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Outcomes following PCI in CABG candidates during the COVID-19 pandemic: The prospective multicentre UK-ReVasc registry

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Abbreviations: ACS, acute coronary syndrome; CABG, coronary artery bypass grafting; CAD, coronary artery disease; LAD, left anterior descending; LMS, left main stem; MI, myocardial infarction; NSTE-ACS, non-ST elevation acute coronary syndrome; PCI, percutaneous coronary intervention; SD, standard deviation; STEMI, ST-elevation myocardial infarction; TIMI, thrombosis in myocardial infarction.

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Abstract

Objectives: To describe outcomes following percutaneous coronary intervention (PCI) in patients who would usually have undergone coronary artery bypass grafting (CABG).

Background: In the United Kingdom, cardiac surgery for coronary artery disease (CAD) was dramatically reduced during the first wave of the COVID-19 pandemic. Many patients with "surgical disease" instead underwent PCI.

Methods: Between 1 March 2020 and 31 July 2020, 215 patients with recognized "surgical" CAD who underwent PCI were enrolled in the prospective UK-ReVasc Registry (ReVR). 30-day major cardiovascular event outcomes were collected. Findings in ReVR patients were directly compared to reference PCI and isolated CABG pre-COVID-19 data from British Cardiovascular Intervention Society (BCIS) and National Cardiac Audit Programme (NCAP) databases.

Results: ReVR patients had higher incidence of diabetes (34.4% vs 26.4%, $P = .008$), multi-vessel disease with left main stem disease (51.4% vs 3.0%, $P < .001$) and left anterior descending artery involvement (94.8% vs 67.2%, $P < .001$) compared to BCIS data. SYNTAX Score in ReVR was high (mean 28.0). Increased use of transradial access (93.3% vs 88.6%, $P = .03$), intracoronary imaging (43.6% vs 14.4%, $P < .001$) and calcium modification (23.6% vs 3.5%, $P < .001$) was observed. No difference in in-hospital mortality was demonstrated compared to PCI and CABG data (ReVR 1.4% vs BCIS 0.7%, $P = .19$; vs NCAP 1.0%, $P = .48$). Inpatient stay was half compared to CABG (3.0 vs 6.0 days). Low-event rates in ReVR were maintained to 30-day follow-up.

Conclusions: PCI undertaken using contemporary techniques produces excellent short-term results in patients who would be otherwise CABG candidates. Longer-term follow-up is essential to determine whether these outcomes are maintained over time.

KEYWORDS
coronary artery bypass grafting, COVID-19, percutaneous coronary intervention

1 | INTRODUCTION

COVID-19 has had an unprecedented impact on the delivery of routine health care in the United Kingdom (UK). During the first wave in March 2020 the National Health Service (NHS) was forced to undergo a significant transformation, repurposing resources to frontline care while increasing intensive care unit (ICU) capacity in preparation for the expected surge of COVID-19 patients requiring ventilatory support.

Consequently, elective care for patients with a stable condition across medical and surgical disciplines in the UK was dramatically reduced, and clinicians requested to defer care of those who under normal circumstances would be considered urgent.[1] Specialties such as cardiac surgery were worst affected as the requirement for ventilated beds is a routine part of clinical practice. Thus, as NHS services were reconfigured to only provide care for true emergency cases, UK cardiac units reported an up to 83% reduction in surgical activity.[2,3]

However, despite the ongoing COVID-19 pandemic there remained a cohort of patients who required urgent revascularisation because of (a) high-risk coronary anatomy, (b) severe symptoms refractory to medical therapy or (c) presentation with NSTE-ACS. Established data demonstrate a significant reduction in death and MI if revascularisation is undertaken expeditiously in these groups,[4-6] with coronary artery bypass grafting (CABG) recognized as the optimal treatment in specific patterns of coronary artery disease (CAD). Thus, in the absence of access to CABG, and in spite of complex disease, percutaneous coronary intervention (PCI) was offered to some patients as an alternative mode of revascularisation.

Against this backdrop a web-based prospective registry was established to capture the demographics, procedural characteristics and short-term clinical outcomes of patients who would otherwise have been CABG candidates, but were in fact treated with PCI during the COVID-19 pandemic first wave in the UK. Such patients can be regarded as a novel patient cohort.

2 | MATERIALS AND METHODS

2.1 | Study design

The University Hospitals of Leicester (UHL) NHS Trust in collaboration with the Robertson Centre for Biostatistics at The University of Glasgow developed an online remote data entry system, which allowed participants from UK PCI centers to include anonymised data on patients deemed CABG candidates who underwent PCI.

2.2 | Data collection

As well as collecting baseline demographics, relevant previous medical history and cardiovascular risk factors, the reasons for not undergoing CABG were noted. Also recorded were mode of presentation, arterial access site used, anatomical distribution of CAD, the SYNTAX Score (SS)[7] and the residual SYNTAX Score (rSS),[8] as well as PCI procedural characteristics (ie, use of imaging, calcium modification). Complete revascularisation (CR) was defined as intervention on all vessels >2.25 mm with at least one stenosis >50%. Participating centers were asked to enter data on PCI success (defined as TIMI III flow with <30% residual stenosis) and record in-hospital and 30-day major adverse cardiovascular events (MACE) composed of all-cause mortality, MI (as defined by fourth Universal Definition of Myocardial Infarction),[9] heart failure (typical signs, symptoms, and investigation results consistent with the diagnosis),[10] stroke, unplanned revascularisation, and Bleeding Academic Research Consortium (BARC) 3-5 bleeding.[11] Length of inpatient stay was also recorded.

2.3 | Comparative analyses

Data were compared with the British Cardiovascular Intervention Society (BCIS) National Audit of PCI (2018-2019), which is part of the National Cardiac Audit Programme (NCAP), run by the National Institute for Cardiovascular Outcomes Research (NICOR). Data are collected on all PCI procedures performed in the UK, including all elective and urgent/emergency PCI, and patients turned down for surgery. However, patients treated with primary PCI for STEMI were excluded from this analysis as this is a group in whom CABG is rarely performed. The comparisons aimed to determine if patients in our ReVR had differing demographics, procedural characteristics or outcomes than patients typically treated by PCI. ReVR in-hospital mortality, stroke, bleeding, and length of stay data were also compared with isolated CABG patients from the National Adult Cardiac Surgery project of the NCAP database held at NICOR (2017-2018).

2.4 | Statistical methods

Continuous data are expressed as mean (SD) or median (range), and categorical data as counts and percentages. To compare groups, an independent samples *t*-test was used for continuous data and chi-squared tests (Fisher's Exact) for categorical data. Formal statistical comparisons were made only where raw data were available and if few cases are reported in both groups only summaries are provided. Statistical significance was set at 0.05.

3 | RESULTS

3.1 | Baseline characteristics

Data from 215 patients across 45 UK centers were entered into our ReVR. The baseline demographic, clinical, and angiographic characteristics for both ReVR and BCIS cohorts are detailed in Table 1. Patients were of similar age and men accounted for approximately three-quarters of the population in both groups. ReVR patients had significantly higher incidence of hyperlipidaemia and diabetes. Conversely, there was a higher incidence of prior PCI and prior CABG in the BCIS cohort.

In the BCIS cohort 56.0% presented with NSTE-ACS compared with 74.9% in ReVR. The differences between the two groups in terms of presentation were highly significant: stable (ReVR 25.1% vs BCIS 44.0%, $P < .001$) and NSTE-ACS (74.9% vs 56.0%, $P < .001$).

Patients in ReVR presented with anatomically complex CAD. Multivessel disease (MVD) with LMS involvement was high at 51.4% (vs 3.0% in BCIS), with 45.2% having MVD without LMS involvement (vs a more similar 41.6% in BCIS). 94.8% of patients had LAD disease (vs 67.2% in BCIS). The mean SS was 28.0 (SD 10.4), and 141 (67.1%) registered a SS in the two highest tertiles. In the 202 patients where SYNTAX II Score was calculated, a mean 4-year predicted mortality of 14.2% (SD 13.2) for PCI and 10.5% (SD 10.4) for CABG was recorded.

3.2 | Procedural characteristics

Use of the radial approach was significantly higher in our ReVR cohort (93.3% vs 88.6%, $P = .03$) (Table 2). CR was achieved in 51.6% of

TABLE 1 Baseline demographics

	ReVR (n = 215)	BCIS (n = 60 515)	*P*-value
Mean age-year (SD)	67.4 (10.2)	66.3 (11.5)	.12
Male sex-% (n)	77.2 (167/215)	74.2 (44 897/60 481)	.25
Hypertension-% (n)	65.1 (140/215)	62.7 (36 971/58 929)	.47
Hyperlipidaemia-% (n)	69.3 (149/215)	55.7 (32 828/58 929)	<.001
Diabetes-% (n)	34.4 (74/215)	26.4 (15 685/59 323)	.008
Smoking status			
• Current smoker-% (n)	12.1 (26/215)	17.5 (9625/55 096)	.03
• Ex-smoker-% (n)	37.7 (81/215)	41.0 (22 477/55 096)	
• Non-smoker-% (n)	49.3 (106/215)	41.7 (22 994/55 096)	
Previous admission with heart failure-% (n)	6.0 (13/215)	NA	
Previous MI-% (n)	24.7 (53/215)	30.4 (18 027/59 357)	.07
Previous PCI-% (n)	17.7 (38/215)	31.1 (18 618/59 939)	<.001
Previous CABG-% (n)	0.0 (0/215)	8.8 (5272/59 941)	<.001
Chronic kidney disease-% (n)	14.4 (31/215) (eGFR <60 mL/min)	3.0 (1769/58 808) (creatinine >200 or dialysis)	<.001
Lung disease-% (n)	10.2 (22/215)	NA	
Presentation			
• Stable-% (n)	25.1 (54/215)	44.0 (26 651/60 515)	<.001
• NSTE-ACS-% (n)	74.9 (161/215)	56.0 (33 864/60 515)	<.001
Pattern of CAD			
• Multi-vessel disease with LMS-% (n)	51.4 (108/210)	3.0 (1370/46 168)	<.001
• Multi-vessel disease without LMS-% (n)	45.2 (95/210)	41.6 (19 024/46 168)	.24
• LMS only-% (n)	1.4 (3/210)	0.4 (165/46 168)	.04*
• LAD only-% (n)	3.3 (7/210)	29.6 (13 664/46 168)	<.001
• LAD disease involvement-% (n)	94.8 (199/210)	67.2 (31 062/46 168)	<.001
• Non-LMS/non-LAD-% (n)	2.4 (5/210)	31.9 (14 733/46 168)	<.001
SYNTAX score-mean (SD)	28.0 (10.4)	NA	
SYNTAX score tertiles			
• <23% (n)	32.9 (69/210)	NA	
• 23%-32% (n)	35.7 (75/210)		
• >32% (n)	31.4 (66/210)		
SYNTAX II score		NA	
• PCI 4-year mortality-mean (SD) (%)	14.2 (13.2)		
• CABG 4-year mortality-mean (SD) (%)	10.5 (10.4)		
On surgical waiting list-% (n)	25.6 (55/215)	NA	
Reasons for not undergoing CABG		NA	
• Insufficient number of surgeons-% (n)	0.5 (1/215)		
• Lack of surgical lists-% (n)	48.8 (105/215)		
• No ICU bed available-% (n)	42.3 (91/215)		
• Risk of COVID-19-% (n)	5.6 (12/215)		
• Current or previous COVID-19-% (n)	2.8 (6/215)		

Abbreviations: BCIS, British Cardiovascular Intervention Society; CABG, coronary artery bypass grafting; eGFR, estimated glomerular filtration rate; ICU, intensive care unit; LAD, left anterior descending; LMS, left main stem; NA, not available; PCI, percutaneous coronary intervention; SD, standard deviation.

patients. The mean rSS in those with incomplete revascularisation (ICR) was 15.7 (SD 9.1). In those a rSS >8, operators reported future plans to undertake further PCI in 29 cases (27.9%). The remaining patients were treated medically (n = 37) or with future CABG (n = 6) (Figure 1). 13.8% of procedures in ReVR involved chronic total occlusion (CTO) PCI. Although BCIS only reports CTO PCI undertaken in

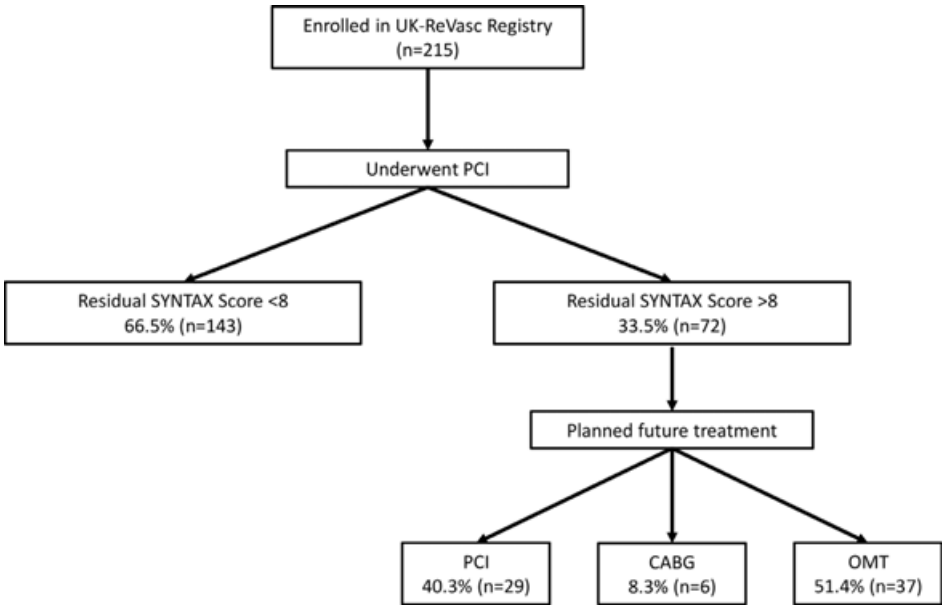

FIGURE 1 Revascularisation and future treatment plans of ReVR patients. CABG, coronary artery bypass grafting; OMT, optimal medical therapy; PCI, percutaneous coronary intervention

TABLE 2 Procedural characteristics

	ReVR	BCIS	*P*-value
Transradial access-% (n)	93.3 (210/225[a])	88.6 (52 723/59 484)	.03
Complete revascularisation-% (n)	51.6 (111/215)	57.3 (26 164/45 671)	.09
Residual SYNTAX score			
• Incomplete revascularisation-mean (SD)	15.7 (9.1)	NA	
Image-guided PCI-% (n)	43.6 (98/225)	14.4 (7835/54 517)	<.001
• IVUS-% (n)	40.9 (92/225)	11.2 (6085/54 517)	<.001
• OCT-%	2.7 (6/225)	3.3 (1817/54 517)	.58
Calcium modification-% (n)	23.6 (53/225)	3.5 (2123/60 520)	<.001
• Rotational atherectomy-% (n)	14.2 (32/225)	3.4 (2054/60 520)	<.001
• Intravascular lithotripsy-% (n)	8.9 (20/225)	NA	
• Laser atherectomy-% (n)	0.4 (1/225)	0.1 (81/60 520)	.26
CTO PCI performed-% (n)	13.8 (31/225)	NA	
• Stable-% (n)	16.4 (9/55)	11.9 (3357/28 204)	.31
• NSTE-ACS-% (n)	12.9 (22/170)	NA	
CTO PCI success-% (n)	96.8 (30/31)	NA	
Mechanical circulatory support-% (n)	0.9 (2/225)	NA	
PCI success-% (n)	94.2 (212/225)	90.5 (54 452/60 171)	.06

Abbreviations: CTO, chronic total occlusion; IVUS, intravascular ultrasound; OCT, optical coherence tomography; NA, not available; PCI, percutaneous coronary intervention.
[a]Total number of procedures (n = 225), 10 patients underwent two procedures.

stable patients, no differences were observed as compared to our ReVR stable cohort (16.4% vs 11.9%, *P* = .31).

Imaging, mostly intravascular ultrasound, to guide PCI success in ReVR was higher than in the BCIS reference cohort (43.6% vs 14.4%, *P* < .001). Calcium modification was undertaken in 23.6% of cases (vs 3.5% in BCIS, *P* < .001), with greater rotational atherectomy use than recorded in the BCIS comparator group (14.2% vs 3.4%, *P* < .001). Two procedures (0.9%) were performed with the use of mechanical circulatory support (both intra-aortic balloon pump). PCI success was high in ReVR patients at 94.2% and compares well with the BCIS figure of 90.5% (*P* = .06).

3.3 | In-hospital outcomes

The in-hospital outcomes for ReVR cases and reference data from BCIS and NCAP are displayed in Table 3. Data according to the mode of presentation are presented in Table 4.

TABLE 3 In-hospital outcomes of total ReVR cohort

Outcomes	ReVR	BCIS	*P*-value	Isolated CABG (n = 14 527)	*P*-value
Death-% (n)	1.4 (3/215)	0.7 (423/61 147)	.19	1.0 (144/14 527)	.48
Myocardial infarction-% (n)	0.4 (1/215)	0.2 (161/88 184)	.32	NA	
Heart failure-% (n)	0.0 (0/215)	NA		NA	
Stroke-% (n)	0.0 (0/215)	0.04 (35/88 184)	[a]	0.6 (89/14 527)	.64
Unplanned revascularisation-% (n)	0.4 (1/215)	0.3 (165/62 366)	.57	NA	
Stent thrombosis-% (n)	0.5 (1/215)	NA			
Bleeding (BARC 3-5)-% (n)	0.0 (0/215)	0.1 (44/41 473)	[a]	2.6 (373/14 527)	.007
Length of stay-median (IQR), (days)	3.0 (1.0-7.0)	1.0 (0.0–4.0)		6.0	
Day case PCI-% (n)	15.8 (36/228)	37.8 (20 688/54 719)	<.001		

Abbreviations: BCIS, British Cardiovascular Intervention Society; CABG, coronary artery bypass grafting; NA, not available; PCI, percutaneous coronary intervention.
[a]Statistical comparisons not performed due to small numbers.

TABLE 4 In-hospital outcomes of ReVR cohort according to mode of presentation

Outcomes	ReVR (stable) (n = 54)	BCIS (stable)	*P*-value	ReVR (NSTE-ACS) (n = 161)	BCIS (NSTE-ACS)	*P*-value
Death-%	0.0 (0/54)	0.16 (45/28 223)	1[a]	1.9 (3/161)	1.1 (378/32 924)	.44a
Myocardial infarction-% (n)	0.0 (0/54)	0.2 (52/28 533)	1[a]	0.6 (1/161)	0.2 (109/59 651)	.26a
Heart failure-% (n)	0.0 (0/54)	NA		0.6 (1/161)	NA	
Stroke-% (n)	0.0 (0/54)	0.03 (9/28 533)	1[a]	0.0 (0/161)	0.04 (26/59 651)	[b]
Unplanned revascularisation-% (n)	0.0 (0/54)	0.22 (64/28 533)	1[a]	0.6 (1/161)	0.3 (101/33 833)	.38a
Stent thrombosis-% (n)	0.0 (0/54)	NA		0.6 (2/161)	NA	
Bleeding (BARC 3-5)-% (n)	0.0 (0/54)	0.08 (16/19 028)	1[a]	0.0 (0/161)	0.1 (28/22 445)	[b]
Length of stay-median (IQR), (days)	0.0 (0.0-1.0)	0.0 (0.0-1.0)		4.0 (2.0–9.0)	2.7 (1.5-4.7)	
Day case PCI-% (n)	53.7 (29/54)	71.0 (19 608/27 607)	.005	4.3 (7/161)	4.0 (1080/27 112)	.81

Abbreviations: BARC, Bleeding Academic Research Consortium; BCIS, British Cardiovascular Intervention Society; PCI, percutaneous coronary intervention.
[a]Fisher's exact test; NA, not available.
[b]Statistical comparisons not performed due to small numbers.

In-hospital outcomes for the ReVR cohort (stable and NSTE-ACS) compare favorably with the isolated CABG reference data. Specifically, mortality was 1.4% for ReVR and 1.0% for the surgical group ($P = .48$). No differences in stroke were observed, yet higher rates of BARC 3-5 major bleeding were seen in the CABG cohort (0.0% vs 2.6%, $P = .007$). Median length of stay in ReVR patients was shorter than in the surgical cohort (3.0 vs 6.0 days).

In ReVR, MACE was rare and associated with a NSTE-ACS presentation. There were no in-hospital events in the ReVR stable cohort but significantly fewer were treated as a day case compared to the BCIS reference population (53.7% vs 71.0%, $P = .005$). In the NSTE-ACS cohort, event rates between the two groups were low and similar. Statistical testing for interaction should be treated with caution because of small numbers.

3.4 | 30-day outcomes

30-day outcomes in the ReVR group are displayed in Table 5. There was one further death and one stroke within 30-day follow-up. Five patients were readmitted to hospital – four for anginal symptoms (all of which were subsequently controlled with medical therapy), and one for the aforementioned stroke. As the BCIS audit only captures in-hospital outcomes, we do not have 30-day data for statistical comparisons.

4 | DISCUSSION

The ReVR was a UK multicenter prospective registry that investigated the short-term outcomes of a novel cohort of patients with "surgical" CAD who would under normal circumstances be treated with CABG, but instead underwent PCI. When compared to historical PCI and isolated CABG reference groups, no significant differences in outcomes to hospital discharge were demonstrated other than a reduction in BARC 3-5 bleeding versus the CABG cohort. Low-event rates at 30-day follow-up were also observed in ReVR patients. Although small numbers of outcomes were recorded, our data suggest contemporary PCI techniques offer an alternative revascularisation strategy that enables complex CAD patients to be safely discharged from hospital.

TABLE 5 ReVR 30-day outcomes

Outcomes	ReVR (n = 215)
Death-% (n)	1.9 (4/215)
Myocardial infarction-% (n)	0.5 (1/215)
Heart failure-% (n)	0.0 (0/215)
Stroke-% (n)	0.5 (1/215)
Unplanned revascularisation-% (n)	0.5 (1/215)
Stent thrombosis-% (n)	0.5 (1/215)
Bleeding (BARC 3–5)-% (n)	0.0 (0/215)
Readmission for any cause-% (n)	2.3 (5/215[a])

Abbreviation: BARC, Bleeding Academic Research Consortium.
[a]1 admission for stroke, 4 admissions for recurrent angina.

4.1 | Revascularisation in patients with complex CAD: PCI vs CABG

Our findings support that patients enrolled in ReVR would ordinarily have received surgical treatment were it not for COVID-19 and the repurposing of healthcare resources. High rates of LMS involvement (52.8%), MVD (96.6%), LAD involvement (94.8%), and a mean SS of 28.0 indicate a group with more complex and higher-risk coronary anatomy, generally considered a pattern of disease best treated with CABG.[7,12] The elevated incidence of diabetes in our cohort (34.4% vs 26.4%, $P = .008$ when compared to BCIS) further supports this notion, since the FREEDOM trial demonstrated superiority of CABG over PCI in patients with MVD plus diabetes.[13] Moreover, where the robustly validated SYNTAX II Score[14] was calculated in our ReVR patients (n = 202), predicted mean 4-year mortality following PCI was higher than that following CABG (14.2% vs 10.5%).

While 25.1% of ReVR patients were considered stable and on a surgical waiting list (but treatment likely expedited due to high-risk anatomy or refractory symptoms), 74.9% required urgent revascularisation due to presentation with NSTE-ACS, a figure significantly higher than our historical BCIS reference cohort (74.9% vs 56.0%, $P < .001$). As elective PCI for chronic coronary syndromes reduced by up to 66% due to widespread postponement of routine services during the COVID-19 first wave,[15] our cohort includes a greater proportion of acute patients who underwent urgent coronary angiography as part of routine care for NSTE-ACS. The reduction in subsequent cardiovascular death or MI from early inpatient revascularisation in this group is well established, with effects greatest in those with high-risk features such as biomarker elevation.[5,6] However, in meta-analyses of these comparisons, patients treated with CABG comprised nearly 40% of the total cohort, a treatment largely unavailable during the ReVR study period.

The 2018 European Guidelines on Myocardial Revascularisation recommend consideration of either PCI or CABG for LMS disease >50%, proximal LAD disease >50%, and 2 or 3-vessel disease >50% with impaired left ventricular ejection fraction (≤35%) to improve prognosis.[16] While acknowledging the role of the heart team and patient preference, recommendations for CABG over PCI are made in these guidelines for those patients with diabetes, or MVD with SS >23.[16] Our ReVR cohort, with high rates of diabetes and complex disease (mean SS 28.0, including a majority with LMS disease), were indeed appropriate for revascularisation and furthermore fulfilled criteria indicated dominance for CABG, which in these circumstances is given a Class 1A recommendation.[16]

Moreover, guidelines recommend that CR is prioritized in these patient groups to minimize residual ischaemia. This assertion is largely based on observational data and post hoc analyses of randomized trials that, when compiled in a large meta-analysis of nearly 90 000 patients, demonstrate a reduction in long-term mortality regardless of treatment modality (RR 0.71, 95% CI 0.65-0.77, $P < .001$).[17] Risk stratification by calculating rSS is also recommended as a rSS of >8 is associated with significantly increased 5-year mortality risk, while scores >0 increase the risk of repeat revascularisation.[18] In ReVR, although we achieved CR rates approaching those in the original SYNTAX study (51.6% vs 56.7%), in 38.7% of ICR patients future staged procedures were planned. These data suggest that the initial focus was to achieve a level of revascularisation to enable safe discharge from hospital during the COVID-19 first wave. Thus, the final rates of CR (and whether ICR was associated with excess events or repeat revascularisation) will not be known until longer-term follow-up and comparison of these groups is performed.

4.2 | Outcomes in ReVR

In our ReVR cohort, higher rates of transradial access (93.3% vs 88.6%, $P = .02$), calcium modification techniques (23.6% vs 3.5%, $P < .001$) and image-guided PCI (43.6% vs 14.4%, $P < .001$) were associated with equivalent short-term outcomes as compared to pre-COVID-19 data. Indeed, rates of in-hospital MACE of 2.8% (6/215) in ReVR compare favorably to the historic SYNTAX study (in-hospital MACE 4.4% in PCI arm, 5.4% in CABG arm);[7] however, it must be acknowledged that first generation pacliataxel-eluting stents and increased of femoral access was utilized in SYNTAX.ReVR 30-day MACE outcomes of 3.7% (8/215) are numerically lower as compared to the NOBLE trial (30-day MACE 4.9% in PCI arm, 6.6% in CABG arm) that used second generation sirolimus-eluting stents.[12] Furthermore, use of mechanical circulatory support (MCS) in ReVR was low (0.9%). Our data suggest it is therefore possible to safely perform the majority of these complex cases without MCS, given the lack of randomized data that demonstrate improved outcomes in complex high-risk PCI.[19]

It should be acknowledged that similarly complex cases are taken on for PCI if surgical risk is prohibitive during normal times in order to facilitate safe discharge from hospital. Therefore, in patients with complex CAD these data support this approach and suggest that PCI may be considered in cohorts traditionally deemed only suitable for CABG.

4.3 | Limitations

Due to the design of the study, some findings may be subject to selection bias. All cases were investigator reported and not centrally adjudicated. However, participating centers are familiar with systematic data collection for national BCIS audit purposes and should be considered accurate. We only report 30-day outcomes—collection of longer-term events and need for repeat procedures will be essential and is planned. While the number of patients enrolled in ReVR is relatively small and few events were observed, the statistical analyses are robust and significant differences exist in demographics, procedural variables, and outcomes as compared with robust national BCIS data that, while not independently adjudicated, are subject to data validation cycles that underpin public reporting of operator outcomes. These data are thus scrutinized carefully by the submitting centers who are responsible for correcting any errors identified. Furthermore, since BCIS does not collect SS data, our comparisons for anatomical complexity of CAD between groups were limited. However, the higher rates of calcium modification techniques, multi-vessel and LMS PCI in ReVR suggest increased complexity relative to the BCIS cohort.

5 | CONCLUSION

During the first wave of the COVID-19 pandemic, in patients normally regarded as surgical candidates, PCI undertaken using contemporary techniques with high rates of intravascular imaging and calcium modification provides equivalent acute results to historical CABG reference data, and to PCI reference cohorts of lower complexity. Longer-term follow-up of this novel cohort is planned and may help to inform current discussions between patients and clinicians regarding optimal revascularisation strategies.

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CONFLICT OF INTEREST

The authors report no relevant disclosures.

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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REFERENCES

1. NHS England. Next steps on NHS response to COVID-19: Letter from Sir Simon Stevens and Amanda Pritchard. 2020.
2. Mohamed Abdel Shafi A, Hewage S, Harky A. The impact of COVID-19 on the provision of cardiac surgical services. J Card Surg. 2020;35:1295-1297.
3. Harky A, Harrington D, Nawaytou O, et al. COVID-19 and cardiac surgery: the perspective from United Kingdom. J Card Surg. 2020. https://doi.org/10.1111/jocs.15039. [Epub ahead of print].
4. Yusuf S, Zucker D, Peduzzi P, et al. Effect of coronary artery bypass graft surgery on survival: overview of 10-year results from randomised trials by the coronary artery bypass graft surgery trialists collaboration. Lancet. 1994;344:563-570.
5. Bavry AA, Kumbhani DJ, Rassi AN, Bhatt DL, Askari AT. Benefit of early invasive therapy in acute coronary syndromes: a meta-analysis of contemporary randomized clinical trials. J Am Coll Cardiol. 2006;48:1319-1325.
6. Fox KAA, Clayton TC, Damman P, et al. Long-term outcome of a routine versus selective invasive strategy in patients with non-ST-segment elevation acute coronary syndrome a meta-analysis of individual patient data. J Am Coll Cardiol. 2010;55:2435-2445.
7. Serruys PW, Morice MC, Kappetein AP, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med. 2009;360:961-972.
8. Genereux P, Palmerini T, Caixeta A, et al. Quantification and impact of untreated coronary artery disease after percutaneous coronary intervention: the residual SYNTAX (synergy between PCI with taxus and cardiac surgery) score. J Am Coll Cardiol. 2012;59:2165-2174.
9. Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction (2018). Eur Heart J. 2019;40(3):237–269.
10. Hicks KA, Mahaffey KW, Mehran R, et al. 2017 cardiovascular and stroke endpoint definitions for clinical trials. Circulation. 2018;137:961-972.
11. Mehran R, Rao SV, Bhatt DL, et al. Standardized bleeding definitions for cardiovascular clinical trials: a consensus report from the bleeding academic research consortium. Circulation. 2011;123:2736-2747.
12. Makikallio T, Holm NR, Lindsay M, et al. Percutaneous coronary angioplasty versus coronary artery bypass grafting in treatment of unprotected left main stenosis (NOBLE): a prospective, randomised, open-label, non-inferiority trial. Lancet. 2016;388:2743-2752.
13. Farkouh ME, Domanski M, Sleeper LA, et al. Strategies for multivessel revascularization in patients with diabetes. N Engl J Med. 2012;367:2375-2384.
14. Farooq V, van Klaveren D, Steyerberg EW, et al. Anatomical and clinical characteristics to guide decision making between coronary artery bypass surgery and percutaneous coronary intervention for individual patients: development and validation of SYNTAX score II. Lancet. 2013;381:639-650.
15. Kwok CS, Gale CP, Curzen N, et al. Impact of the COVID-19 pandemic on percutaneous coronary intervention in England: insights from the British cardiovascular intervention society PCI database cohort. Circ Cardiovasc Interv. 2020;13:e009654.
16. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J. 2019;40:87-165.
17. Garcia S, Sandoval Y, Roukoz H, et al. Outcomes after complete versus incomplete revascularization of patients with multivessel coronary artery disease: a meta-analysis of 89,883 patients enrolled in randomized clinical trials and observational studies. J Am Coll Cardiol. 2013;62:1421-1431.
18. Farooq V, Serruys PW, Bourantas CV, et al. Quantification of incomplete revascularization and its association with five-year mortality in

the synergy between percutaneous coronary intervention with taxus and cardiac surgery (SYNTAX) trial validation of the residual SYNTAX score. Circulation. 2013;128:141-151.
19. O'Neill WW, Kleiman NS, Moses J, et al. A prospective, randomized clinical trial of hemodynamic support with Impella 2.5 versus intra-aortic balloon pump in patients undergoing high-risk percutaneous coronary intervention: the PROTECT II study. Circulation. 2012;126:1717-1727.

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