ORIGINAL ARTICLE

Clinical characteristics and outcomes of myocardial infarction, stroke, and cardiovascular mortality among patients undergoing complex high-risk indicated percutaneous coronary intervention: A one-year review in a single non-surgical centre

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ABSTRACT

Introduction: Complex High-risk Indicated Percutaneous Coronary Intervention (CHIP-PCI) addresses complex coronary artery disease in patients unsuitable for or declining surgery. Performing CHIP-PCI in non-surgical centres presents unique challenges requiring robust risk mitigation. CHIP-PCI was defined as PCI in any patient meeting at least one of the following criteria: PCI to left main stem, chronic total occlusion, severe coronary artery calcification (CAC), bifurcation lesions, left ventricular ejection fraction (LVEF) < 30%, serum creatinine > 200µmol/L, chronic dialysis, intra-aortic balloon pump use, previous coronary artery bypass graft, or age ≥ 80 years. Locally, the outcomes of major adverse cardiovascular events (MACE) - a composite of myocardial infarction, stroke, and cardiovascular mortality - and their associated factors after CHIP-PCI remain poorly understood. This study aims to evaluate 30-day MACE, patient characteristics and variables associated with mortality in CHIP-PCI.

Materials and Methods: This single-centre retrospective cohort study with 30-day follow-up utilised anonymous secondary data from CHIP-PCI patients treated at the Department of Cardiology, Hospital Raja Permaisuri Bainun between 1st January and 31st December 2024. Data extracted included demographics, comorbidities, laboratory investigations (low-density lipoprotein [LDL], serum creatinine, echocardiography findings), and intra- and post-procedural findings. Patients with missing data for ≥ 3 variables of interest were excluded. A multivariate binary logistic regression analysis was conducted to identify the variables associated with mortality post CHIP-PCI.

Results: Of the 161 total patients, 146 (90.7%) were included in the analysis. Among these, 71.9% were male, and the mean age was 63.03 ± 10.19 years. Common comorbidities included hypertension (83.6%), diabetes mellitus (66.4%), elevated LDL (51.6%), serum creatinine > 200µmol/L (38.4%), prior Acute Coronary Syndrome (37.0%), chronic dialysis (30.1%), and LVEF < 30% (9.6%). Radial access was the most common approach (72.6%), and PCI was most frequently performed for severe CAC (46.6%). Intracoronary imaging was used in 43.8% of cases, and 39.0% required advanced calcium modification technique (atherectomy or intravascular lithotripsy). Most were single-lesion PCI (80.8%), with the left anterior descending artery (80.8%) being the most treated vessel. The 30-day MACE rate was 5.5% (4.8% mortality, 0.7% stroke, and 0% recurrent myocardial infarction). Multivariate analysis demonstrated that LVEF < 30% (AOR: 41.1, 95% CI: 1.1–1563.8, p = 0.04), severe CAC (AOR: 28.2, 95% CI: 1.3–619.3; p = 0.03), elevated LDL (AOR: 28.7, 95% CI: 1.2–701.1; p = 0.04), and re-admission (AOR: 81.7, 95% CI: 4.1–1618.3, p < 0.001) were exploratory variables associated with 30-day mortality.

Conclusion: This study demonstrates that the 30-day MACE rate for CHIP-PCI was 5.5%, suggesting the procedure may be feasible with acceptable short-term outcomes in a non-surgical centre. Severely reduced LVEF, severe CAC, elevated LDL levels, and hospital re-admission showed potential associations with 30-day mortality highlighting the need for optimised strategies for patient risk mitigation.

KEYWORDS:
Percutaneous coronary intervention; complex high-risk indicated percutaneous coronary intervention; major adverse cardiovascular event; non-surgical centre

INTRODUCTION

Percutaneous Coronary Intervention (PCI) has become a cornerstone in the management of coronary artery disease,

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particularly for patients with Acute Coronary Syndrome (ACS).[1] For patients with complex coronary lesions and significant comorbidities, a subset of procedures known as Complex High-risk Indicated Percutaneous Coronary Intervention (CHIP-PCI) presents considerable procedural and clinical challenges. These patients often have multiple high-risk features, including left main stem disease, chronic total occlusions, bifurcation lesions, severe coronary artery calcification, prior coronary artery bypass grafting (CABG), severely reduced left ventricular ejection fraction (LVEF) < 30%, presence of significant comorbidities such as chronic kidney disease (serum creatinine > 200µmol/L or on chronic dialysis), or age ≥ 80 years old.[2-4]

While surgical revascularisation remains the standard of care for many high-risk patients, CHIP-PCI has emerged as a viable alternative for individuals who are poor surgical candidates or those who do not consent for surgical procedure.[5] Advances in PCI techniques, including the use of drug-eluting stents, advanced calcium modification techniques such as atherectomy or intravascular lithotripsy, intravascular imaging, and mechanical circulatory support devices (such as intra-aortic balloon pump), has significantly expanded the scope of PCI for this population.[6] However, the success and safety of CHIP-PCI remain a major concern, especially when performed in centres without on-site surgical backup.

Non-surgical centres performing CHIP-PCI face distinct challenges, including the need for sufficient operator experience, sound clinical judgment, careful case selection, and the implementation of risk-mitigation strategies to reduce major adverse cardiovascular events (MACE), defined as a composite of myocardial infarction, stroke, and cardiovascular mortality.[7-8] While previous studies have examined outcomes of CHIP-PCI in tertiary surgical centres, there is relative paucity of data evaluating the safety and efficacy of these procedures in non-surgical settings.[2] Understanding the clinical characteristics and outcomes of patients undergoing CHIP-PCI in these environments is critical for improving procedural safety, refining risk stratification, and optimising post-procedural management.

The primary objective of this study was to determine the 30-day incidence of MACE following CHIP-PCI. Secondary objectives included a characterisation of baseline patient demographics and the identification of factors associated with MACE. By elucidating factors of adverse outcomes, this study endeavours to contribute to evidence-based advancements in the management of CHIP-PCI patients and to provide guidance for centres performing CHIP-PCI without immediate on-site surgical support.

MATERIALS AND METHODS

Study Design and Study Population

This was a single-centre retrospective cohort study with 30-day follow-up conducted at the Department of Cardiology, Hospital Raja Permaisuri Bainun, utilising secondary data from patients who underwent CHIP-PCI between January and December 2024. Data were extracted from electronic medical records, coronary angiography and echocardiography reports from 1 January 2024 to 31 December 2024, with MACE data extracted up to 31 January 2025. Extracted data were then entered into an online spreadsheet by designated study personnel. Parameters extracted included demographics, comorbidities (diabetes mellitus, hypertension, history of ACS, stroke, PCI, CABG, peripheral vascular disease, chronic dialysis), laboratory variables (low-density lipoproteins [LDL] and serum creatinine), coronary angiography and echocardiography findings (LVEF). Only the most recent laboratory values documented within the preceding six months before PCI were included for analysis. Data on re-admission and major bleeding events were also extracted. A major bleeding event was defined according to the standardised bleeding definition of the Bleeding Academic Research Consortium.[9] From the extracted data, only patients who underwent PCI with at least one of the following characteristics were included: PCI to left main stem, chronic total occlusion, severe coronary artery calcification, bifurcation lesion, LVEF < 30%, chronic kidney disease with serum creatinine > 200µmol/L, chronic dialysis (peritoneal or haemodialysis), use of an intra-aortic balloon pump, previous CABG, or age ≥ 80 years. The study definitions used were adapted from the criteria used in the British Cardiovascular Intervention Society (BCIS) National PCI Dataset.[2-3] Patients who underwent primary or rescue PCI for ST-elevation myocardial infarction were excluded. Additionally, patients with missing data for ≥ 3 variables of interest with were excluded from the final analysis.

Sample size

The sampling frame consisted of 161 patients identified from the general database. The minimum required sample size was calculated using the population to proportion method with the Raosoft® online calculator.[10] Using a 95% confidence interval, a 5% margin of error, a population size of 161, and a response distribution of 50% (to yield the maximum sample size), the minimum sample size required for analysis was determined to be 114.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), Version 25. Categorical data were expressed as numbers and percentages, while continuous data were presented as mean ± standard deviation (SD). Continuous variables were tested for normality; normally distributed data were expressed as mean ± SD, while non-parametric variables were presented as median and interquartile range (IQR). The comparison of categorical data between groups was performed using the Chi-square test, and continuous variables were compared across different groups using an independent t-test (for normally distributed data) or a Mann-Whitney U test (for non-normally distributed data). All variables with a p-value ≤ 0.3 in the univariate analysis were included in the multivariate analysis using binary logistic regression. For the multivariate analysis, a p-value < 0.05 was considered statistically significant. The final model's goodness-of-fit was assessed using the Hosmer-Lemeshow test (indicating good fit if p ≥ 0.05), the percentage of correctly classified cases (target > 70% accuracy), and the Nagelkerke R^2 value (moderate model fit if 0.5–0.7 and > 0.7 indicates a very good fit).

Table I: Basic demography, laboratory data, echocardiography findings, coronary anatomy and procedural characteristics of the patients

Parameter	Overall N (%) n = 146	Mortality N (%) n = 7	No mortality N (%) n = 139	p-value
Age (years)	63.03 ± 10.19	69.00 [13.00]	64.00 [12.00]	0.30
Gender				
Male	105 (71.9)	6 (5.7)	99 (94.3)	0.67
Female	41 (28.1)	1 (2.4)	40 (97.6)	
LDL* (mmol/L)	2.44 ± 1.13	2.60 [1.60]	2.15 [1.33]	0.38
Not elevated	45 (48.4)	2 (4.4)	43 (95.6)	0.29
Elevated	48 (51.6)	5 (10.4)	43 (89.6)	
Serum creatinine (μmol/L)	109.00 [384.00]	99.00 [429.00]	109.00 [381.00]	0.97
≤ 200	90 (61.6)	5 (5.6)	85 (94.4)	
> 200	56 (38.4)	2 (3.6)	54 (96.4)	0.71
LVEF (%)	48.39 ± 12.67	47.00 [30.00]	47.00 [18.00]	0.94
< 30	14 (9.6)	2 (14.3)	12 (85.7)	0.14
≥ 30	132 (90.4)	5 (3.8)	127 (96.2)	
Comorbidities				
Diabetes Mellitus	97 (66.4)	4 (4.1)	93 (95.9)	0.69
Hypertension	122 (83.6)	6 (4.9)	116 (95.1)	0.99
ACS	54 (37.0)	3 (5.6)	51 (94.4)	0.99
Cerebrovascular accident	9 (6.2)	1 (11.1)	8 (88.9)	0.37
History of PCI	32 (21.9)	2 (6.2)	30 (93.8)	0.99
History of CABG	4 (2.7)	0	4 (100)	0.99
Peripheral vascular disease	1 (0.7)	0	1 (100)	0.99
Chronic dialysis	44 (30.1)	2 (4.5)	42 (95.5)	0.99
Number of lesions treated	1.00 [0]	1.00 [0]	1.00 [0]	0.88
One	118 (80.8)	6 (5.1)	112 (94.9)	
Two	26 (17.8)	1 (3.8)	25 (96.2)	0.99
Three	2 (1.4)	0	2 (100)	
Stent length** (mm)	45.89 ± 21.13	51.50 [21.00]	42.00 [34.75]	0.65
Intracoronary Imaging	64 (43.8)	5 (7.8)	59 (92.2)	0.24***
Intra-arterial balloon pump	3 (2.1)	1 (33.3)	2 (66.7)	0.14
Access during PCI				
Radial	106 (72.6)	5 (4.7)	101 (95.3)	
Femoral	35 (24.0)	2 (5.7)	33 (94.3)	0.99
Radial and femoral	5 (3.4)	0	5 (100)	
Atherectomy / Intravascular Lithotripsy	57 (39.0)	4 (7.0)	53 (93.0)	0.43
Type of lesion				
LMS	30 (20.5)	1 (3.3)	29 (96.7)	0.99
Chronic total occlusion	19 (13.0)	0	19 (100)	0.60
Bifurcation	10 (6.8)	1 (10.0)	9 (90.0)	0.40
Severe CAC	68 (46.6)	5 (7.4)	63 (92.6)	0.25
CABG graft	2 (1.4)	0	2 (100)	0.99
Target vessel				
LMS	31 (21.2)	1 (3.2)	30 (96.8)	0.99
LAD	118 (80.8)	6 (5.1)	112 (94.9)	0.99
LCx	19 (13.0)	1 (5.3)	18 (94.7)	0.99
RCA	19 (13.0)	0	19 (100)	0.60
CABG graft	2 (1.4)	0	2 (100)	0.99

Data are shown as number (percentage), mean ± standard deviation, median [interquartile range].
LDL low-density lipoprotein, LVEF left ventricular ejection fraction, ACS acute coronary syndrome, PCI percutaneous coronary intervention, CABG coronary artery bypass graft, CAC coronary artery calcification, LMS left main stem, LAD left anterior descending, LCx left circumflex, RCA right coronary artery. *53 missing, **24 missing, ***rejected univariate to be included in multivariate.

RESULTS

A flow chart of the patient enrolment is provided as Fig. I. A total of 907 records were initially identified through database search. Following screening and eligibility assessment, 161 records were evaluated, of which 15 were excluded due to having ≥3 variables with missing data or being lost to follow-up (final outcomes unknown). This resulted in a final study population of 146 patients (90.7% of the extracted data). Table I shows the basic demography, laboratory and echocardiography findings as well as coronary anatomy and procedural characteristics.

The mean age of the cohort was 63.03 ± 10.19 years. Males constituted the majority (71.9%), reflecting the well-established male predominance in coronary artery disease. Cardiovascular comorbidities were highly prevalent: 66.4% of patients had diabetes mellitus and 83.6% had hypertension. A history of ACS was present in 37.0% of the patients while prior PCI was found in 21.9%. From the total, 6.2% had a history of stroke, and 2.7% had undergone CABG while 0.7% had peripheral vascular disease. Renal dysfunction was common, with 38.4% exhibiting baseline serum creatinine > 200μmol/L and 30.1% were undergoing chronic dialysis.

Table II: 30-day MACE outcomes compared with mortality outcomes

Parameter	Overall N (%) n = 146	Mortality N (%) n = 7	No mortality N (%) n = 139	p-value
Death	7 (4.8)	7 (100)	-	-
Stroke	1 (0.7)	0	1 (100)	0.99
Recurrent myocardial infarction	0	0	0	-
Re-admission	7 (4.8)	3 (42.9)	4 (57.1)	< 0.001
Major bleeding event	1 (0.7)	0	1 (100)	0.99

Table III: Multivariate logistic regression analysis comparing different univariate outcomes with the outcome of mortality

Parameter	OR (95% CI)	p-value	AOR (95% CI)	p-value
Age	1.05 (0.96–1.14)	0.30	1.13 (0.96–1.32)	0.14
Intra-arterial balloon pump	11.42 (0.90–144.16)	0.06	9.71 (0.16–592.11)	0.28
LVEF < 30%	4.23 (0.74–24.20)	0.14	41.11 (1.08–1563.83)	0.04
Severe CAC	3.02 (0.57–16.08)	0.25	28.18 (1.28–619.27)	0.03
Elevated LDL*	2.50 (0.46–13.60)	0.29	28.72 (1.18–701.13)	0.04
Re-admission	25.31 (4.20–152.69)	< 0.001	81.69 (4.12–1618.32)	< 0.001

OR odds ratio, AOR adjusted odds ratio, CI confidence interval, LVEF left ventricular ejection fraction, CAC coronary artery calcification, LDL low-density lipoprotein. No intra-arterial balloon pump, LVEF ≥ 30%, no severe CAC, not elevated LDL level, and no re-admission were references. *53 missing.

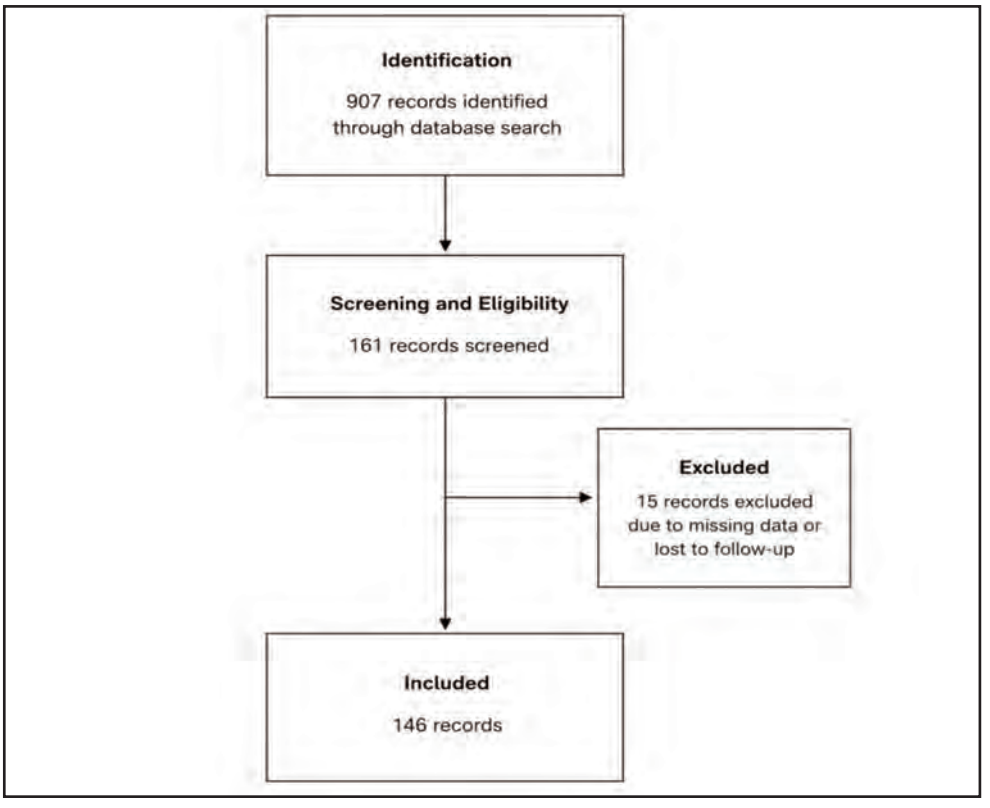

Fig. 1: Flow chart of patient enrolment

Laboratory and Echocardiographic Findings

The mean LDL was 2.44 ± 1.13mmol/L, and more than half of the cohort (51.6%) had elevated LDL levels. LDL levels were categorised according to prior ACS history: for patients with a history of ACS, an elevated LDL was considered > 1.4mmol/L, whereas for those without a prior ACS history, elevated LDL was > 2.6mmol/L.[11] The mean LVEF was 48.39 ± 12.67%; however, 9.6% of patients presented with severely impaired systolic function with LVEF < 30%. The median serum creatinine was 109.0µmol/L (IQR: 384.0).

Coronary Anatomy and Procedural Characteristics

The complexity of coronary lesions was notable. Severe coronary artery calcification was found in 46.6% of patients. PCI involved the left main stem (LMS) artery in 20.5% of cases, chronic total occlusion lesions in 13.0%, and bifurcation lesions in 6.8%. The mean stent length was 45.89 ± 21.13 mm, and most patients (80.8%) underwent single-lesion PCI. Lesions in the left anterior descending (LAD) artery were most frequently treated (80.8%), followed by the left circumflex artery (LCx) and right coronary artery (RCA),

each at 13.0%. Only 1.4% of procedures targeted coronary artery bypass grafts (CABG). The radial artery was the common access site (72.6%), whereas femoral access was used in 24.0% of the patients and combined radial–femoral access in 3.4%. Advanced calcium modification techniques were performed in 39.0% of patients and intracoronary imaging was used in 43.8% of cases. Use of mechanical circulatory support was uncommon, with only 2.1% of patients utilising intra-aortic balloon pump during PCI.

30-Day Clinical Outcomes

Table II compares the overall 30-days MACE outcomes with mortality outcomes. The MACE outcomes were low (5.5%) despite the high-risk profile of the cohort. Mortality occurred in 7 patients (4.8%), while stroke was reported in 1 patient (0.7%). All deaths were incidental cardiovascular in nature, with 6 deaths attributed to cardiogenic shock and 1 death due to ventricular tachycardia storm. Four deaths occurred during index hospitalisation whereas 3 occurred during subsequent readmission.

No recurrent myocardial infarction was observed. Non-MACE complications included hospital re-admission in 7 patients (4.8%) and a major bleeding event occurred in 1 patient (0.7%). Due to the small number of MACE events, which were driven predominantly by mortality rather than stroke or recurrent myocardial infarction, hence mortality alone was used as the final outcome measure.

Exploratory analysis for variables associated with of 30-Day Mortality

The model demonstrated good predictive accuracy, correctly classifying 92.5% of cases (target > 70%). The non-significant result (p=0.81) of the Hosmer–Lemeshow goodness-of-fit test suggested an adequate model, and the Nagelkerke R^2 of 0.53 indicated moderate explanatory power. Collectively, the developed model exhibited a moderate-good overall fit.

Univariate analyses indicated that several factors were potentially associated with 30-day mortality ($p \leq 0.30$), including advanced age (p=0.30), elevated LDL levels (p=0.29), LVEF<30% (p=0.14), severe coronary artery calcification (p=0.25), the use of an intra-aortic balloon pump (p=0.14), and hospital re-admission (p<0.001).

Hospital re-admission was included in the final outcome because previous studies have shown that re-admitted patients have a higher risk of mortality after PCI.[12] The variable of intracoronary imaging (p=0.24) was clinically rejected, as current guidelines recommend that PCI for anatomically complex lesions—left main stem, bifurcations, and long lesions—be guided by intravascular imaging.[13] The other statistically significant variables ($p \leq 0.3$) were included into a multivariate binary logistic regression model. The final exploratory analysis showed that LVEF < 30% (AOR: 41.11, 95% CI: 1.08–1563.83, p=0.04), severe coronary artery calcification (AOR: 28.18, 95% CI: 1.28–619.27, p=0.03), elevated LDL level (AOR: 28.72, 95% CI: 1.18–701.13, p=0.04), and hospital re-admission (AOR: 81.69, 95% CI: 4.12–1618.32, p<0.001) were potential factors associated with 30-day mortality. However, given the wide confidence intervals observed in the results, the data should be interpreted cautiously.

DISCUSSION

This single-centre retrospective cohort study with 30-day follow-up provides valuable real-world insights into the clinical characteristics and short-term outcomes of patients undergoing CHIP-PCI in a non-surgical centre. The principal finding is that in a carefully selected high-risk cohort, CHIP-PCI can be performed with a low incidence of MACE of 5.5%. This study also identifies four exploratory variables potentially associated with 30-day mortality: severely reduced LVEF, severe coronary artery calcification, elevated LDL level, and hospital re-admission.

The patient cohort in this study aligns with the typical demographic and clinical profile of patients undergoing CHIP-PCI as documented in international literature.[2,14] More than two-thirds of patients were male and over 60 years of age, with a very high burden of diabetes mellitus, hypertension, and chronic kidney disease. Nearly half of all cases involved severe coronary calcification and one-fifth required left main stem intervention. These features are well recognised to increase procedural complexity and heighten the risk of periprocedural complications such as coronary perforation, suboptimal stent expansion, and peri-procedural myocardial infarction.[15-16] Notably, advanced calcium modification techniques was used in 39% of cases, underscoring the technical challenges posed by heavily calcified lesions. Contemporary plaque-modification tools such as rotational or orbital atherectomy, intravascular lithotripsy and specialised angioplasty balloons are essential to achieve adequate lesion preparation and stent expansion in this setting.[15,17] The high uptake of radial access despite lesion complexity reflects a growing preference for "radial-first strategies" even in CHIP-PCI, given their well-documented association with lower risk of all-cause mortality, major bleeding and major vascular complications.[18-19]

The MACE rate observed in the present cohort was similar when compared with outcomes reported in large-scale registries, including those from high-volume tertiary centres with on-site surgical backup. For instance, the retrospective analysis by Peles et al. of 1890 patients undergoing high-risk PCI - defined as unprotected left main disease, last patent vessel, or three-vessel disease with LVEF < 35% - reported a 30-day MACE rate of 14.2% and a 30-day all-cause mortality rate of 8.8%.[20] Similarly, the OPTIMUM registry by Salisbury et al., which investigated 726 patients with complex multivessel or left main coronary artery disease deemed ineligible for CABG, reported an all-cause mortality of 5.6% at 30 days.[21] Finally, Yeoh et al., analysing the Melbourne Interventional Group registry's data of 20,973 PCI patients stratified by a clinical and anatomical risk score, reported that the most complex and very high-risk patients had a 30-day mortality rate of 7.1%.[22] It is noteworthy that the MACE in our study was driven exclusively by mortality and stroke, with no reported cases of recurrent myocardial infarction. This finding may reflect successful procedural techniques that minimised periprocedural myocardial injury, a critical goal in CHIP-PCI. While the differences in study inclusion criteria prevent a direct head-to-head comparison of all results, the MACE rate from our study provides a useful benchmark for subsequent investigations.

Multivariate analysis identified several potential variables of short-term mortality. Reduced LVEF exhibited a high adjusted odds ratio, suggesting a potential association with increased odds of adverse outcomes in this patient population. This finding aligns with established cardiovascular literature documenting the strong association between left ventricular systolic dysfunction and increased adverse outcomes, as independently reported by Ye et al. and Mankerious et al. in their observational studies demonstrating higher rates of in-hospital MACE associated with reduced LVEF.[23-25] The challenge of CHIP-PCI in this group is rooted in their limited physiological reserve, rendering them poorly tolerant of repeated procedural myocardial ischaemia and significantly increasing their vulnerability to haemodynamic compromise, worsening heart failure, and ultimately, incomplete revascularisation.[26-28] Despite this inherent risk, Abudukeremu et al. reported in a meta-analysis of 25 observational studies (mean LVEF 30%) that PCI is a reasonable revascularisation strategy for patients with coronary artery disease and severe left ventricular systolic dysfunction, demonstrating acceptable short- and long-term outcomes, with no significant difference in long-term mortality compared with CABG.[29] Consequently, the high-risk profile necessitates meticulous procedural planning and the selective utilisation of haemodynamic support devices to mitigate MACE risk and achieve optimal revascularisation.[26]

Severe coronary artery calcification similarly emerged as a potential variable associated with 30-day mortality. The presence of severe coronary artery calcification significantly complicates PCI and is independently associated with an increased incidence of MACE.[15,30] The technical challenge posed by these lesions heightens the probability of procedural failure (e.g., balloon uncrossability or stent underexpansion), acute complications (e.g., coronary dissection or perforation, or balloon rupture), and higher periprocedural morbidity and mortality.[30] Consequently, this frequently necessitates advanced calcium modification techniques. While these techniques, such as mechanical atherectomy or intravascular lithotripsy (used in 39.0% of this cohort), may improve procedural success, they may not completely mitigate the inherent risk associated with severe coronary artery calcification, which remained potentially associated with adverse outcomes in this study. This highlights the essential role of intravascular imaging, meticulous technique selection, and clinical judgment based on individual lesion characteristics for optimal treatment of calcified lesions.[15]

A finding from our analysis was that elevated LDL level emerged as a potential variable associated with 30-day mortality. While LDL is a cornerstone of long-term cardiovascular risk management, its role as a predictor of acute outcomes is less clearly defined, and prior studies highlighted the nuanced nature of this association. For instance, Pres et al. reported that elevated admission LDL-C predicted in-hospital mortality in diabetic ST-elevation myocardial infarction (STEMI) patients treated with PCI, but not in their non-diabetic counterparts.[31] Similarly, Zhong et al. reported that a high LDL-C/HDL-C ratio was an independent predictor for 1-year MACE following PCI.[32] Although there is an important methodological distinction between the LDL-C measurement used in the cited studies and the less specific LDL measurement (as used in this present study), these collective evidences suggest that elevated admission LDL likely serves as a surrogate marker for a constellation of high-risk features, such as heightened systemic inflammation, plaque instability or poorly managed atherosclerotic disease.[33] While this association warrants further investigation, our findings suggest that baseline lipid status could be an important component of immediate risk assessment in the CHIP-PCI population.

In this study, it was observed that hospital re-admission was a potential variable associated with 30-day mortality and should be interpreted not as an independent baseline risk factor, but rather as a post-procedural complication that may indicate subsequent adverse outcomes. Large-scale analyses, such as Kwok et al., demonstrated that 30-day unplanned readmission following PCI occurs in nearly 1 in 10 patients and is associated with a higher risk of subsequent mortality and adverse events.[34] This association likely reflects that patients requiring re-admission are experiencing a decompensation of their fragile physiological state, often manifesting as significant, immediate postprocedural complications (e.g. major bleeding, stent thrombosis, or access-site complications) or acute clinical deterioration (e.g. worsening heart failure or infection). This underscores the necessity of multidisciplinary post-discharge surveillance and the implementation of transitional care protocols to mitigate the elevated risk of early mortality in this vulnerable patient population.

The authors acknowledge that several factors demonstrated very wide confidence intervals, likely due to the low number of mortality events observed in this study, resulting in statistical instability of the multivariable model. Although some variables appeared to be associated with increased odds of 30-day mortality, the magnitude of these associations should be interpreted with caution. For example, the adjusted odds ratio (AOR) for readmission was 81.69 (95% CI: 4.12–1618.32, $p<0.001$). While this suggests a possible association, the extremely wide confidence interval indicates substantial uncertainty around the effect estimate despite statistical significance. Therefore, these findings should be regarded as exploratory and hypothesis-generating rather than definitive evidence of independent predictors of mortality. Accordingly, terms implying strong or definitive associations should be interpreted cautiously within the context of the study's limited event rate and sample size.

LIMITATIONS

Several limitations merit consideration. First, the single-centre retrospective cohort study with 30-day follow-up design limits the generalisability of the findings and allows only the identification of associations rather than causation. Second, the relatively small number of mortality events (the outcome of interest) resulted in wide confidence intervals for the odds ratios, and these findings should therefore be interpreted with caution. Third, although the exclusion of patients with incomplete data was methodologically necessary, it may have influenced the observed outcomes, particularly as some excluded patients had unknown 30-day outcomes due to loss to follow-up. Fourth, the 30-day follow-

up period does not provide insight into the long-term outcomes and safety of CHIP-PCI in this cohort. Fifth, elevated LDL levels as a potential variable associated with mortality may reflect an underlying high-risk comorbidity burden rather than a direct causal relationship. Additionally, the substantial proportion of missing LDL data (approximately 36%) limits confidence in the observed association between elevated LDL levels and 30-day mortality. Therefore, this finding should be interpreted cautiously. Sixth, re-admission as a potential variable may have been related to non-cardiac conditions (e.g., pneumonia) that were not captured in the database. Lastly, Firth's penalized logistic regression was not applied despite the small number of outcome events, due to limitations in the statistical package used for the analysis.

Future Directions

Future studies should incorporate larger, multicentre cohorts with extended follow-up periods to validate these findings and identify modifiable factors of adverse outcomes. Prospective evaluation of structured post-discharge care pathways and early implementation of intensive lipid-lowering strategies may further enhance clinical outcomes.

CONCLUSION

In this single non-surgical centre experience, CHIP-PCI was associated with a low 30-day incidence of MACE despite the high clinical and procedural complexity of the patient cohort. Exploratory variables potentially associated with 30-day mortality included severely reduced LVEF, severe coronary artery calcification, elevated LDL levels, and hospital re-admission.

Overall, this study suggests that CHIP-PCI may be feasible in non-surgical centres with acceptable short-term outcomes in carefully selected patients. The findings add to the growing body of evidence indicating that, with experienced operators, meticulous procedural planning, and the use of contemporary interventional techniques, CHIP-PCI may be performed safely even in centres without on-site surgical backup.7 It also highlights the potential importance of aggressive lipid management and early detection of post-discharge complications. However, these observations should be regarded as exploratory and interpreted cautiously. The researchers acknowledge that 30-day mortality does not reflect long-term outcomes or overall long-term safety of CHIP-PCI. Therefore, larger multicentre studies with extended follow-up are warranted to validate these findings and further refine risk stratification and management strategies for this complex and expanding patient population.

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CONFLICT OF INTEREST

All authors of this study have no conflict of interest to declare.

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ETHICAL APPROVAL

Ethical approval was obtained from Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (NMRR ID-25-01644-KLT). Permission was obtained from the hospital authorities to assess the medical records.

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