

A National Evaluation of Emergency Cardiac Surgery After Percutaneous Coronary Intervention and Postsurgical Patient Outcomes



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There is limited national data regarding emergency cardiac surgery for complications sustained after percutaneous coronary intervention (PCI). This study aimed to examine emergency cardiac surgery after PCI in England and Wales and postsurgical patient outcomes. We analyzed patients in the British Cardiovascular Intervention Society database who underwent PCI between 2007 and 2014 and compared characteristics and outcomes for patients with and without emergency cardiac surgery. A total of 549,303 patients were included in the analysis and 362 (0.07%) underwent emergency cardiac surgery. There was a modest decline in the annual rate of emergency cardiac surgery from 0.09% to 0.06% between 2007 and 2014. Variables associated with emergency cardiac surgery included receipt of circulatory support (Odds ratio (OR) 39.20 95% confidence interval (CI) 27.75 to 55.36), aortic dissection (OR 28.39 95% CI 14.59 to 55.26), coronary dissection (OR 18.50 95% CI 13.60 to 25.18), coronary perforation (OR 7.86 95% CI 4.27 to 14.46), cardiac tamponade (OR 6.77 95% CI 3.13 to 14.66), and on-site surgical cover (OR 2.15 95% CI 1.56 to 2.97). After adjustments, patients with emergency cardiac surgery were at increased odds of 30-day mortality (OR 4.41 95% CI 2.94 to 6.62) and in-hospital major adverse cardiac and cerebrovascular events (OR 1.63 95% CI 1.07 to 2.48). On site surgical cover was independently associated with increased odds of mortality (OR 1.26 95% CI 1.20 to 1.33) following emergency cardiac surgery. In conclusion, emergency cardiac surgery after PCI is a rarely required procedure and in England and Wales there appears to be a decline in recent years. Patients who underwent emergency cardiac surgery have higher risk of adverse outcomes and longer length of hospital stay. © 2020 Elsevier Inc. All rights reserved. (Am J Cardiol 2020;130:24–29)

Percutaneous coronary intervention (PCI) is one of the most commonly performed procedures in hospital.¹ Although PCI has evolved to become a safe procedure with improved training of operators and equipment, there are still complications such as coronary perforations,² coronary dissections,³ and cardiac tamponade.⁴ In some situations where these complications occur, patients may require emergency cardiac surgery. Although several studies have evaluated emergency cardiac surgery after PCI,^{5–7} emergency cardiac surgery has not been previously studied on a national level, particularly in healthcare systems such as the

United Kingdom where not all PCI centers have on site cardiac surgery available. In addition, less is known about which patients are more likely to have emergency cardiac surgery and the magnitude of its association with adverse outcomes. Furthermore, the proportion of patients in surgical compared with nonsurgical centers who have emergency cardiac surgery is unknown and whether the types of patients that have emergency cardiac surgery is different depending on the type of center they are admitted to. We aimed to evaluate the use of emergency cardiac surgery after PCI in a national cohort of patients from England and Wales and study temporal trends, predictors, and clinical outcomes.

Methods

The British Cardiovascular Intervention Society (BCIS) collects information on 99% of all PCI procedures in England and Wales performed in the National Health Service.

We analyzed all patients who underwent PCI in England and Wales between January 2006 to December 2014, on the BCIS database. We then classified participants as those who had in-hospital emergency cardiac surgery and those who did not have emergency cardiac surgery. Patients were excluded if they had missing values for mortality and emergency cardiac surgery. Emergency cardiac surgery was

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defined by the variable “PCI Hospital Outcome” in the BCIS dataset which is defined in the data dictionary as “Emergency CABG” which includes any emergency cardiothoracic surgical procedure which could be cardiothoracic (rather than peripheral vascular complications at access sites) and be prompted and indicated by a need to perform emergency revascularization to a coronary distribution that has been the subject of a PCI or attempted PCI and/or to correct as an emergency a complication of PCI such as abrupt vessel closure, cardiac or vessel perforation, dissection of a thoracic great vessel, and so on.⁸ The 2 primary outcomes were 30-day mortality and in-hospital major adverse cardiac and cerebrovascular events (MACCE) defined by re-infarction, re-intervention PCI, death, stroke, and myocardial infarction. Additional data on demographics, co-morbidities, and care received were collected which included age, sex, body mass index, smoking, hypertension, hypercholesterolemia, previous myocardial infarction, previous stroke, peripheral vascular disease, renal disease, valvular heart disease, previous PCI, previous coronary artery bypass graft (CABG), radial access, cardiogenic shock, circulatory support (composite of intraaortic balloon pump and cardiopulmonary support), ventilation, diagnosis of acute coronary syndrome (ACS), glycoprotein IIb/IIIa inhibitor use, clopidogrel use, prasugrel use, ticagrelor use, warfarin use, thrombolysis use, year, length of stay, left main PCI, unprotected left main, rotational atherectomy, cutting balloon use, laser use, surgical cover on site (defined by variable 5.24 “surgical cover”). Additional in-hospital complications of aortic dissection, coronary dissection, coronary perforation, and cardiac tamponade were collected.

Statistical analysis was performed on Stata.MP version 15.0 (Stata Corp, College Station, TX). A flow diagram was used to illustrate the population included in the analysis. Descriptive statistics were presented in a table by in-hospital emergency cardiac surgery. We also evaluated the descriptive statistics according to on-site or off-site surgical cover in patients with emergency cardiac surgery. Rates over time for emergency cardiac surgery were plotted

graphically for the overall cohort as well as by the availability of surgical cover on site. The `npntrend` function on Stata was used to determine if the trend was statically significant. Multiple logistic regression models were used to identify predictors of emergency cardiac surgery and the odds of 30-day mortality and in-hospital MACCE for emergency cardiac surgery compared with no surgery after PCI. Missing values for variables were imputed using multiple imputations with chained equations for mortality, MACCE, emergency cardiac surgery, aortic dissection, coronary dissection, coronary perforation, cardiac tamponade, length of stay, ticagrelor, and circulatory support. Ticagrelor and circulatory support were not imputed because the imputed models failed to converge. Multiple logistic regressions were performed on the imputed dataset to identify independent predictors of the receipt of emergency cardiac surgery and to examine the unadjusted and adjusted impact of emergency cardiac surgery on 30-day mortality and in-hospital MACCE. Furthermore, 30-day mortality rates were determined according to subgroups by age, sex, diagnosis of ACS, and availability of surgical cover on-site.

Results

A total of 549,303 patients who underwent PCI were included in the analysis between 2007 and 2014 and did not have missing data for mortality and emergency cardiac surgery (Figure 1). In these patients 362 underwent emergency cardiac surgery (0.07%). There were 70 emergency cardiac surgeries where patients were initially admitted to a PCI center with no surgical cover (0.04%) whereas there were 266 patients initially admitted to a PCI center with surgical cover (0.09%).

The changes in rate of emergency cardiac surgery over the study duration showed a modest decline from 0.09% to 0.06% between 2007 and 2014 (Figure 2). This trend toward lower mortality was statistically significant ($p < 0.001$). The rate for centers where PCI took place and there was no surgical cover remained similar (0.04% in

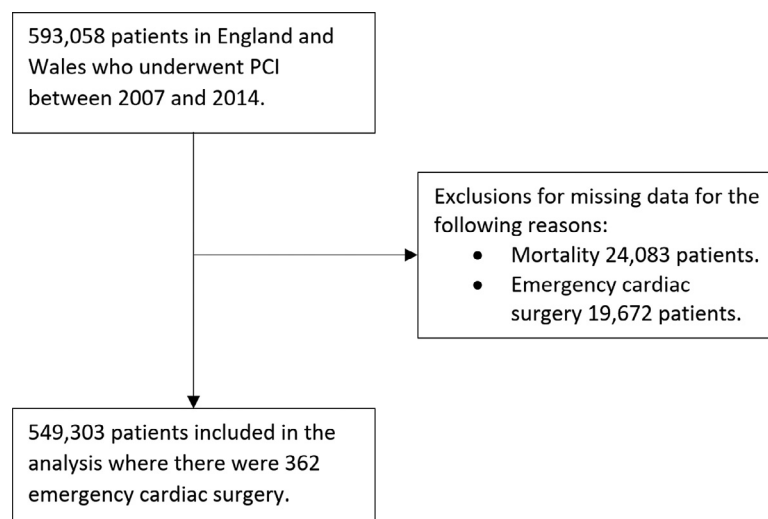


Figure 1. Flow diagram of participant inclusion.

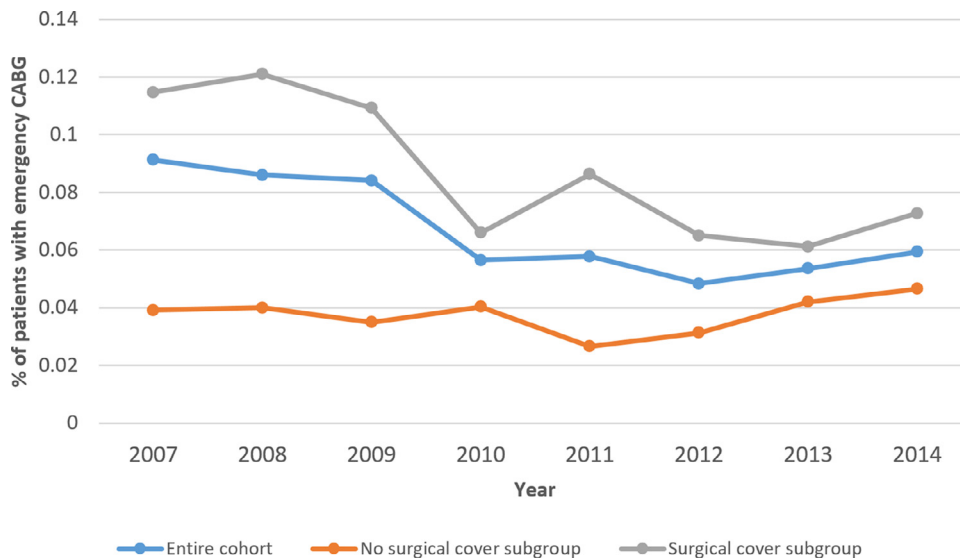


Figure 2. Changes in rates of emergency cardiac surgery over time.

2007 to 0.05% in 2014) and the decline was mainly observed in centers where there was surgical cover (0.11% in 2007 and 0.07% in 2014).

Table 1 shows the preprocedural characteristics of patients with and without emergency cardiac surgery. There was no significant difference in mean age ($p=0.96$) and proportion of patients who were male ($p=0.055$). The 63% of patients with ACS are made up of 1,719 patients (0.5%) with facilitated PCI, 114,420 patients (35.1%) with primary PCI for STEMI, 5,347 patients (1.6%) with rescue PCI and 204,339 patients (62.7%) with unstable angina or NSTEMI or convalescent STEMI. There were significantly more patients with diabetes mellitus (24.4% vs 19.5%, $p=0.022$), cardiogenic shock (7.5% vs 2.3%, $p<0.001$), circulatory support (37.0% vs 1.6%, $p<0.001$), and ventilation (3.3% vs 1.6%, $p=0.016$). There was a major difference in on-site or off-site surgical cover where patients with emergency cardiac surgery were more likely to have on-site cover (79.2% vs 62.4%, $p<0.001$). The outcomes of 30-day mortality (16.0% vs 2.2%, $p<0.001$) and in-hospital MACCE (14.4% vs 1.9%, $p<0.001$) were also significantly greater in the group with emergency cardiac surgery. The length of stay was on average more than 9 days longer for patients with emergency cardiac surgery compared with no surgery (11.2 vs 2.0 days).

The Supplementary Table 1 shows the baseline characteristics of patients with emergency cardiac surgery according to on-site or off-site surgical cover. Patients who had off-site surgical cover were more likely to have previous valve disease (4.8% vs 0.8%), glycoprotein IIb/IIIa inhibitors (28.8% vs 19.7%), and ticagrelor (14.0% vs 4.3%) but had less MACCE (5.7% vs 17.0%) and shorter length of stay (3.2 vs 13.7 days).

The rate of complications post PCI in patients with emergency cardiac surgery was much higher compared with patients without emergency cardiac surgery for aortic dissection (4.1% vs 0.04%), coronary dissection (32.3% vs 1.6%), coronary perforation (10.1% vs 0.3%), and cardiac tamponade (6.4% vs 0.08%; Table 2).

The multiple logistic regression model exploring factors associated with emergency cardiac surgery is shown in Table 3. The strongest factors associated with emergency cardiac surgery were circulatory support (OR 39.20 95%CI 27.75 to 55.36), aortic dissection (OR 28.39 95%CI 14.59 to 55.26), coronary dissection (OR 18.50 95%CI 13.60 to 25.18), coronary perforation (OR 7.86 95%CI 4.27 to 14.46), and cardiac tamponade (OR 6.77 95%CI 3.13 to 14.66). A few factors were associated with reduced odds of emergency cardiac surgery which included incremental increase in age (OR 0.98 95%CI 0.97 to 1.00), previous CABG (OR 0.28 95%CI 0.13 to 0.60), cardiogenic shock (OR 0.43 95%CI 0.25 to 0.72), and glycoprotein IIb/IIIa inhibitor use (OR 0.33 95%CI 0.30 to 0.62).

Without adjustments for potential confounders, there was an 8.6-fold increase in odds of 30-day mortality and in-hospital MACCE associated with emergency cardiac surgery which was reduced to 4.4-fold increase in odds of 30-day mortality and 1.6-fold increase in odds of in-hospital MACCE after adjustments (Table 4).

The 30-day mortality rate in different subgroups of patients who had emergency cardiac surgery after PCI is shown in Figure 3. The proportion of patients who had the greatest 30-day mortality were those who were age 71 to 80 years (26.0%), female (17.4%), with stable angina (16.9%), and from centers where there was no surgical cover (17.1%).

Discussion

This is the first national analysis of emergency cardiac surgery after PCI and we report several key findings. First, aortic dissection (28-fold increased risk), coronary artery dissection (18-fold increased risk), and coronary perforations (8-fold increased risk) are the commonest reasons for patients who underwent emergency cardiac surgery. Second, in England and Wales, there has been a decline in emergency cardiac surgery over time and that it is a relatively rare event. Third, there has been a modest decline in

Table 1
Preprocedural characteristics and baseline treatments

Variable	Emergency cardiac surgery		p value
	No (n = 548,941)	Yes (n = 362)	
Age (year)	65 ± 12	65 ± 11	0.96
Men	74.2%	69.8%	0.055
Body mass index (kg/m ²)	28 ± 5	28 ± 5	0.20
Smoking	24.3%	23.5%	0.76
Diabetes mellitus	19.5%	24.4%	0.022
Hypertension	54.6%	54.7%	0.99
Hypercholesterolemia	56.5%	54.1%	0.37
Previous myocardial infarction	27.7%	31.1%	0.17
Previous stroke	4.0%	4.4%	0.74
Peripheral vascular disease	4.9%	6.1%	0.31
Renal disease	2.7%	2.7%	0.94
Previous valve disease	1.3%	1.5%	0.84
Previous PCI	22.7%	21.0%	0.44
Previous CABG	8.5%	4.0%	0.003
Radial access	50.0%	32.0%	<0.001
Cardiogenic shock	2.3%	7.5%	<0.001
Circulatory support	1.6%	37.0%	<0.001
Ventilation	1.6%	3.3%	0.016
Diagnosis			0.32
Stable angina	37.4%	34.8%	
ACS	62.6%	65.2%	
Glycoprotein IIb/IIIa inhibitor use	22.2%	21.6%	0.77
Prasugrel use	4.7%	4.6%	0.98
Ticagrelor use	5.6%	6.4%	0.57
Warfarin use	1.2%	1.1%	0.87
Thrombolysis use	5.4%	3.6%	0.22
Surgical cover			<0.001
On-site (Cover)	62.4%	79.2%	
Off-site (No cover)	37.6%	20.8%	
Severe LMS disease	3.5%	17.1%	<0.001
Severe multivessel disease	31.2%	52.0%	<0.001
Unprotected LMS	1.0%	1.1%	0.81
CTO PCI	8.0%	15.9%	<0.001
Rotational atherectomy	2.2%	2.5%	0.73
Laser	0.2%	0.4%	0.68
Cutting balloon	4.0%	2.8%	0.31
30-day mortality	2.2%	16.0%	<0.001
In-hospital MACCE	1.9%	14.4%	<0.001
Length of stay (days)	2.0 ± 5.3	11.2 ± 16.5	<0.001

CABG = coronary artery bypass graft; CTO = chronic total occlusion; LMS = left main stem; MACCE = major adverse cardiovascular and cerebrovascular event; PCI = percutaneous coronary intervention.

use of emergency cardiac surgery after PCI which was more pronounced in centers where there was surgical cover. Fourth, patients who had diabetes mellitus, cardiogenic shock, received circulatory support, ventilation, and underwent PCI in a center with on-site surgery were more likely to have emergency cardiac surgery. Finally, patients who underwent emergency cardiac surgery were more likely to have 30-day day mortality and in-hospital MACCE as well as a longer hospital stay.

The low risk of emergency cardiac surgery may be explained by a few reasons. First, complications after PCI that require emergency cardiac surgery are often catastrophic and some patients may not make it to the operating theater. Second, the BCIS supports the provision of PCI in

Table 2
Complications post percutaneous coronary intervention in patients with and without emergency cardiac surgery

Reason	Rate in emergency cardiac surgery (n = 362)	Rate in no emergency cardiac surgery (n = 548,941)
Aortic dissection	15 (4.1%)	222 (0.04%)
Coronary dissection	117 (32.3%)	8,643 (1.6%)
Coronary perforation	39 (10.8%)	1,600 (0.3%)
Cardiac tamponade	23 (6.4%)	463 (0.08%)
Reason	Rate in emergency cardiac surgery	
Aortic dissection	15/237 (6.3%)	
No aortic dissection	347/549,066 (0.06%)	
Coronary dissection	117/8,760 (1.3%)	
No coronary dissection	245/540,543 (0.05%)	
Coronary perforation	39/1,639 (2.4%)	
No coronary perforation	323/547,664 (0.06%)	
Cardiac tamponade	23/486 (4.7%)	
No cardiac tamponade	339/548,817 (0.06%)	

Table 3
Independent predictors of emergency cardiac surgery (n = 428,200)

Variable	Odds ratio (95% CI)*	p-value
Age (per year)	0.98 (0.97-1.00)	0.010
Diabetes mellitus	1.57 (1.15-2.15)	0.005
Previous CABG	0.28 (0.13-0.60)	0.001
Radial access	0.61 (0.45-0.82)	0.001
Cardiogenic shock	0.43 (0.25-0.72)	0.001
Circulatory support	39.20 (27.75-55.36)	<0.001
Glycoprotein IIb/IIIa inhibitor use	0.43 (0.30-0.62)	<0.001
Year 2012 vs 2007	0.56 (0.32-0.98)	0.042
Length of stay (per day)	1.03 (1.03-1.04)	<0.001
Surgical cover on-site	2.15 (1.56-2.97)	<0.001
Aortic dissection	28.39 (14.59-55.26)	<0.001
Coronary dissection	18.50 (13.60-25.18)	<0.001
Coronary perforation	7.86 (4.27-14.46)	<0.001
Cardiac tamponade	6.77 (3.13-14.66)	<0.001

CABG = coronary artery bypass graft.

* Candidate variables in the model included age, sex, BMI, smoking, hypertension, hypercholesterolemia, previous MI, previous stroke, PVD, renal disease, valvular heart disease, previous PCI, previous CABG, radial access, cardiogenic shock, circulatory support, ventilation, diagnosis of ACS, GPI use, clopidogrel use, prasugrel use, ticagrelor use, warfarin use, thrombolysis use, year, length of stay, left main PCI, unprotected left main, rotational atherectomy, cutting balloon use, laser use, surgical cover on site, aortic dissection, coronary dissection, coronary perforation and cardiac tamponade. Only significant predictors (p<0.05) shown.

appropriately selected patients in centers without on-site cardiac surgery and the number and proportion of centers performing PCI without on-site surgery has increased and now represents the majority of centers.⁹ These sites however should have a viable protocol for emergency transfer to the nearest surgical center within 1 hour with the ability to start cardiopulmonary bypass within 2 hours from the call for surgical intervention.¹⁰ Third, over time there has been refinement of PCI techniques and equipment such as catheter-based intravascular imaging techniques which enable better assessment of lesion severity, preprocedural planning, optimization, and management of immediate complications.¹¹ Fourth, although the improvement of PCI

Table 4
Mortality at 30-days and in-hospital major adverse cardiovascular events with emergency cardiac surgery

Outcome	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
30-day mortality	8.61 (6.50-11.41) (n = 549,303)	4.41 (2.94-6.62) (n = 428,200)
In-hospital MACCE	8.64 (6.42-11.64) (n = 549,295)	1.63 (1.07-2.48) (n = 428,192)

*Adjusted for age, sex, BMI, smoking, hypertension, hypercholesterolemia, previous MI, previous stroke, PVD, renal disease, valvular heart disease, previous PCI, previous CABG, radial access, cardiogenic shock, circulatory support, ventilation, diagnosis of ACS, GPI use, clopidogrel use, prasugrel use, ticagrelor use, warfarin use, thrombolysis use, year, length of stay, left main PCI, unprotected left main, rotational atherectomy, cutting balloon use, laser use, surgical cover on site, aortic dissection, coronary dissection, coronary perforation, and cardiac tamponade.

MACCE = major adverse cardiovascular and cerebrovascular event.

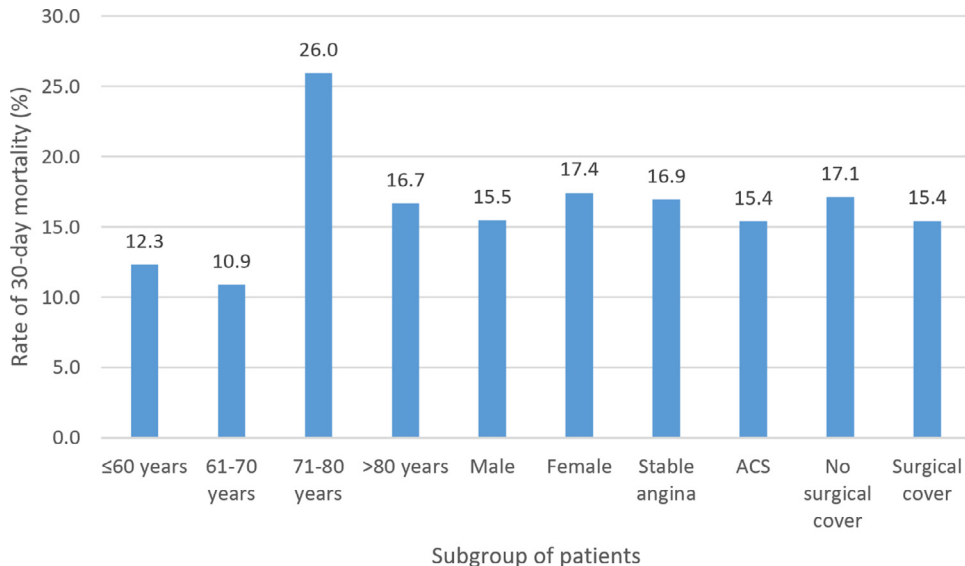


Figure 3. Rate of 30-day mortality in subgroups of patients with emergency cardiac surgery.

techniques has increased the number of high-risk PCI cases,¹² PCI operators in the United Kingdom must submit data to the BCIS which can be used to provide real-time feedback to participating hospitals about the provision of care.¹³ Operators are then fed back individual statistics which may encourage some operators to adopt a better case selection for elective PCI and this may further promote more risk averse behavior during PCI which would lower the chance of complications and need for emergency cardiac surgery.

Our study adds to the literature on comparing on-site and off-site cardiac surgery for PCI. The Atlantic C-PORT trial has shown that on-site cardiac surgery was noninferior to PCI performed at hospitals of off-site cardiac surgery with respect to mortality at 6 weeks and major adverse cardiac events at 9 months.¹⁴ This is also supported by real world data from the Swedish Coronary and Angiography and Angioplasty Registry suggesting no difference in outcome comparing on-site cardiac surgery backup and off-site cardiac surgery.¹⁵ The support for the need for on-site surgery standby has been from the days of early angioplasty where emergency CABG occurred in more than 5% of cases but the use of stents, glycoprotein IIb/IIIa inhibitors, and pre-treatment with dual antiplatelet therapy has significantly reduced the need for emergency CABG.¹⁶ However, more recent studies from the BCIS dataset suggest that PCI performed at centers without onsite surgical backup is not

associate with increased risk of mortality.¹⁷ In the present study we show that on-site surgical cover was associated with a 2-fold increase in odds of emergency cardiac surgery. The 30-day mortality was lower for on-site surgery compared with off-site (15.4% vs 17.1%) but after adjustment surgical cover was actually associated with increased odds of mortality (OR 1.26 95%CI 1.20 to 1.33). This may be related to more complex patients and coronary disease in patients who underwent PCI at hospitals with on-site surgery cover.

Hospital volume and operator volume are potentially important factors that influence the need for emergency surgery and rates of PCI complications. Although it has been shown previously that operator volume was not associated with mortality following PCI in an evaluation of the BCIS registry,¹⁸ higher PCI volume centers are likely to have higher volume operators and their operator may be more skilled at PCI resulting in fewer complications but they may also take on higher risk cases such as those with chronic total occlusions (CTO) or lesions that require rotablation which are at high risk of adverse outcomes.

We observed that the CTO PCI was associated with increased odds of emergency surgery. As patients with on-site cardiac surgery had a lower rate of 30-day mortality, this finding may support the undertaking of CTO PCI at centers with on-site surgical backup. The reason for this is that CTO PCI are high-risk procedures compared with non-

CTO PCI so they are a greater risk of complications such as coronary perforation and dissection which may require emergency surgery.

Our study has several strengths and limitations. This is a large national cohort that is necessary to sufficiently capture the rare case of PCI requiring emergency cardiac surgery. The multicenter nature of the national cohort enables the capture of differences in hospitals in terms of on or off-site cardiac surgery and well as national PCI practices. This dataset also includes a variety of variables including patient demographics, co-morbidities, procedural variables, and outcomes which we were able to adjust for in the analysis. A key limitation of this study is the definition of emergency cardiac surgery as it represents a range of procedures and one cannot differentiate between emergency CABG or dissection of a thoracic great vessel. Also, the dataset does not include detailed information on non-PCI-related medications and the periprocedural adverse events are self-reported. Our study is limited because of potential bias from underreporting of adverse outcomes because these events were self-reported without any kind of audit to ensure accuracy and validity. There is no information about the cause of death at 30-days nor information on the care received after PCI which includes cardiac surgeries after discharge which may impact adverse events and mortality at 30-days. Another limitation is that we do not have information on the severity of the coronary artery disease which is particularly relevant in patients with left main disease or multivessel disease.

In conclusion, emergency cardiac surgery after PCI is a rarely required and in England and Wales there appears to be a decline in recent years. Patients who underwent emergency cardiac surgery have higher risk of adverse outcomes and longer length of hospital stay. For patients who underwent elective PCI, better patient selection, and use of intra-coronary imaging to guide PCI procedures may reduce complications and the need for emergency cardiac surgery.

Contributorship

MAM was responsible for the design and concept. CSK performed the data cleaning and analysis. CSK and MAM wrote the first draft of the manuscript and all authors contributed to the writing of the report.

Disclosures

The authors declare that they have no known competing financial interests or personal relations that could have appeared to influence the work reported in this report.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amjcard.2020.05.041>.

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