vs. 2.5% (>2011); $p < 0.001$]. There were no changes in the prevalence of dyslipidaemia, prior MI, or previous stroke across all age groups. Radial access trends show an increase in all age groups, and the greatest was seen among the octogenarians (≤2011, 31% vs. >2011, 64%); $p < 0.001$. Interestingly, mortality trends across the three age groups did not change (G1, $p < 0.051$; G2, $p < 0.450$; G3, $p < 0.0.185$). Whereas major bleeding and MACCE events showed significant declines seen across all age groups, with the greatest decline observed in the octogenarians (MACCE: 2.1%, ≤2011 vs. 1.5%, >2011; major bleeding: 1.2%, ≤2011 vs. 0.6%, >2011), $p < 0.001$ for all.

4 | DISCUSSION

This study of a national cohort of 138,831 CHiP procedure' records undertaken in patients with stable angina provided, to the best of our knowledge, the very first insight into the risk profile, trends, nature of CHiP cases undertaken, and their clinical outcomes stratified by age. The findings can be summarized in the following points: (a) The risk factor profile evolved toward a lower cardiometabolic risk profile as patients aged, with a lower prevalence of diabetes mellitus and current smokers in the octogenarians compared to younger age groups; although there was a clear trend toward an increase in the prevalence of cardiovascular risk factors within the same age group; (b) type of CHiP cases varied by age, with CTO, prior CABG, and severe vascular calcification most often encountered in younger patients, while prior CABG, severe vascular calcification, and renal failure were most common in the elderly group; (c) mortality, major bleeding and MACCE risks increased by age, even when differences in baseline risk are adjusted for; (d) mortality trends within the same age group did not change; however, MACCE and major bleeding trends significantly declined, with the greatest decline seen in the octogenarians.

There were significant differences in the baseline clinical characteristics between the study groups, with overall trends toward an increase in the prevalence of cardiovascular risk factors across all age groups. Hypertension was the most prevalent risk factor among the groups, with the highest prevalence seen in octogenarians. Interestingly, the heaviest comorbid burden was observed in those aged 65–79 years (G2), suggesting that those with heavy cardiovascular comorbidities either die before they get to 80 years of age or that elderly patients with multiple comorbidities are more likely to be managed medically. Studies from the USA registries examining outcomes of noncomplex PCI in patients with stable angina according to age groups observed similar findings.[24,25] Procedural characteristics varied too. For example, increased trends and rates for radial artery access use were seen most commonly in the octogenarian cohort compared to other age groups, probably in recognition of higher bleeding risks in the octogenarian group. This may also reflect the case mix, younger patients had higher rates of PCI to a CTO, which could require larger sheaths via femoral access or use of multiple access sites. Similarly, the use of calcium modification devices and LMS PCI was higher in younger patients, which may partly explain the greater propensity toward femoral access in these patient groups.

The most common CHiP variable in octogenarians was prior CABG. A finding that aligns with studies that suggest long-term benefits from CABG, which in turn delays the patients' need for intervention until later in their lives.

There was a gradual increase in all CHiP procedures undertaken across all age groups, particularly octogenarians, over the 12 years.

FIGURE 3 Temporal changes in the prevalence of each CHiP factor among patients with stable angina who underwent a CHiP procedure, stratified according to age into three groups: group 1, <65 years; group 2, 65–79 years; group 3, 80 and above years). CABG, coronary artery bypass graft; CHiP, complex high-risk percutaneous coronary intervention; CRF, chronic renal failure; CTO, chronic thrombus occlusion; LMS, left main stem; LV, left ventricle; PCI, percutaneous coronary intervention. [Color figure can be viewed at wileyonlinelibrary.com]

This might be reflective of broader adoption of new management modalities following changes in the guidelines, such as the LMS guidelines,[26,27] or expert consensus in, for example, the management of a CTO vessel[28] using new crossing algorithms[2,3,29,30] as well as the more widespread availability of advanced technologies in managing cases with severe vascular calcification[32] and severe heart failure.[33] Furthermore, the widespread availability of intracoronary imaging[34] has aided better assessment of disease severity, complexity (calcium identification), and helped guide decision making.[35]

The odds for adverse outcomes were worse in the octogenarian cohort despite having a lower comorbidity burden and CAD complexity than in the other two groups. Mortality odds were almost two- to threefolds higher in the octogenarians, and trends suggest no change of the same over time; this may relate to age per se. Age has been consistently shown to be an important predictor of adverse outcomes in all contemporary PCI risk scores studied.[36–40] Moreover, one must not forget the effect of unmeasured confounders in the older ager group, such as age-related physiological changes, frailty, anemia, and poor control of important comorbidities like diabetes that may contribute to the observed high event rates in the octogenarian cohort. Similar mechanisms may account for the higher odds of major bleeding events recorded in the octogenarian population, despite the higher rates of radial access used. Additional mechanisms may, in part, relate to higher rates of warfarin prescriptions and other unmeasured confounders such as frailty.[41]

4.1 | Study limitations

To the best of our knowledge, this is the first study that has examined CHiP outcomes according to different age groups in a real-world, unselected setting at a national level. The BCIS database records over 99% of cases performed in England and Wales. The sample size is sufficiently large to study temporal trends in the type of ChiP cases undertaken in different age groups and determine whether there is a real difference in CHiP outcomes according to age groups. As with all observational studies, this study has a few limitations. First, there is always the risk of reporting and coding errors that could represent a potential bias, such as underreporting other comorbidities and self-reported complications with no external validation. Second, there is the potential for unmeasured confounders in clinical and procedural variables such as socioeconomic status, anemia, frailty,[42] control of cardiovascular risk factors such as diabetes, and lesion complexity that may impact the clinical outcomes we report.

Moreover, the BCIS data set does not provide information on the completeness of revascularization. Although it meets statistical significance due to a large number of patients, many variables presented in the result section have small differences. The clinical significance of these small differences is unclear. Lastly, the BCIS data set only captures in-hospital outcomes. Hence, we cannot rule out significant differences in the longer term.

5 | CONCLUSION

Types of CHiP undertaken for stable angina differ according to age. There was a tendency toward less cardiovascular risk burden and disease complexity in the octogenarians. Age remains an independent risk factor for worse mortality, major bleeding, and MACCE in CHiP. Although trends for death did not change within the same age group, MACCE and major bleeding trends were in decline, with the greatest seen across the octogenarian cohort.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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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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