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Clinical Research

Complex High-Risk Percutaneous Coronary Intervention Types, Trends, and Outcomes in Nonsurgical Centres

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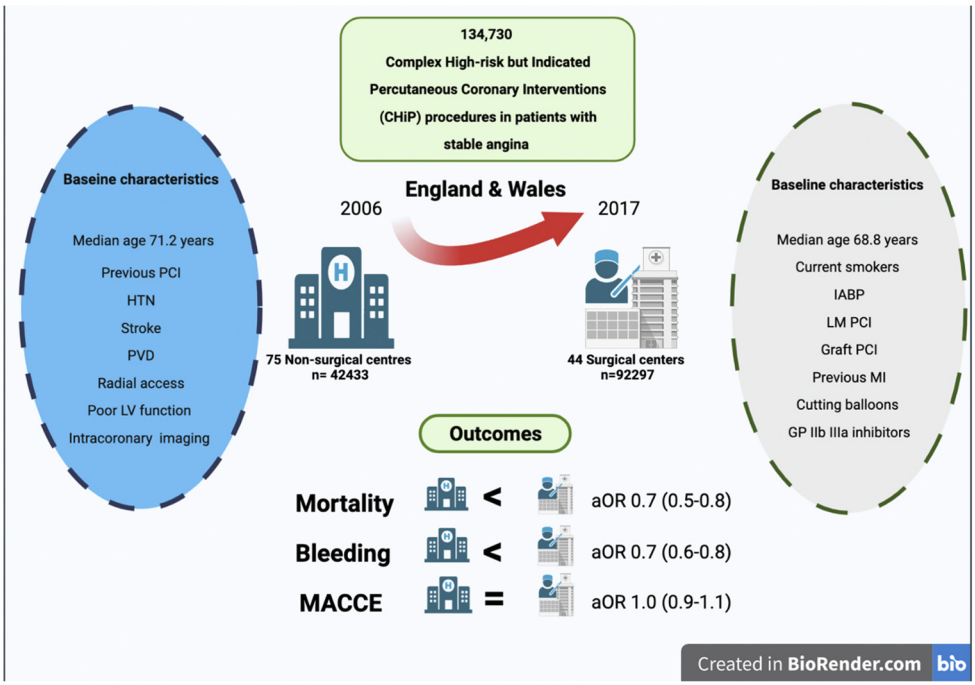
See editorial by Azzalini and Johal, pages 1247-1249 of this issue.

Graphical Abstract summarises the CHiP analysis's key findings according to the type of surgical cover.



Abbreviations: CHiP, complex high-risk but indicated percutaneous coronary interventions; GP, glycoprotein; HTN, hypertension; IABP; intra-aortic balloon pump; LM, left main; LV, left ventricle; MI, myocardial infarction; PCI percutaneous coronary intervention; PVD, peripheral vascular disease.

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ABSTRACT

Background: Limited data are available on complex high-risk percutaneous coronary intervention (CHiP) trends and outcomes in nonsurgical centres (NSCs), particularly in health care systems where most centres are NSCs.

Methods: Using data from a national registry, we studied the characteristics and outcomes of CHiP procedures performed for stable angina from 2006 to 2017 according to the presence or absence of on-site surgical cover. Multivariate regression analyses and propensity score matching were used to determine risks for in-hospital death, major bleeding, and major cardiovascular or cerebral events (MACCE).

Results: Out of 134,730 CHiP procedures, 42,433 (31.5%) were performed in NSCs, increasing from 12.5% in 2006 to 42% in 2017. Compared with surgical centres (SCs), patients who had a CHiP procedure undertaken in NSCs were, on average, 2.4 years older and had a greater prevalence of cardiovascular risks. Common CHiP procedures performed in NSCs included poor left ventricular function (41.6%), chronic renal failure (38.8%), and chronic total occlusion percutaneous coronary intervention (31.1%). NSC-based CHiP is associated with lower odds of mortality (adjusted odds ratio [aOR] 0.7, 95% confidence interval [CI] 0.5-0.8) and major bleeding (aOR 0.7, 95% CI 0.6-0.8). In both groups, MACCE odds were similar (aOR 1.0, 95% CI 0.9-1.1).

Conclusions: CHiP numbers have steadily increased in NSCs. NSC patients were older and had a higher prevalence of cardiovascular risks than SC patients. Mortality and major bleeding odds were significantly lower in those cases undertaken in NSCs, although MACCE odds were not different between the groups.

RÉSUMÉ

Introduction : Peu de données sur les tendances et les résultats cliniques de l'intervention coronarienne percutanée indiquée chez les patients complexes et exposés à un risque élevé (CHiP, de l'anglais *Complex and high-risk intervention in indicated patients*) des centres non chirurgicaux (CNC) sont disponibles, particulièrement dans les systèmes de soins de santé où la plupart des centres sont des CNC.

Méthodes : Grâce aux données du registre national, nous avons étudié les caractéristiques et les résultats des interventions CHiP réalisées pour des angines stables de 2006 à 2017 en fonction de la présence ou de l'absence de couverture chirurgicale sur place. Nous avons utilisé les analyses de régression multivariées et l'appariement sur score de propension pour déterminer les risques de décès à l'hôpital, d'hémorragies majeures et d'événements cardiovasculaires ou cérébraux indésirables majeurs (ECCIM).

Résultats : Sur 134 730 interventions CHiP, 42 433 (31,5 %) ont été réalisées dans des CNC, c'est-à-dire qu'elles sont passées de 12,5 % en 2006 à 42 % en 2017. Par rapport aux centres chirurgicaux (CC), les patients qui subissaient une intervention CHiP entreprise dans un CNC étaient en moyenne 2,4 ans plus âgés et avaient une plus grande prévalence de risques cardiovasculaires. Les interventions CHiP courantes réalisées dans des CNC étaient notamment en lien avec une mauvaise fonction ventriculaire gauche (41,6 %), l'insuffisance rénale chronique (38,8 %) et l'intervention coronarienne percutanée de l'occlusion totale chronique (31,1 %). La CHip des CNC est associée à une plus faible probabilité de mortalité (rapport de cotes ajusté [RCa] 0,7, intervalle de confiance [IC] à 95 % 0,5-0,8) et d'hémorragies majeures (RCa 0,7, IC à 95 % 0,6-0,8). Dans les 2 groupes, la probabilité d'ECCIM était similaire (RCa 1,0, IC à 95 % 0,9-1,1).

Conclusions : Le nombre de CHiP a augmenté progressivement dans les CNC. Les patients des CNC étaient plus âgés et avaient une prévalence plus élevée de risques cardiovasculaires que les patients des CC. La probabilité de mortalité et d'hémorragie majeure était significativement plus faible dans ces cas réalisés dans les CNC, bien que la probabilité d'ECCIMne fût pas différente entre les groupes.

Complications following percutaneous coronary intervention (PCI) that necessitate emergency coronary bypass surgery (CABG) are rare in contemporary practice, occurring in less than 0.5% of cases, compared with a rate of 6%-10% in the 1980s.[1-4] PCI complications that would have previously required emergency CABG are effectively managed in the catheterisation laboratory in contemporary practice. As a result, over the past decade, many centres in the world have started successful PCI programs in nonsurgical centres (NSCs).[5,6]

Although evidence from both observational studies[7,8] and randomised control trials (RCT)[9,10] supports PCI in NSCs in patients with stable coronary artery disease (CAD), less is known about the outcomes of complex high-risk percutaneous coronary intervention (CHiP) procedures in these centres. Specifically, high-risk procedures were excluded from many of the original studies or represented only a small number of procedures, so outcome data from this group of patients are limited.[9,11]

The present analysis sought to examine the characteristics and outcomes of CHiP undertaken in patients with stable angina over 12 years according to the type of centre (surgical vs nonsurgical) with the use of data from a national PCI registry.

Methods

Data source

The data were obtained from the British Cardiovascular Intervention Society (BCIS), which is managed by the National Institute of Cardiovascular Outcomes and Research. More than 95% of PCI procedures undertaken in England and Wales are recorded annually in the BCIS database by health professionals, and data input is mandatory for professional revalidation.[12] Data recorded include important demographics, cardiovascular comorbidities, pharmacologic treatments, procedural characteristics, and in-hospital

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See page 1245 for disclosure information.

outcomes. The BCIS data set has been used for research and national audit purposes, and its quality and accuracy have been previously ascertained.[13] All data have section 251 approval of National Health Service Act 2006, allowing use for audit and research matters without the formal need for individual patient consent.[14]

Study design and definitions

This is a retrospective analysis of prospectively collected data from patients who underwent a CHiP procedure for stable angina in England and Wales from January 1, 2006, to December 31, 2017. All nonelective cases and acute coronary syndrome cases were excluded.

CHiP was defined based on our previous work[15-17] as any patient who met at least 1 of the following characteristics: previous coronary artery bypass graft (CABG), chronic renal failure (CRF), Severely impaired left ventricle (LV) function, PCI to a left main (LM) or a chronic total occlusion vessel (CTO), treatment for severe vascular calcification, and use of LV support devices. The collected data were then categorised into Surgical centre (SC) and nonsurgical centre (NSC) groups.

We defined CRF as creatinine $>$ 200 μmol/L or dialysis-dependent patients, as it is predefined in the BCIS dataset; LV support use as any elective case that required the elective/*ad hoc* or bail-out use of Impella or intra-aortic balloon pump (IABP); severely impaired function as LV with an ejection fraction of $<$ 30%; and extensive vascular calcification as any case involving the use of cutting balloons or rotational or laser atherectomy.

Study end points

The primary outcome of interest was inpatient mortality. Secondary outcomes included major bleeding events and major cardiovascular and cerebral events (MACCE).

Major bleeding events were defined as any case that met the Bleeding Academic Research Consortium's definition for bleeding type 2 and above[18]; this includes 1) access site bleeding requiring intervention or surgery; 2) access site bleeding complications such as retroperitoneal hematoma or bleeding, arterial dissection, or false aneurysm; 3) clinically evident bleeding into the gastrointestinal tract; 4) radiologic evidence of bleeding into the brain or retroperitoneal space; and 5) any periprocedural overt bleeding that required blood transfusion.

MACCE was defined as the cumulative incidence of in-hospital death, periprocedural cerebrovascular accidents (CVAs), and myocardial infarction (MI). We defined periprocedural MI as a composite of Q-wave MI or non−Q-wave MI, reinfarction, and reintervention (emergency PCI or CABG), all predefined within, albeit not adjudicated in, the BCIS registry.

Statistical analysis

Following the initial selection process, we divided the study population into NSC and SC groups. All missing observations in the age, sex, and outcomes variables were excluded. We then summarised the patient baseline demographics and characteristics as median (interquartile range [IQR]) for continuous data, comparing by means of the Kruskal-Wallis test, and as frequency (percentage) for categoric data, comparing by means of Pearson chi-square test. Details about the missing data are presented in Supplemental Table S1. We used multiple imputations with chained equations to impute missing data to create 10 data sets, assuming that data were missing at random.[19] The following variables (all registered as complete variables) were included in our model: surgical site, age, sex, and outcomes. The following variables required imputation: ethnicity, dyslipidemia, previous MI, previous CABG, previous PCI, previous stroke, hypertension, diabetes mellitus, smoking, CRF, peripheral vascular disease (PVD), clopidogrel, family history of CAD, LV function, vascular access, coronary imaging, LM PCI, IABP, severe vascular calcifications, number of treated lesions, number of stents used, stent size and length, 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.[20-22] Subsequent analyses were performed on the imputed data set, and results were pooled with the use of Rubin's rule.[23] Multivariate logistic regression analyses were used to generate adjusted odds ratios (aORs), 95% confidence intervals (CIs), and corresponding *P* values of outcomes between the SC and NSC groups. We used forward stepwise variable selection on the data with an inclusion criterion of $P < 0.1$ to help select predictors into the final multivariate model. We ran additional analyses using propensity score matching to evaluate the robustness of our results and to control for differences and imbalances in the baseline characteristics between the 2 groups. The following variables were matched: age, sex, ethnicity, dyslipidemia, previous MI, previous CABG, previous PCI, previous stroke, hypertension, diabetes mellitus, smoking, CRF, PVD, LV function, clopidogrel, family history of CAD, vascular access, intracoronary imaging, IABP, severe vascular calcifications, LM PCI , number of treated lesions, number of stents used, stent size and length, and BMI. We then performed logistic regression to estimate the propensity score and matching to the nearest algorithm (Supplemental Fig. S1). We then converted the coefficients to ORs to help with a better interpretation of the results. Finally, we performed sensitivity analyses (Supplemental Table S2) on the nonimputed data set to better assess the consistency of the results obtained. Stata version 14.1 was used to conduct the analyses (StataCorp, College Station, Texas). Statistical significance was evaluated at a type I error at a rate of 0.05.

Results

We included 119 centres, of which 75 (63%) were nonsurgical; 134,730 (31.8%) out of 424,290 procedure records of patients with stable angina treated with PCI from January 1, 2006, to December 31, 2017, met the eligibility criteria. Figure 1 summarises the selection process for this analysis. Figure 2 shows that around two-thirds of procedures for each CHiP factor (type) were performed in a SC (see also CHiP factors section in Table 1). However, there was a gradual increase in the number of CHiP procedures performed across all CHiP types in NSCs (12.5% in 2006

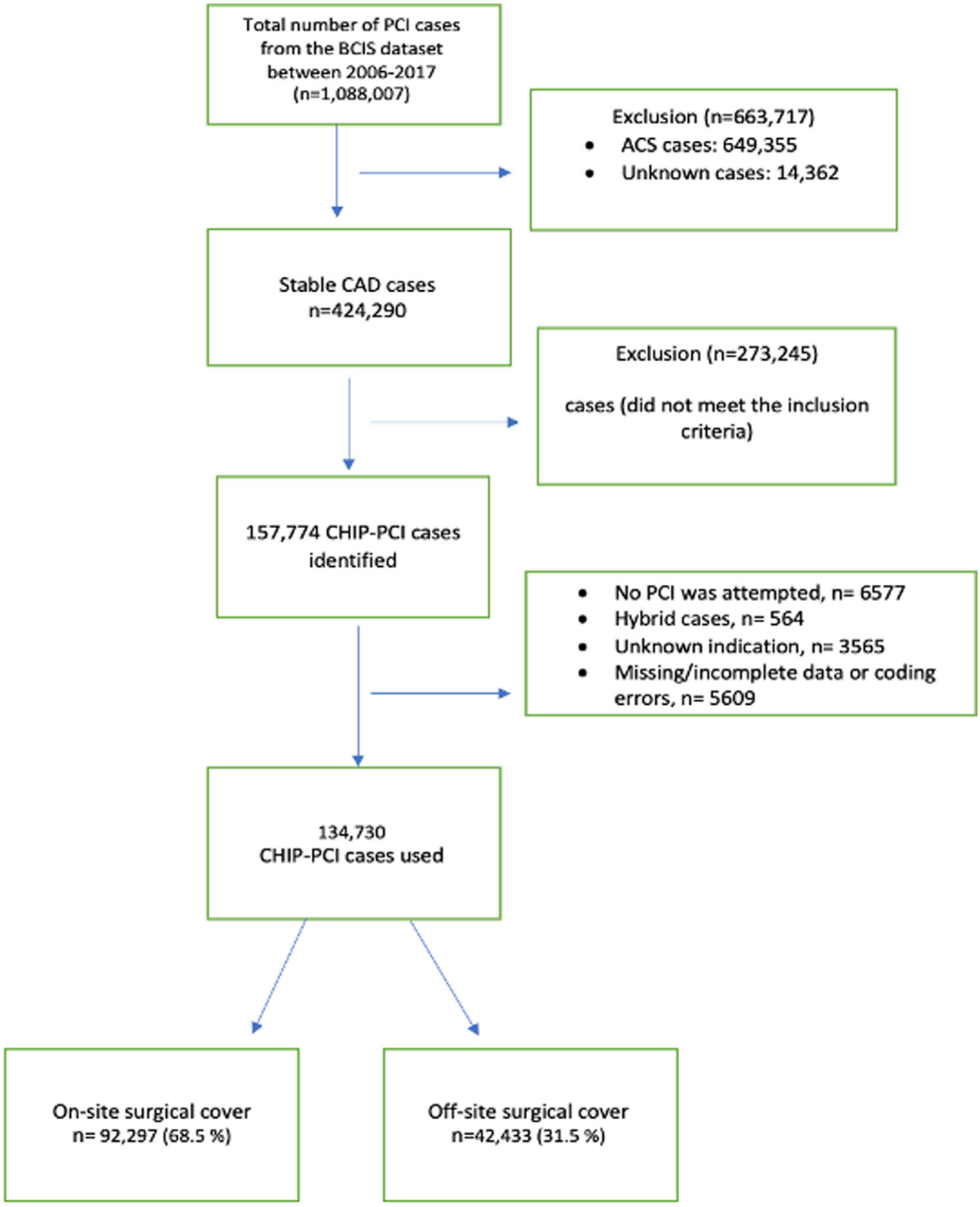

Figure 1. Flow diagram illustrating the process of patients' inclusion and exclusion for the CHiP analysis. ACS, acute coronary syndrome; BCIS, British Cardiovascular Intervention Society; CAD, coronary artery disease; CHiP, complex high-risk percutaneous coronary intervention; PCI, percutaneous coronary intervention.

to 42% in 2017) (Fig. 3). Table 1 details the baseline clinical and procedural characteristics of the study cohorts as follows.

Demographic and clinical characteristics

Overall, 92,297 (68.5%) of the cases were performed in SCs vs 42,433 (31.5%) in NSCs. On average, the NSC patients were 2.4 years older than the SC patients. The 2 groups had a similar sex mix, although more black, Asian, and other ethnic minorities patients had their CHiP undertaken in NSCs. SC patients had a higher prevalence of current smokers and previous history of MI. In contrast, NSC patients had a higher prevalence of hypertension (66.9% vs 64.2%), severely impaired LV function (11.9% vs 9.3%), dyslipidemia (65.1% vs 64.2%), family history of CAD (49.9% vs 45.2%), and previous PCI (40.1% vs 38.1%), stroke (5.7 % vs 4.1%), and PVD (8.1% vs 6.3%) (all $P < 0.001$).

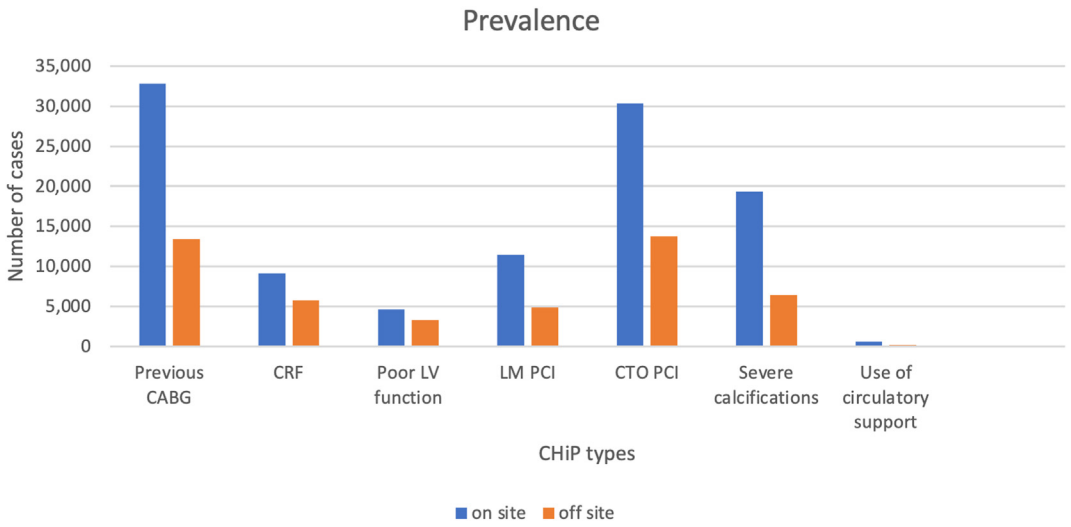

Figure 2. Distribution of procedures for each CHiP factor (type), indicating that approximately two-thirds of the interventions were performed under surgical cover. CHiP, complex high risk but indicated percutaneous coronary interventions; CABG, coronary artery bypass graft; CHiP, complex high-risk percutaneous coronary intervention; CTO, chronic total occlusion; CRF, chronic renal failure; LM, left main; LV, left ventricle; PCI, percutaneous coronary intervention.

Procedural characteristics

A greater proportion of CHiP cases were performed via the radial access in the NSCs compared with the SCs (58.2% vs 41.8%, respectively; $P < 0.001$). Similarly, intracoronary imaging was used in 15.1% of CHiPs undertaken in NSCs vs 10.8% in SCs ($P < 0.001$). IABP was used slightly less frequently in NSCs than in SCs (0.4% vs 0.6%, respectively; $P < 0.001$). More NSC patients had 2 or more lesions treated than SC patients (38.4% vs 35%, respectively; $P < 0.001$). PCI to a graft (11% vs 8.2%) or LM (12.6% vs 11.5%), respectively (both $P < 0.001$), was performed more frequently in SCs than in NSCs.

Inpatient clinical outcomes

Mortality and major bleeding crude rates were significantly lower in the NSC group than in the SC group (mortality: 0.2% vs 0.3%; major bleeding: 0.4% vs 0.6%, respectively; $P < 0.001$). Following adjustment for baseline covariates, odds for both mortality (aOR 0.7, 95% CI 0.5-0.8) and major bleeding (aOR 0.7, 95% CI 0.6-0.8) were 30% lower in the NSCs than the SCs. PSM confirmed lower odds for mortality (OR 0.6, 95% CI 0.3-0.8) and major bleeding (OR 0.5, 95% CI 0.2-0.7) in NSCs. However, the odds for MACCE did not differ between the groups (Tables 2 and 3; Supplemental Fig. S1).

Discussion

This study represents the first nationwide analysis comparing CHiP characteristics and outcomes in SCs vs NSCs. The findings of this analysis confirmed that all types of CHiP procedures were more commonly performed in SCs; more interestingly, it noted a gradual increase in the number of cases performed in NSCs across all CHiP types (12.5% in 2006 to 42% in 2017). In NSCs, CHiP procedures are more likely to be performed via the radial approach and with intracoronary imaging guidance. Although NSC patients have higher cardiovascular risk profiles than SC patients, we observed lower odds for mortality and major bleeding during CHiPs undertaken in NSCs, whereas MACCE risks did not differ. Our analysis suggests that selected CHiP procedures are performed safely in NSCs. Of note, the overall mortality and major bleeding events in the CHiP cohort was less than 1%.

The introduction of PCI in NSCs was initially driven by a number of factors, including the evidence-based drive to treat ST-segment elevation MI patients with primary PCI as quickly as possible, unacceptable delay in accessing evidence-based early revascularisation in non−ST-segment elevation MI patients, and patient preference to have access to this treatment as close to where they lived as possible. PCI services inevitably expanded to include increasingly complex elective cases as the evidence for safety became apparent.[24] This expansion of complex PCI into NSCs has been supported by the evolution of multidisciplinary decision making (heart team) meetings, which have become more accessible to NSC interventionalists and accommodate increasing patient and procedural complexity. Despite these advances in clinical practice, the most recent American Heart Association/American College of Cardiology/European Society of Cardiology (ESC) guidelines on CHiP in the NSC settings are less supportive and more cautious about such activity.[25-28] For example, the ESC guidelines on myocardial revascularisation from 2010 recommended that high-risk procedures such as distal LM or complex bifurcation stenosis that involves large side branches should be performed in SCs.[29] The Society for Cardiovascular Angiography and Interventions 2020 guidelines recommend transferring stable patients to SCs for unprotected LM PCIs or for complex cases where an advanced approach such as atherectomy is indicated and is not otherwise available or cannot be carried out safely.[30] However, there is a body of evidence on the safety and success of PCI in NSCs from randomised control trials (RCTs), such as CPORT-E (The Cardiovascular Patient Outcomes Research Team)[9]

Table 1. Baseline clinical and procedural characteristics of complex high-risk percutaneous coronary intervention (CHiP) undertaken in patients with stable angina, stratified by type of surgical cover

	Total	On-site cover	Off-site cover	*P* value
No. of participants	134,730 (100)	92,297 (68.5)	42,433 (31.5)	
Female	29,320 (22.7)	29,320 (21.6)	9355 (22.1)	0.080
Age, y	69.5 (61.1-77.6)	68.8 (60.5-76.9)	71.2 (62.7-79.9)	< 0.001
BMI, kg/m^2	28.1 (25.4-31.6)	28.1 (25.4-31.4)	28.2 (25.4-31.6)	< 0.001
Ethnicity				< 0.001
White	84,240 (84.3)	60,549 (85.8)	23,691 (87.7)	
BAME	16,400 (16.3)	9991 (14.2)	6409 (21.3)	
CHiP risk factors				
Patient factors				
Previous CABG	46,232 (33.4)	32,818 (71.0)	13,414 (29.1)	< 0.001
Chronic renal failure	14,890 (11.6)	9106 (61.2)	5784 (38.8)	< 0.001
Poor LV function	7835 (10.2)	4574 (58.4)	3261 (41.6)	< 0.001
Procedural factors				
LMS PCI	16,204 (12.3)	11,396 (70.3)	4808 (29.7)	< 0.001
CTO PCI	44,129 (34.8)	30,399 (68.9)	13,730 (31.1)	< 0.001
Severe coronary calcifications	25,743 (23.6)	19,352 (75.2)	6,391 (24.8)	< 0.001
Use of LV support	767 (0.6)	584 (76.1)	183 (23.9)	< 0.001
Cardiovascular risk factors				
Hypertension	82,254 (65.0)	55,210 (64.2)	27,044 (66.9)	< 0.001
Dyslipidemia	81,557 (64.5)	55,215 (64.2)	26,342 (65.1)	0.001
Diabetes mellitus	33,890 (26.4)	23,060 (26.4)	10,830 (26.4)	0.962
Smoking				< 0.001
Never	47,968 (41.1)	33,431 (42.0)	14,537 (39.1)	
Ex-smoker	57,147 (48.9)	37,876 (47.6)	19,271 (51.8)	
Current smoker	11,654 (10.0)	8275 (10.4)	3379 (9.1)	
Family history of CAD	54,613 (46.7)	36,388 (45.2)	18,225 (49.9)	< 0.001
History of AMI	54,211 (43.2)	37,338 (43.9)	16,873 (41.8)	< 0.001
Previous PCI	50,695 (38.7)	34,192 (38.1)	16,503 (40.1)	< 0.001
Previous stroke	5882 (4.7)	3564 (4.1)	2318 (5.7)	< 0.001
History of PVD	8732 (6.9)	5,451 (6.3)	3281 (8.1)	< 0.001
LV systolic function				< 0.001
Normal (EF > 50%)	53,113 (69.3)	334,526 (70.1)	18,587 (67.9)	
Impaired (EF 30%-50%)	15,670 (20.5)	10,135 (20.6)	5535 (20.2)	
Severe (EF < 30%)	7835 (10.2)	4574 (9.3)	3261 (11.9)	
Pharmacology				
Warfarin	2562 (2.1)	1747 (2.1)	815 (2.1)	0.831
GPIIb/IIIa inhibitors	9611 (7.7)	6693 (7.9)	2918 (7.3)	< 0.001
Clopidogrel	98,527 (81.3)	64,767 (78.6)	33,760 (87.1)	< 0.001
Prasugrel	1126 (0.9)	793 (1.0)	333 (0.9)	0.079
Ticagrelor	4260 (3.5)	2717 (3.3)	1543 (4.0)	< 0.001
Vascular access				< 0.001
Radial artery	58,852 (45.0)	37,440 (41.8)	21,412 (58.2)	
Femoral artery	71,826 (55.0)	52,117 (58.2)	19,709 (47.9)	
Intracoronary imaging				< 0.001
IVUS or OCT	13,631 (12.2)	8062 (10.8)	5569 (15.1)	
Circulatory support				
IABP	713 (0.6)	550 (0.6)	163 (0.4)	< 0.001
Impella	57 (0.04)	37 (0.04)	20 (0.05)	0.607
No. of treated lesions				< 0.001
1	85,677 (64.3)	59,764 (65.6)	25,913 (61.6)	
2	33,293 (25.1)	22,020 (24.1)	11,273 (26.8)	
≥3	14,161 (10.6)	9283 (10.9)	4878 (11.6)	
Stent size	3.5 (3.0-3.75)	3.5 (3.0-3.5)	3.5 (3.0-4.0)	< 0.001
Stent length	24 (18-36)	24 (18-33)	24 (18-38)	< 0.001
Procedural devices				
None	83,775 (76.6)	56,533 (74.7)	27,242 (81.3)	< 0.001
Cutting balloon	15,268 (14.0)	12,522 (16.5)	2746 (8.2)	< 0.001
Rotational atherectomy	10,542 (9.6)	7007 (9.3)	3535 (10.5)	< 0.001
Laser atherectomy	868 (0.8)	442 (0.6)	426 (1.3)	< 0.001
No. of stents used				< 0.001
1	53,483 (40.1)	37,221 (40.8)	16,262 (38.4)	
2	33,903 (25.4)	22,911 (25.1)	10,992 (26.0)	
≥ 3	26,845 (20.1)	18,229 (20.0)	8616 (20.4)	
PCI target vessel				
LM	16,204 (12.3)	11,396 (12.6)	4808 (11.5)	< 0.001
LAD	52,920 (40.2)	35,035 (38.8)	17,885 (42.8)	< 0.001
LCX	33,835 (25.6)	22,753 (25.2)	11,082 (26.5)	< 0.001
RCA	47,210 (35.7)	32,118 (35.5)	15,092 (36.1)	0.039
Graft	13,397 (10.1)	9958 (11.0)	3439 (8.2)	< 0.001

Table 1. Continued.

	Total	On-site cover	Off-site cover	*P* value
No. of PCI target vessels				< 0.001
1	97,392 (74.6)	66,836 (75.2)	30,556 (73.4)	
2	26,183 (20.1)	17,517 (19.7)	8666 (20.8)	
≥ 3	6994 (5.3)	4587 (5.1)	2407 (5.8)	

Values are n (%) or median (interquartile range).

AMI, acute myocardial infarction; BAME, Black, Asian, and minority ethnic; BMI, body mass index; CABG, coronary artery bypass graft; CTO, chronic total occlusion; CAD, coronary artery disease; EF, ejection fraction; GPIIb/IIIa, glycoprotein IIb/IIIa; IABP, intra-aortic balloon pump; IVUS, intravascular ultrasound; LV, left ventricle; LM, left main; LCX, left circumflex; MI, myocardial infarction; OCT, optical coherence tomography; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; RCA, right coronary artery.

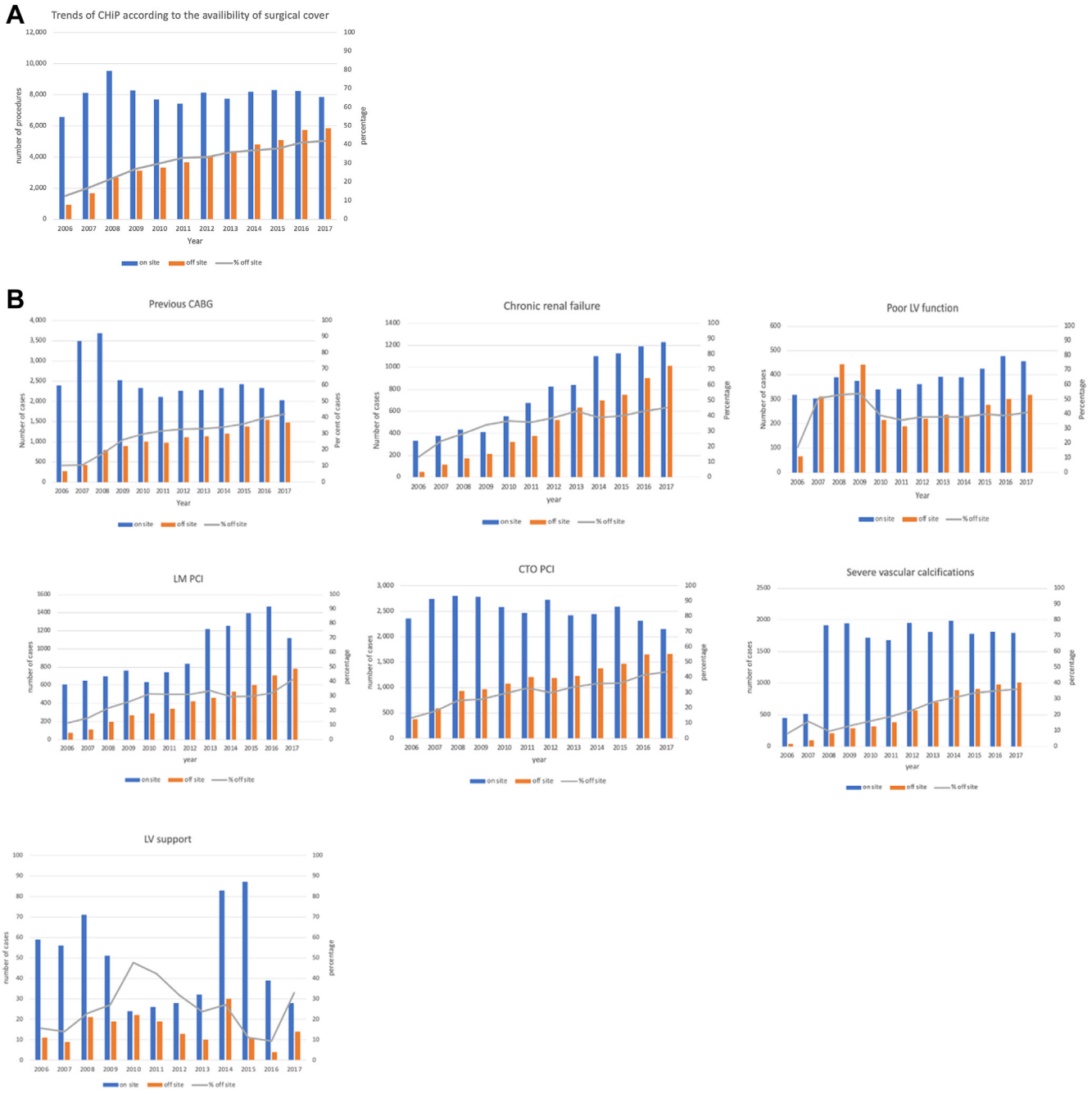

Figure 3. Temporal changes in complex high-risk percutaneous coronary intervention (CHiP) procedure prevalence and percentage changes over time (**A**) in the entire CHiP cohort and (**B**) in each CHiP factor, stratified by the type of surgical cover. A gradual increase is observed, with overall CHiP trends in nonsurgical centres rising from 12.5% in 2006 to 42% in 2017. CABG, coronary artery bypass graft; CRF, chronic renal failure; CTO, chronic total occlusion; LV, left ventricle; LM, left main; PCI, percutaneous coronary intervention.

Table 2. Crude and adjusted outcomes of patients with stable angina who had a complex high risk percutaneous coronary intervention procedure, stratified by type of surgical cover

Variable	Total	On-site	Off-site	aOR (95% CI), *P* value
Mortality	396 (0.3)	300 (0.3)	96 (0.2)	0.7 (0.5-0.8), < 0.001
Major bleeding events	694 (0.5)	517 (0.6)	177 (0.4)	0.7 (0.6-0.8), < 0.001
MACCE	1964 (1.5)	1332 (1.4)	632 (1.5)	1.0 (0.9-1.1), 0.420

Values are n (%).
aOR, adjusted odds ratio; CI, confidence interval; MACCE, major cardiovascular and cerebral events.

and MASS COMM (Massachusetts Hospitals with Cardiac Surgery On-Site and Community Hospitals Without Cardiac Surgery On-Site),[10] that have led to guideline recommendations supporting PCI in stable patients in nonsurgical centres.[31] Still, however, less is known about the outcomes of CHiP *per se* in these centres.

There was a clear difference between the 2 groups' baseline characteristics in our study. Overall, previous history of MI and current smokers were prevalent among the SC group. In contrast, the NSC patients had a higher prevalence of stroke and hypertension, which may relate to the fact that patients treated in NSCs were older. This case mix differs from other registries comparing PCI outcomes between NSCs and SCs. For example, a study from the National Cardiovascular Data Registry in 2009 reported a heavier burden of both risks for and established cardiovascular diseases and diabetes in SC patients.[32] We also noted differences in the types of procedures undertaken between the 2 different centre types. PCI procedures for LM or CTO vessels were more frequently performed at the SCs, in line with the current guideline recommendations on LM PCI.[27]

Even when baseline differences between the 2 groups were adjusted for, inpatient mortality and major bleeding events were 30% lower in procedures undertaken in NSCs compared with SCs, although the odds for MACCE were similar. These findings must be interpreted with caution, taking into account our inability to exclude certain confounders such as frailty, anemia, anatomic complexity of CAD, and other unrecorded comorbidities that are associated with worse outcomes, such as COPD and cancer. [33] Furthermore, the severity of coronary diseases is not captured in the BCIS dataset, with no measures of the severity of calcification or the severity of disease as defined by SYNTAX score[34] or classification of CTOs by complexity.[35] The worse outcomes seen in SCs may be driven by a higher-risk case selection. Likewise, it is possible that lower-risk CHiP cases are performed in NSCs. Interestingly, we observe more frequent use of radial access and intracoronary imaging in NSCs. It is unclear why this may be the case, although it may reflect newer faculty, whose training routinely incorporated intracoronary imaging, practicing in NSCs.

There is a growing body of evidence from single-centre experiences,[36] RCTs,[9,10] and observational registries,[8] all of which demonstrate similar outcomes of PCI in general in NSCs vs SCs. The present study extends this knowledge to those patients undergoing CHiP procedures. This is pertinent because the expansion of CHiP to NSCs is met with many advantages, such as a greater opportunity for patients to remain in their own community, as well as supporting the primary PCI program in NSCs by increasing the volume of PCIs performed at such centres. While there have been no reports concerning CHiP in NSCs, other studies have looked specifically into LM outcomes in NSCs vs SCs. For example, an analysis from the Victorian Cardiac Outcome Registry data showed that SCs were not a predictor for in-hospital mortality (aOR 0.68, 95% CI 0.32-1.43; $P = 0.350$), 30-day mortality, or survival at 60 months (hazard ratio 0.88, 95% CI 0.62-1.27; $P = 0.510$).[37] Furthermore, studies around CTO PCI in NSCs are rare; 1 prospective analysis in 2009 of 152 patients from 10 NSCs in China showed higher odds for procedure failure (OR 13.023, 95% CI 6.67-13.69; $P = 0.002$).[38]

Study strengths and limitations

This is the first study, at a national level, that examined, in a real-world unselected setting, CHiP outcomes according to the type of surgical cover. The study was powered to determine real differences between the groups. The cohort represents the UK national practice, given that 95% of the PCI cases in England and Wales are recorded in the BCIS dataset.

The study's limitations are mainly related to its observational nature, including errors during reporting and coding, which could result in potential bias, such as the underreporting of comorbidities, and self-reporting of complications without external validation. Furthermore, lesion complexity and severity of CAD are not captured by the BCIS registry, which may confound outcomes data. Moreover, there were significant differences between the 2 groups in major bleeding events, which must be interpreted after considering the differences in baseline demographics as well as the possibility of other unmeasured confounders such as anemia, frailty, lesion

Table 3. Average treatment effects (ATEs) and adjusted odds ratios (aORs) for adverse outcomes of patients with stable angina following a complex high risk percutaneous coronary intervention procedure, using propensity score matching (reference: on-site surgical cover)

Variable	ATE (95% CI)	aOR (95% CI)	*P* value
Mortality	−0.0013523 (−0.0021744 to −0.0005302)	0.6 (0.3-0.8)	0.001
Bleeding	−0.0028264 (−0.0039191 to −0.0017338)	0.5 (0.2-0.7)	< 0.001
MACCE	−0.0009283 (−0.0028826 to 0.0010259)	0.9 (0.8-1.1)	0.351

CI, confidence interval; MACCE, major cardiovascular and cerebral events.

complexity, and surgical turndown status that may contribute to the observed differences. Despite our efforts to adjust for numerous variables through PSM, the possibility of residual confounding remains. Specifically, the channelling of higher-risk cases to SCs could influence the outcomes, and lesion complexity may play a role. Also, while the incidence of periprocedural MI is clearly defined in the BCIS dataset, the data set fails to specify whether this diagnosis was based on a particular definition (eg, the fourth or the third universal MI definition). Finally, because the BCIS dataset captures only in-hospital outcomes, we cannot rule out significant differences in the longer term.

Conclusion

This extensive nationwide analysis underscores a significant uptick in the adoption of CHiP cases in NSCs, suggesting a trend toward managing complex cases in those centres. Our findings suggest that PCI in nonsurgical centres may be safe, with no excess mortality demonstrated. Nevertheless, these findings must be interpreted with recognition that given the inherent limitations in observational studies, the possibility of unmeasured confounders influencing the observed trends cannot be excluded. This study emphasises the need for further research to discern the factors driving these patterns and their implications for patient care.

Ethics Statement

All authors confirm strict adherence to the journal's ethical guidelines. Our research maintains integrity in authorship, avoids plagiarism, ensures data accuracy, and complies with regulations.

Patient Consent

By submitting this manuscript to the *Canadian Journal of Cardiology*, the authors confirm that all patient data presented herein has received Section 251 approval under NHS Act 2006. This approval permits the use of patient data for audit and research purposes without the formal requirement for individual patient consent. The authors recognise and adhere to the ethical guidelines and regulatory approvals governing the use of patient information, ensuring confidentiality, and compliance with applicable laws.

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Disclosures

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Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Cardiology* at www.onlinecjc.ca and at https://doi.org/10.1016/j.cjca.2024.01.003.