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Outcomes of Percutaneous Coronary Intervention Performed at Offsite Versus Onsite Surgical Centers in the United Kingdom

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ABSTRACT

BACKGROUND Percutaneous coronary intervention (PCI) is increasingly being performed at centers with offsite surgical support. Strong guideline endorsement of this practice has been lacking, in part because outcome data are limited to modest-size populations with short-term follow-up.

OBJECTIVES The aim of this study was to compare the outcomes of PCI performed at centers with and without surgical support in the United Kingdom between 2006 and 2012.

METHODS A retrospective analysis was performed of centrally tracked outcomes from index PCI procedures entered in the British Cardiovascular Intervention Society database between 2006 and 2012, stratified according to whether procedures were performed at centers with onsite or offsite surgical support. The primary endpoint was 30-day all-cause mortality, with secondary endpoints of mortality at 1 and 5 years.

RESULTS Outcomes at a median of 3.4 years follow-up were available for 384,013 patients, of whom 31% (n = 119,096) were treated at offsite surgical centers. In an unadjusted analysis, crude mortality rates were lower in patients treated at centers with offsite versus onsite surgical coverage (2.0% vs. 2.2%; $p < 0.001$). On multivariate adjustment, there were no between-group differences in survival between the naive and imputed populations at 30 days (naive population hazard ratio [HR]: 0.87; 95% confidence interval [CI]: 0.71 to 1.06; $p = 0.16$; imputed population HR: 0.99; 95% CI: 0.89 to 1.09; $p = 0.82$), 1 year (naive population HR: 0.92; 95% CI: 0.79 to 1.07; $p = 0.26$; imputed population HR: 0.99; 95% CI: 0.92 to 1.06; $p = 0.78$), or 5 years (naive population HR: 0.92; 95% CI: 0.84 to 1.01; $p = 0.10$; imputed population HR: 0.97; 95% CI: 0.92 to 1.03; $p = 0.29$). Results were consistent irrespective of procedural indication. No differences in mortality were seen in sensitivity analyses performed using a propensity-matched population of 74,001 patients.

CONCLUSIONS PCI performed at centers without onsite surgical backup is not associated with any mortality hazard. (J Am Coll Cardiol 2015;66:363–72) © 2015 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

BCIS = British Cardiovascular Intervention Society

CABG = coronary artery bypass grafting

MI = myocardial infarction

NSTEMI = non-ST-segment elevation myocardial infarction

PCI = percutaneous coronary intervention

STEMI = ST-segment elevation myocardial infarction

The site of delivery of percutaneous coronary intervention (PCI) has evolved from provision by interventional cardiology departments with onsite cardiothoracic support to a more geographically widespread service, including centers without onsite cardiothoracic surgery backup. This change has evolved partly through the improved safety of PCI, such that emergency coronary artery bypass grafting (CABG) is required only for rare catastrophic situations. Other potentially influential factors include the geographic expansion of cardiologic services, economic factors, and the popularity of local cardiology services.

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The acceptance of this mode of delivery of PCI has not been universal, and consequently the volume of PCI performed at offsite surgical centers varies worldwide. Data from the U.S. National Cardiovascular Data Registry show that in 2009, only 13% of all PCI centers were offsite surgical centers, accounting for a mere 3% of the total U.S. PCI volume (1). This in part stems from the American College of Cardiology and American Heart Association PCI guidelines, which gave elective PCI at offsite surgical centers a Class III recommendation in 2005 (2) and only a Class IIb (Level of Evidence: B) recommendation in 2011 (3). Primary PCI has had a marginally stronger recommendation (Class IIa). In contrast, the United Kingdom has embraced the use of offsite surgical centers to deliver PCI, with these centers accounting for 63% of PCI institutions and 39% of the total annual PCI volume in 2012 (4). Additional factors driving the uptake in the United Kingdom include the high rates of cardiovascular disease and a national directive to improve revascularization rates after many years of inequitable distribution of service provision, particularly for patients living outside major cities.

Historically, there were concerns that PCI performed without onsite surgical support would lead to inferior outcomes (5) because of staff inexperience, low institutional volume, and the delay in emergency CABG when needed. Data from registries (1), randomized studies (6,7), and meta-analyses (8) have not substantiated these concerns; however, important qualifications within these studies (e.g., small sample size) limit the strength of the conclusions and subsequent guideline recommendations (9).

Since 2005, outcomes from all PCI procedures in the United Kingdom have been recorded in the British Cardiovascular Intervention Society (BCIS) database, and this now includes data from >700,000 patients. Between 2006 and 2012, the number of patients undergoing PCI at offsite surgical centers more than doubled, from approximately 15,000 to >36,000 (4). The aim of this study was to report and compare the outcomes of PCI performed at centers with and without surgical support in the United Kingdom between 2006 and 2012.

METHODS

PATIENT POPULATION. This study is based on a retrospective analysis of data collected in the BCIS database under the auspices of the National Institute for Cardiovascular Outcomes Research. From January to December 2012, a total of 92,445 PCIs were performed, representing a rate of 1,452 per million population at 118 PCI centers. One hundred thirteen variables are recorded for each patient, covering demographics, indications for PCI, procedural details, and outcome data. During the upload of data to the central servers, some range and internal consistency checks are applied. The Medical Research Information Service uses data collected by the Office of National Statistics to undertake mortality tracking. This is facilitated by the use of National Health Service numbers, which provide a unique identifier for any person registered with the National Health Service in England and Wales. Tracked mortality data are not available for the small minority of patients who underwent their procedures in the devolved countries of the United Kingdom (Scotland and Northern Ireland).

The study population comprised all index (first or primary attendance) PCI procedures entered into the BCIS database between January 1, 2006, and December 31, 2012. Patients <20 and >105 years of age were excluded, along with procedures performed outside England or Wales, in view of the absence of tracked mortality data. Records containing missing data regarding the presence or absence of onsite surgical backup were also excluded.

The authors have reported that they have no relationships relevant to the contents of this paper to disclose. Drs. Garg and Anderson contributed equally to this work.
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DEFINITIONS. An offsite surgical center was defined as a PCI institution that did not have cardiothoracic surgery available at the same hospital site or within the same institution. Death was defined as mortality from any cause. Severe renal dysfunction was defined as a history of renal disease and a creatinine level >200 μmol/l or requirement for dialysis. Moderate renal dysfunction was defined as a history of renal disease with a creatinine level <200 μmol/l or a functioning transplant. No renal impairment was defined as no history of renal disease and a creatinine level <200 μmol/l.

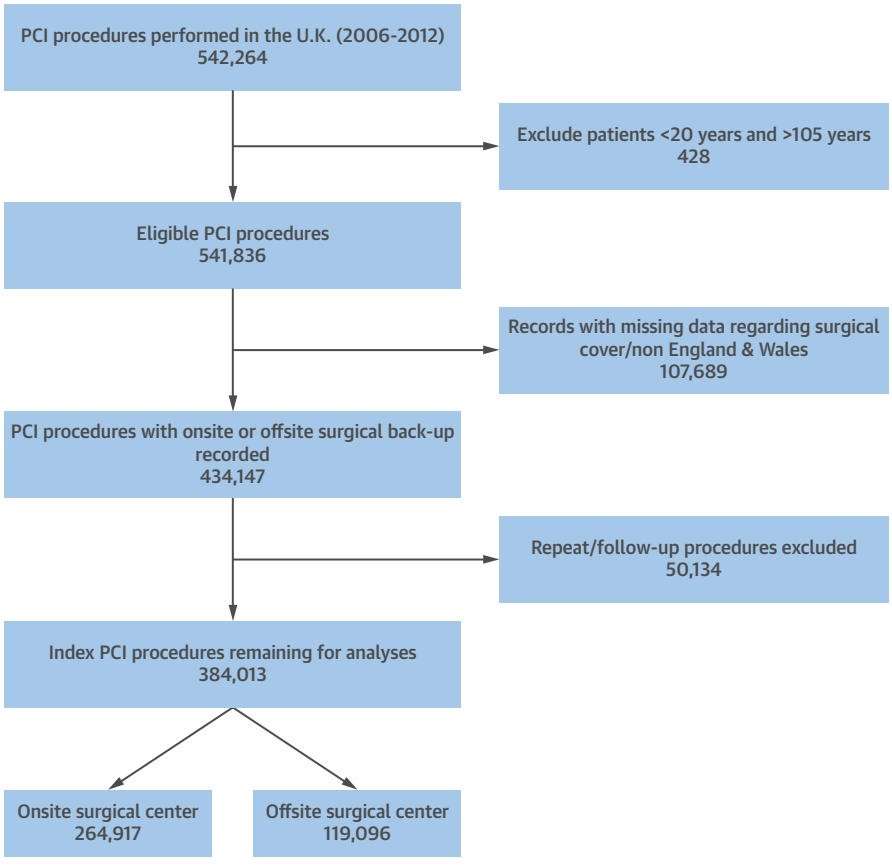
ENDPOINTS. The primary endpoint of the study was 30-day mortality from any cause. Secondary endpoints were all-cause mortality at 1- and 5-year follow-up.

FOLLOW-UP. By using the national mortality database (and without considering those patients who have emigrated from the United Kingdom), we were able to ensure the accuracy of our outcome data and as such had a follow-up rate for our outcome measure of 100% at all time points.

STATISTICAL ANALYSIS. The cohort was stratified into 2 groups according to whether the procedure was performed at a PCI center with onsite or offsite cardiac surgical support. We selected the index procedure when a patient underwent multiple procedures. Continuous variables are presented as means with 95% confidence intervals, and categorical variables are presented as count (percent). We tested for differences between the groups using chi-square tests for nonparametric data and Student *t* test for normally distributed continuous variables.

Estimated hazard ratios for mortality within 30 days, 1 year, and 5 years were determined from Cox regressions with shared-frailty or cluster models on the naive cohort. A shared-frailty model is the survival-data analogue of a regression model with random effects and is used to model within-group correlation. Each PCI center was assigned as a group

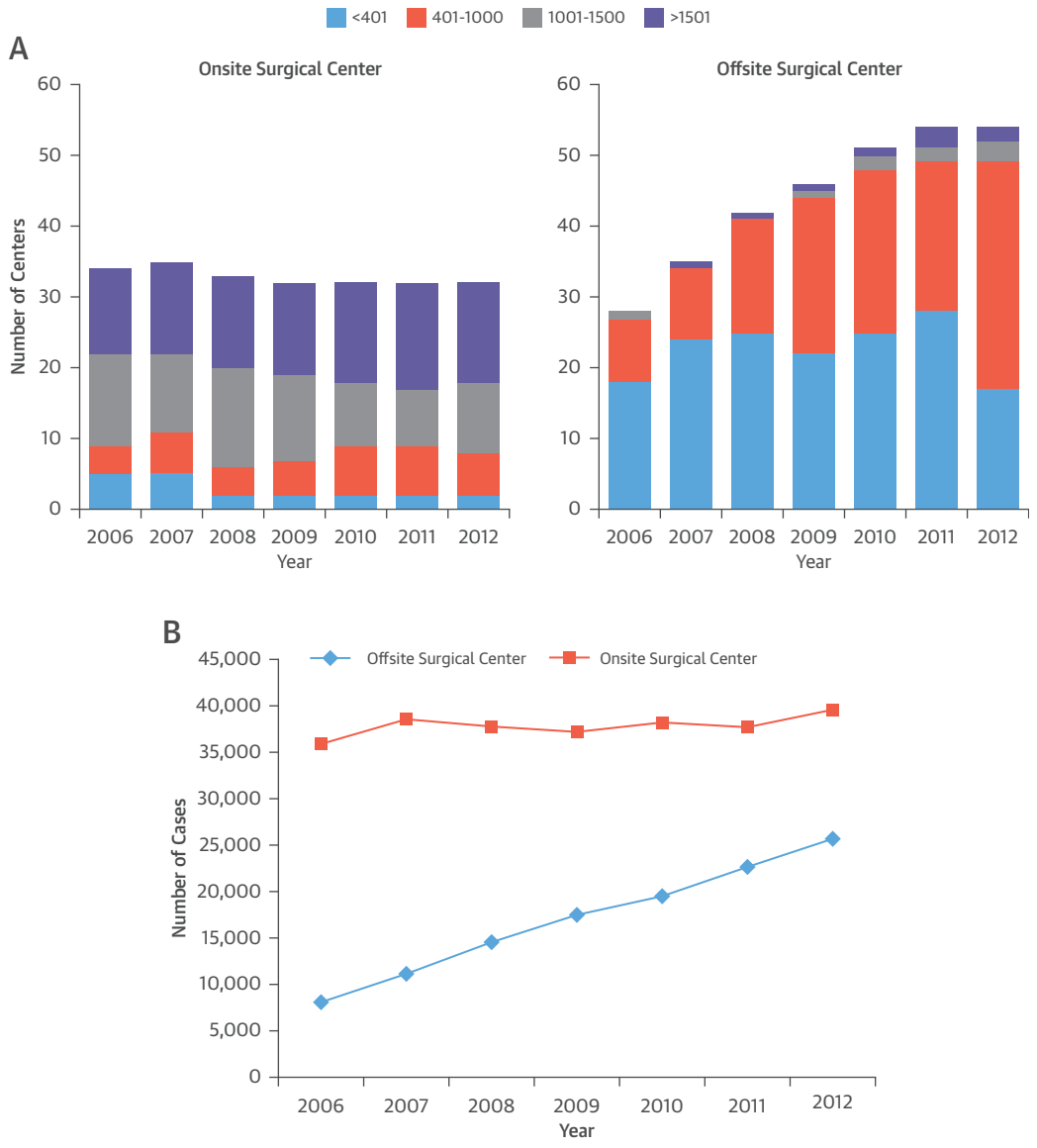
FIGURE 1 Patient Study Flowchart



The study population, composed of approximately 71% of all percutaneous coronary intervention (PCI) procedures carried out in the United Kingdom between 2006 and 2012, with 69% of cases performed at centers with onsite surgical support and 31% at centers without.

variable within the model. In the multivariate models, adjustments were made for potential confounders, including the dichotomized categorical variables (yes vs. no): sex (female vs. male), peripheral vascular disease, valvular heart disease, hypertension, hypercholesterolemia, type 2 diabetes, access site (femoral vs. radial), history of smoking, history of stroke, history of myocardial infarction (MI), history of CABG, Q-wave on electrocardiography, volume of procedures performed (<400 vs. >400 per year), presence of shock pre-procedure, ventilation required, circulatory support, bleeding complication, urgent periprocedural CABG, multivessel disease, and lesion location. Other categorical variables included year of procedure,

FIGURE 2 Temporal Changes in the Number of PCI Centers and Procedural Volume for Onsite and Offsite Centers in the United Kingdom Between 2006 and 2012



(A) The chart illustrates the number of onsite and offsite PCI centers in the United Kingdom between 2006 and 2012, with each **bar** representing the total number of centers in the United Kingdom that year and the slices depicting the numbers of centers with annual PCI case volumes of <401 **(periwinkle)**, 401 to 1,000 **(salmon)**, 1,001 to 1,500 **(grey)**, and >1,500 **(violet)**. The number of onsite centers remained relatively constant, while the number of offsite surgical centers approximately doubled from 28 to 54. **(B)** The **lines** represent the annual volume of PCI procedures performed at onsite and offsite surgical centers over the study period. The absolute increase in PCI volume between 2006 and 2012 was 9.2% for onsite surgical centers and 68.2% for offsite centers.

patient age category (<60, 60 to 69, 70 to 79, or >80 years), procedural indication (ST-segment elevation myocardial infarction [STEMI] or non-ST-segment elevation myocardial infarction [NSTEMI] vs. stable), renal impairment (severe or moderate vs. normal), left ventricular function (good, moderate, poor), and their interaction terms.

Sensitivity analyses to estimate similarly adjusted Cox proportional hazards with shared frailty were performed using 2 separate models. The first was determined from multiple imputations with predictive mean matching to impute missing data. Five imputations were generated. Online Table 1 provides a summary of the variables that were imputed. The second used propensity score matching to further account for confounding and selection bias when estimating causal effects using these observational data. Briefly, a nonparsimonious multivariate logistic regression model was used to compute a propensity score with onsite versus offsite surgical support as the dependent variable, with the following covariates: outcome (alive vs. dead), the Nelson-Aalen estimate of age, sex, peripheral vascular disease, left ventricular ejection fraction, indication for procedure (stable, NSTEMI/unstable angina, or STEMI), hypertension, hypercholesterolemia, type 2 diabetes, access site (femoral vs. radial), history of smoking, history of stroke, renal disease, history of MI, history of PCI, history of CABG, Q-wave on electrocardiography, volume of procedures performed (<400 vs. >400 per year), presence of shock pre-procedure, ventilation required, multivessel disease, and year of procedure, including transformation and their interaction terms. The Hosmer-Lemeshow goodness-of-fit statistic determined for this model was 0.71. Mahalanobis nearest-neighbor matching was performed on the

TABLE 1 Baseline Patient Characteristics by Offsite Versus Onsite Surgical Center

	Total (N = 384,013)	Offsite Surgical Center* (n = 119,096)	Onsite Surgical Center† (n = 264,917)	p Value
Male	280,530/383,203 (73.2)	86,589/118,828 (72.9)	193,941/264,375 (73.4)	0.002
Age, yrs	64.7 (64.7-64.8)	66.0 (65.9-66.0)	64.4 (64.3-64.4)	
Diabetes	65,674/363,937 (18.0)	20,341/113,047 (18.0)	45,333/250,945 (18.1)	0.60
Hypertension	185,891/367,937 (50.5)	58,059/114,358 (50.8)	127,832/253,579 (50.4)	0.04
Previous myocardial infarction	90,161/353,737 (25.5)	27,800/112,586 (24.7)	62,361/241,151 (25.9)	<0.001
Smoking status				
Ex-smoker	128,600/330,205 (39.0)	42,825/104,013 (41.2)	85,775/228,192 (37.9)	<0.001
Current smoker	81,753/330,205 (24.8)	22,840/104,013 (22.0)	58,913/228,192 (26.1)	<0.001
Previous PCI	58,017/363,423 (16.0)	19,391/112,217 (17.3)	38,626/251,256 (15.4)	<0.001
Previous CABG	27,958/364,338 (7.7)	8,866/109,535 (8.1)	19,092/254,803 (7.5)	<0.001
Cerebrovascular disease	13,396/367,937 (3.6)	4,664/114,358 (4.1)	8,732/253,579 (3.4)	<0.001
Peripheral vascular disease	16,281/367,937 (4.4)	5,875/114,358 (5.1)	10,406/253,579 (4.1)	<0.001
Renal impairment				
None	347,266/356,547 (97.4)	109,949/113,001 (97.3)	237,317/243,546 (97.4)	1.00
Moderate	6,389/356,547 (1.8)	2,068/113,001 (1.8)	4,321/243,546 (1.8)	1.00
Severe	2,892/356,547 (0.8)	984/113,001 (0.9)	1,908/243,546 (0.8)	1.00
Indication for PCI				
Stable angina	151,083/375,180 (40.3)	48,641/118,240 (41.2)	102,442/256,940 (39.9)	<0.001
NSTEMI	143,671/375,180 (38.3)	50,797/118,240 (43.0)	92,874/256,940 (36.2)	<0.001
STEMI	80,426/375,180 (21.4)	18,802/118,240 (15.9)	61,624/256,940 (24.0)	<0.001
Left ventricular function				
Good (>50%)	130,501/179,173 (72.8)	48,741/112,234 (72.8)	81,760/66,939 (72.9)	1.00
Moderate (30%-49%)	37,416/179,173 (20.9)	13,412/112,234 (20.0)	24,004/66,939 (21.4)	0.002
Poor (<30%)	11,256/179,173 (6.3)	4,786/112,234 (7.2)	6,470/66,939 (5.8)	0.001
Presenting ECG (STEMI and NSTEMI only)				
No changes	27,562/187,270 (14.7)	12,004/63,237 (19.0)	15,558/124,033 (12.5)	<0.001
ST-segment elevation/LBBB	91,254/187,270 (46.7)	24,971/63,237 (39.5)	66,283/124,033 (53.4)	<0.001
ST-segment depression	27,293/187,270 (14.6)	10,865/63,237 (17.2)	16,428/124,033 (13.2)	<0.001
T-wave changes	35,229/187,270 (18.8)	13,400/63,237 (21.2)	21,829/124,033 (17.6)	<0.001
Other	5,932/187,270 (3.2)	1,997/63,237 (3.2)	3,935/124,033 (3.2)	1.00
Q-wave on ECG	43,419/306,681 (14.2)	15,146/105,075 (14.4)	28,273/201,606 (14.1)	0.003

Values are n/N (%) or mean (95% confidence interval). p values from tests on the equality of proportions or chi-square tests for differences in proportions for offsite versus onsite, respectively. *No cardiac surgery present at PCI center. †Cardiac surgery present at PCI center.

CABG = coronary artery bypass grafting; ECG = electrocardiogram; LBBB = left bundle branch block; NSTEMI = non-ST-segment elevation myocardial infarction; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

imputed cohort within a caliper of 0.2 standard deviations of the logit function of propensity scores to create matched groups for onsite versus offsite surgical centers (10). Online Tables 2 and 3 provide a summary of the propensity-matched cohort as well as the calculated standardized Pearson residuals. All analyses were performed using Stata/MP 13.1 statistical software (StataCorp LP, College Station, Texas).

RESULTS

During the study period, 31.0% of the 384,013 index PCI procedures (n = 119,096) were performed at institutions with offsite surgical support (Figure 1). The median follow-up time was 3.4 years (interquartile range: 1.7 to 5.1 years). The temporal changes in the number of PCI centers and procedural volume for onsite and offsite surgical centers between 2006 and 2012 are shown in Figure 2.

PATIENT DEMOGRAPHICS. The baseline patient characteristics are shown in Table 1. The offsite surgical center population was significantly older. In both groups, over one-half the population had hypertension, and nearly two-thirds were current or ex-smokers. Stable angina was the most common indication for PCI over the study period, with a greater proportion treated at offsite than onsite centers, but as shown in Online Table 4, the actual proportion of all PCIs for stable angina decreased from 50.9% in 2006 to 33.8% in 2012. The distribution in the increase of PCI volume for MI over the study period varied according to syndrome, with NSTEMI constituting a significantly higher proportion of the total annual PCI volume at offsite compared with onsite surgical centers (43.0% vs. 36.2%; $p < 0.0001$), with the opposite seen for patients with STEMI.

PROCEDURAL CHARACTERISTICS. Procedural characteristics are reported in Table 2. The radial artery was used for access more often at offsite compared with onsite surgical centers. There were no between-group differences in the proportion of patients requiring mechanical ventilation before PCI or presenting with cardiogenic shock. Offsite centers inserted intra-aortic balloon pumps significantly less frequently (1.5% vs. 1.9%; $p < 0.001$) and performed a significantly lower proportion of multivessel PCI procedures (13.5% vs. 14.1%; $p < 0.001$).

CLINICAL OUTCOMES. Unadjusted all-cause mortality at 30 days (the primary endpoint) occurred in 2,371 patients (2.0%) treated at offsite surgical centers and 5,798 patients (2.2%) treated at onsite surgical centers ($p < 0.001$). Mortality was 0.2% lower at offsite surgical centers at 30 days and 1.2% lower at 5 years (Online Table 5). The absolute differences in unadjusted 30-day mortality rates between offsite and onsite surgical centers for stable angina, NSTEMI, and STEMI were, respectively, 0.1% (offsite 0.3% vs. onsite 0.4%;

TABLE 2 Procedural Characteristics by Offsite Versus Onsite Surgical Center

	Total (N = 384,013)	Offsite Surgical Center (n = 119,096)	Onsite Surgical Center (n = 264,917)	p Value
Shock pre-procedure	7,283/355,869 (2.0)	2,301/113,115 (2.0)	4,982/242,754 (2.0)	0.72
Multivessel attempted (>1)*	53,459/384,013 (13.9)	16,028/119,096 (13.5)	37,431/264,917 (14.1)	<0.001
Vessel attempted				
Left main stem	4,103/368,162 (1.1)	951/115,347 (0.8)	3,152/252,815 (1.2)	0.27
Left anterior descending	178,392/368,162 (48.4)	57,127/115,347 (49.5)	121,265/252,815 (48.0)	<0.001
Left circumflex	66,496/368,162 (18.1)	21,565/115,347 (18.7)	44,931/252,815 (17.8)	0.004
Right coronary artery	106,471/368,162 (28.9)	33,284/115,347 (28.9)	73,187/252,815 (28.9)	1.00
Coronary artery bypass graft	12,700/368,162 (3.4)	2,420/115,347 (2.1)	10,280/252,815 (4.1)	<0.001
Antithrombotic agent used				
Heparin only	284,466/384,013 (74.0)	89,085/119,096 (74.8)	195,381/264,917 (73.8)	<0.001
Heparin + GPI	89,283/384,013 (23.3)	26,550/119,096 (22.3)	62,733/264,917 (23.7)	<0.001
Bivalirudin	10,264/384,013 (2.7)	3,461/119,096 (2.9)	6,803/264,917 (2.6)	0.31
Any circulatory support	7,441/350,792 (2.1)	2,039/112,294 (1.8)	5,402/238,498 (2.3)	<0.001
IABP use	6,318/350,792 (1.8)	1,676/112,294 (1.5)	4,642/238,498 (1.9)	<0.001
Inotrope use	2,919/350,792 (0.6)	950/112,294 (0.7)	1,969/238,498 (0.7)	0.96
Access site				
Femoral	206,668/362,479 (57.0)	62,531/112,072 (55.8)	144,137/250,407 (57.6)	<0.001
Radial	155,811/362,479 (43.0)	49,541/112,072 (44.2)	106,270/250,407 (42.4)	<0.001
Ventilated	4,471/324,449 (1.4)	1,510/109,336 (1.4)	2,961/215,113 (1.4)	0.92
Referral for emergency CABG	289/370,143 (0.08)	46/115,402 (0.04)	243/254,741 (0.1)	<0.001

Values are n/N (%). p values from tests on the equality of proportions or chi-square tests for differences in proportions for offsite versus onsite, respectively. *No grafts included.

CABG = coronary artery bypass grafting; GPI = glycoprotein IIb/IIIa inhibitor; IABP = intra-aortic balloon pump.

p < 0.001), 0.1% (1.6% vs. 1.7%; p = 0.37), and 1.4% (7.3% vs. 5.9%; p < 0.001). Minimal temporal change was observed in these differences between 2006 and 2012 (**Figure 3**). Unadjusted Kaplan-Meier survival curves are shown in **Central Illustration**.

Multivariate adjustment to account for confounders resulted in no significant between-group differences in hazard ratios for mortality, irrespective of procedural indication, at 30 days, 1 year, and 5 years among the naive and imputed populations (**Figure 4**). These comparable rates of survival, irrespective of procedural indication or follow-up duration, were confirmed in sensitivity analyses of a propensity-matched cohort, totaling 74,001 patients, with 37,391 and 36,610 patients from offsite and onsite surgical centers, respectively (**Figure 4**, Online Figure 1).

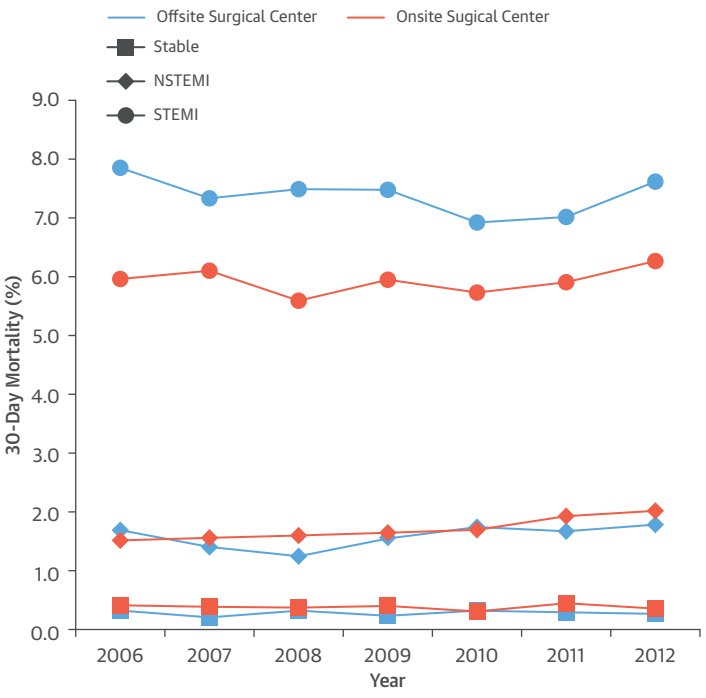
DISCUSSION

This study confirms that there is no association between survival and whether PCI is performed at a center with or without onsite surgical support. Historical unease with PCI performed at these centers has been based on concerns regarding safety (11), particularly in the event of PCI complications necessitating bailout with immediate cardiac surgery. Despite operators dealing with increasingly complex coronary artery disease, rates of emergency CABG have fallen from close to 3% (12) in the pre-stent era, when acute vessel occlusion was not an infrequent complication after balloon angioplasty, to <0.3%. Importantly, the meta-analysis of previous studies confirms comparable rates of emergency cardiac surgery between onsite and offsite centers when performing nonprimary PCI, while significantly lower rates have been observed at offsite centers when performing primary PCI (8). In the present study, <0.1% of the approximately 400,000 PCI procedures resulted in bailout cardiac surgery, and although a significantly lower rate was observed at offsite centers, this must be interpreted with caution considering the low absolute numbers and the inability to account for case selection in terms of which patients operators referred for surgery and which patients surgeons accepted.

Despite the diminished requirement for urgent cardiac surgery, acceptance and hence the volume of PCI at offsite surgical centers varies worldwide. This is due in part to country-specific factors such as health economics, procedural reimbursement, and population density; however, the lack of robust data has prevented strong endorsement by guideline committees (3), which have given elective and primary PCI respective Class IIb and Class IIa recommendations, both at Level of Evidence: B. Prior studies of PCI performed at offsite surgical centers are limited to 2 well-conducted randomized studies, which both excluded patients requiring primary PCI and high-risk features such as poor left ventricular function (6,7), and numerous retrospective observational studies (1,5,9,13), all of which included only modest populations in the offsite surgery group. A meta-analysis of these registries by Singh et al. (8) showed no differences in in-hospital mortality between the 124,074 patients treated with primary PCI for STEMI and the 914,288 patients undergoing nonprimary PCI. Although these represent respectable sample sizes, only 13.3% (n = 16,428) of the primary PCI and 3.3% (n = 30,423) of the nonprimary PCI population were actually treated at offsite surgical PCI centers.

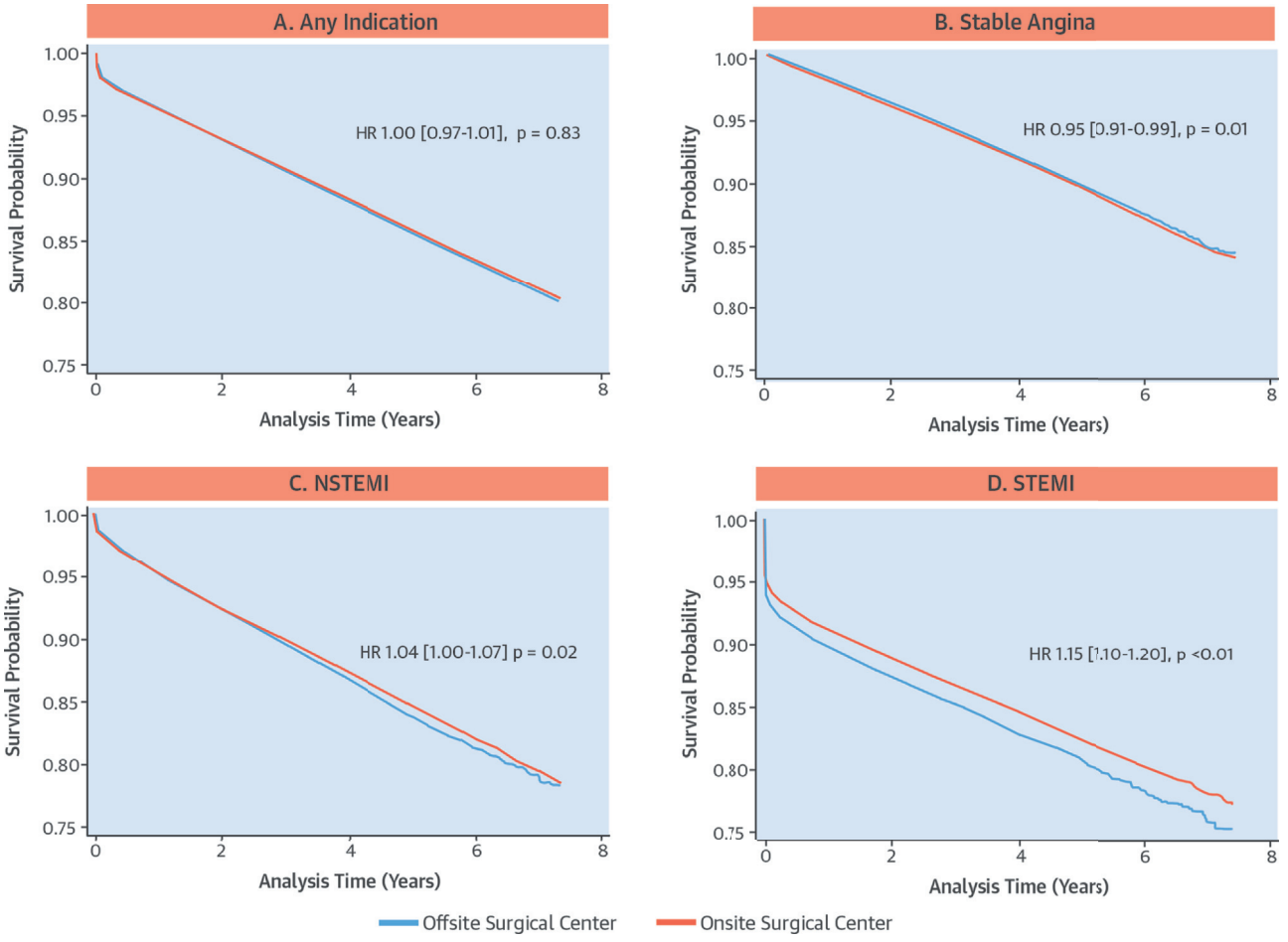
In comparison, the present study reports tracked long-term mortality from >18,000 primary PCI procedures and approximately 100,000 nonprimary PCI procedures performed at offsite surgical centers, representing the largest reported offsite PCI population to date. Although unadjusted survival rates were comparable for the whole population, significant

FIGURE 3 **30-Day Mortality According to Indication for Patients Undergoing PCI at Onsite and Offsite Surgical Centers in the United Kingdom Between 2006 and 2012**



The chart shows minimal change in the rates of 30-day mortality between 2006 and 2012 for patients treated for stable angina, non-ST-segment elevation myocardial infarction (NSTEMI), and ST-segment elevation myocardial infarction (STEMI) at onsite and offsite surgical centers. PCI = percutaneous coronary intervention.

CENTRAL ILLUSTRATION **PCI in Offsite Versus Onsite Surgical Centers: All-Cause Mortality at Long-Term Follow-Up**

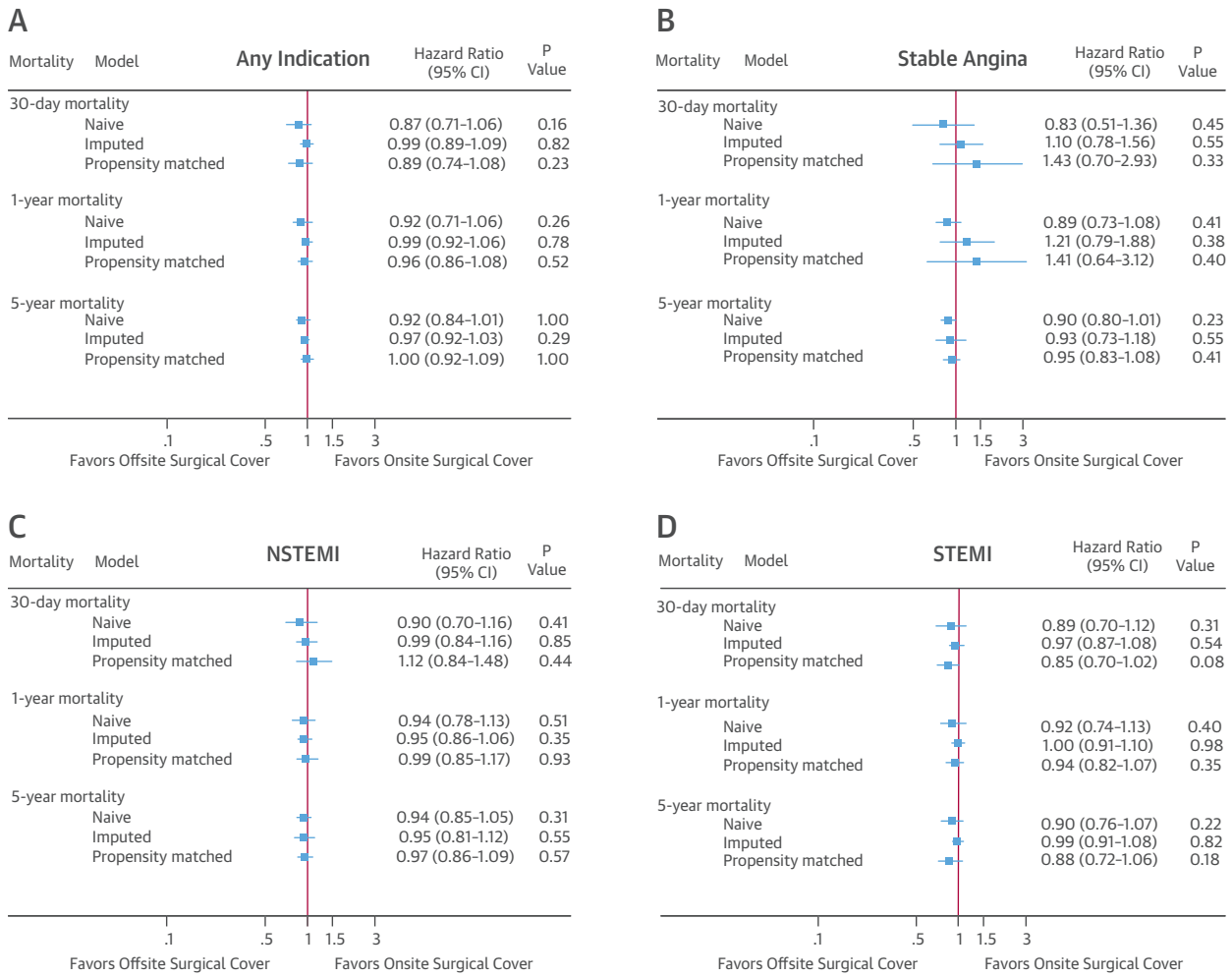


Garg, S. et al. J Am Coll Cardiol. 2015; 66(4):363–72.

The unadjusted Kaplan-Meier survival curves indicate no significant differences in survival between onsite and offsite surgical centers for the pooled population (HR: 1.00; 95% CI: 0.97 to 1.01; p = 0.83); however, increased survival was seen for patients treated for stable angina in centers with offsite surgical support (HR: 0.95; 95% CI: 0.91 to 0.99; p = 0.01), while poorer survival was noted for patients treated for NSTEMI (HR: 1.04; 95% CI: 1.00 to 1.07; p = 0.02), and STEMI (HR: 1.15; 95% CI: 1.10 to 1.20; p < 0.01). CI = confidence interval; HR = hazard ratio; NSTEMI = non–ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction.

differences in survival existed between onsite and offsite populations when dissecting outcomes according to indication. Extensive multivariate analyses and sensitivity analyses of a propensity-matched cohort were performed to minimize the influence of the numerous potential confounders, but some variables could not be taken into consideration. For example, operators practicing at both types of institutions may preferentially perform PCI on high-risk patients at onsite surgical centers because of the close proximity of an operating room. Furthermore, although a rudimentary assessment of the complexity of coronary artery disease has been recorded, quantitative assessments known to have direct correlations with outcomes, such as the SYNTAX score, have not (14,15). Despite these limitations, the comparable outcomes seen in the propensity-matched cohort, and in the multivariate analysis of the naive, imputed, and propensity-matched groups seen irrespective of the indications for PCI are important data to support the current provision of PCI at these centers, while helping remove future barriers to the development of this mode of delivering PCI through more reassuring guideline recommendations.

FIGURE 4 Forest Plots Showing Hazard Ratios For All-Cause Mortality at 30-Days, 1-Year, and 5-Years Follow-Up for Naive, Imputed, and Propensity-Matched Populations



The forest plots show the absence of any significant differences in hazard ratios for all-cause mortality among the naive, imputed, and propensity-matched populations at 30-days, 1-year, and 5-year follow-up for patients in onsite or offsite surgical centers receiving percutaneous coronary intervention for **(A)** any indication; **(B)** stable angina; **(C)** NSTEMI and **(D)** STEMI. The **lines** represent the 95% confidence intervals and the **boxes** are centered on the hazard ratios. Abbreviations as in Figure 3.

Ensuring the safety of PCI is paramount for all institutions, and consistent with recommendations from the joint Society for Cardiovascular Angiography and Interventions, American College of Cardiology Foundation, and American Heart Association consensus document on PCI with onsite surgical backup (16), the BCIS requires all U.K. PCI centers without surgical backup to have written agreements in place from local cardiothoracic institutions to provide assistance in the event of need, together with written protocols to ensure rapid emergency transfers (17). Importantly, both documents reiterate the importance of appropriate case selection, particularly in elective patients treated at PCI centers without surgical backup. However, unlike in the United States, there are no formal criteria regarding which patients can or cannot be treated at an offsite PCI center in the United Kingdom. To address this, facilitate suitable dialogue, and ensure that appropriate, patient-directed revascularization is being performed, Web links and video conferencing have been established to enable a heart team discussion with surgeons who are not physically onsite. The marginally stronger recommendation for primary PCI compared with nonprimary PCI at offsite surgical centers (3) illustrates the fine balance between timely revascularization of infarct-related arteries,

which may not be feasible in populations large distances away from onsite surgical centers, and clinical competence at dealing with this higher risk population. In the United Kingdom, the majority of primary PCI procedures are currently delivered at onsite surgical centers, reflecting the relatively recent implementation of the national primary PCI program and local geography, together with the difficulties in achieving the recommended case volume and delivering a 24/7 service due to a limited number of operators (18).

STUDY LIMITATIONS. The main limitations of this study are those inherent to observational studies. Although we used statistical methods to adjust for differences in baseline characteristics, we were unable to adjust for those variables not collected in the database. In addition, the study does not report other outcome measures, such as repeat revascularization, recurrent MI, completeness of revascularization, or adherence to guideline-recommended medical therapy. Finally, demographic and outcome data of patients presenting to offsite PCI centers who were then transferred for PCI at onsite centers are not available.

CONCLUSIONS

PCI performed at centers without surgical backup is not associated with any mortality hazard.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: PCI performed at institutions without onsite surgical backup is not associated with a higher risk for mortality.

TRANSLATIONAL OUTLOOK: Additional data from registries in other countries where high proportions of PCI procedures are performed without onsite surgical support will better inform whether any specific patients benefit from procedures performed at centers at which onsite surgical backup is available.

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KEY WORDS elective PCI, offsite surgical support, percutaneous coronary intervention, primary PCI

APPENDIX For supplemental tables and a figure, please see the online version of this article.