

# Percutaneous Coronary Intervention at Centers With and Without On-site Surgery

## A Meta-analysis

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CURRENT GUIDELINES RECOMMEND against performing elective percutaneous coronary intervention (PCI) at institutions without on-site cardiac surgery capability (American Heart Association/American Cardiology class III indication).<sup>1</sup> It is considered acceptable to perform PCI at such facilities (class IIb) for patients with ST-segment elevation myocardial infarction (STEMI), but additional requirements must be present at the facility to ensure patient safety.<sup>1</sup> The need for on-site coronary artery bypass grafting (CABG) surgery to back up PCI was considered mandatory during the prior era of angioplasty, when up to 5% of patients required urgent or emergency CABG surgery after failed angioplasty.

Despite the marked decline in the need for emergency CABG surgery after PCI<sup>2,3</sup> and satisfactory outcomes at selected centers,<sup>4</sup> several concerns remain regarding PCI programs without on-site surgical backup. First, favorable results reported from such centers were largely derived from small, single-center observational registries.<sup>4-6</sup>

**For editorial comment see p 2507.**

**Context** Percutaneous coronary interventions are performed at centers without on-site surgery, despite current guidelines discouraging this.

**Objective** To assess literature comparing rates of in-hospital mortality and emergency coronary artery bypass grafting surgery at centers with and without on-site surgery.

**Data Sources** A systematic search of studies published between January 1990 and May 2010 was conducted using MEDLINE, EMBASE, and Cochrane Review databases.

**Study Selection** English-language studies of percutaneous coronary intervention performed at centers with and without on-site surgery providing data on in-hospital mortality and emergency bypass were identified. Two study authors independently reviewed the 1029 articles originally identified and selected 40 for analysis.

**Data Extraction** Study title, time period, indication for angioplasty, and outcomes were extracted manually from all selected studies, and quality of each study was assessed using the strengthening the reporting of observational studies in epidemiology (STROBE) checklist.

**Data Synthesis** High-quality studies of percutaneous coronary interventions performed at centers with and without on-site surgery were included. Pooled-effect estimates were calculated with random-effects models. Analyses of primary percutaneous coronary intervention for ST-segment elevation myocardial infarction of 124 074 patients demonstrated no increase in in-hospital mortality (no on-site surgery vs on-site surgery: observed risk, 4.6% vs 7.2%; odds ratio [OR], 0.96; 95% CI, 0.88-1.05;  $I^2=0\%$ ) or emergency bypass (observed risk, 0.22% vs 1.03%; OR, 0.53; 95% CI, 0.35-0.79;  $I^2=20\%$ ) at centers without on-site surgery. For nonprimary percutaneous coronary interventions (elective and urgent,  $n=914\,288$ ), the rates of in-hospital mortality (observed risk, 1.4% vs 2.1%; OR, 1.15; 95% CI, 0.93-1.41;  $I^2=46\%$ ) and emergency bypass (observed risk, 0.17% vs 0.29%; OR, 1.21; 95% CI, 0.52-2.85;  $I^2=5\%$ ) were not significantly different at centers without or with on-site surgery.

**Conclusion** Percutaneous coronary interventions performed at centers without on-site surgery, compared with centers with on-site surgery, were not associated with a higher incidence of in-hospital mortality or emergency bypass surgery.

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Second, 1 large study using administrative data demonstrated worse outcomes for elective PCIs at sites without on-site surgery, especially at centers with low annual angioplasty volumes.<sup>7</sup> Third, since publication of the guidelines,<sup>1</sup> additional studies at institutions without on-site surgery have reported favorable results.<sup>4,8-12</sup>

This unresolved clinical issue has implications for the delivery of clinical care

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and for health care infrastructure. Given the discrepant results among studies and low power of some studies to detect a difference between centers with and without on-site surgery, we performed a meta-analysis of studies to further define the safety and outcomes of PCI at centers without on-site surgery. We aimed to test the hypothesis that outcomes of elective PCI and primary PCI for STEMI at centers without on-site surgery are not different from those for PCI performed at centers with on-site surgery.

## METHODS

### Search Strategy

Following the meta-analysis of observational studies in epidemiology (MOOSE) guidelines, we conducted a comprehensive literature search of MEDLINE, EMBASE, and Cochrane Library databases for studies published between January 1990 and December 2009.<sup>13</sup> The search was started in 1990 so as to include most studies reporting data at centers without on-site surgery. Keywords related to angioplasty used for searching were *percutaneous transluminal coronary angioplasty* or *PTCA*, *primary angioplasty*, *ST-segment elevation myocardial infarction* or *STEMI*, *PCI*, *angioplasty*, *on-site surgery*, *coronary stents*, *drug-eluting stents*, and *balloon angioplasty*. These terms were cross-referenced to citations pertinent to outcomes (ie, mortality and CABG rates).

Studies that met each of the following criteria were considered eligible for meta-analysis: published in English; PCI results from a center without on-site surgery were available; PCI outcomes were compared with a center with on-site surgery; provided a clear definition of STEMI for studies including patients with STEMI; and had a case-control matching design, with statistical analyses (matching, covariate adjustment, or propensity-based adjustment) to adjust for differences in patient characteristics between centers with and without on-site surgery.<sup>4,12,14-19</sup> Articles were excluded if results were reported only on PCI at centers with-

out on-site surgery without a control population. Unpublished studies and studies that were presented at conferences were not included in the meta-analysis. Reviews were hand-searched for additional references, but yielded no additional articles. Title and abstract review of all articles was completed by 2 of the authors (M.S., M.A.K.). Full reports of 17 potentially relevant articles were independently reviewed by at least 2 investigators (C.S.R., M.S.) to establish eligibility according to the inclusion criteria.

### Data Analysis

A standardized, piloted data extraction form was used for recording information. Data extraction was completed by one of the authors (M.S.). For the primary analyses, we obtained the adjusted odds ratio (OR) for available studies, with corresponding 95% confidence intervals, and noted the type of statistical adjustment (ie, variables examined as possible covariates in relation to the outcomes of interest).

Study populations were characterized at centers with or without on-site surgery, and the following information was recorded: primary author; publication year; study design (single-center or multicenter); PCI type (primary PCI for STEMI or nonprimary PCI [elective and non-STEMI]); number of patients; and mortality, emergency CABG rates stratified by the presence or absence of on-site surgery and by the indication for PCI, or both. Patients with STEMI did not include those with facilitated PCI or rescue PCI; such patients were more likely to be included in the non-STEMI subset of the nonprimary PCI group. Information on the need for transfer out of a facility without on-site surgery was not consistently available but was recorded when available. Disagreement between reviewers during the selection process was resolved through consensus.

The quality of the studies was assessed on the basis of elements from the strengthening the reporting of observational studies in epidemiology (STROBE) checklist for cohort studies.<sup>20</sup> We did not assign a threshold for

study inclusion. All the studies included in the analyses met at least 15 variables in the checklist. Inconsistencies among studies were found in determination of bias, selection of participants in the study, determination of study size, handling of quantitative variables, and determination of the source of funding.

In-hospital mortality and the need for emergency CABG surgery were examined as separate outcomes. There was no uniform definition of emergency CABG surgery. Wherever reported, the need for emergency CABG surgery was largely due to complications during the PCI procedure, and patients were transferred within 24 hours of PCI. However, some patients were also transferred because of unstable hemodynamics. Each study contributed only 1 effect size per analysis. If data were duplicated between studies, the most recent study was used. When available, ORs reported in the article were used, and adjusted ORs (and their corresponding 95% confidence intervals) were used preferentially over unadjusted ORs. If ORs were not reported, we calculated them using the event and sample size frequencies. If frequencies were not given, they were estimated from percentages and rounded to the nearest integer. If any cell had a 0 count, ORs were calculated by adding 0.5 to all cell counts from the study to avoid division by 0.

Random-effects models were used to estimate pooled ORs. Fixed-effects models were only used in sensitivity analyses that examined whether these models yielded similar results. An OR greater than 1 indicates an increased risk of an outcome among patients undergoing PCI at centers without on-site surgery as compared with controls (patients undergoing PCI at centers with on-site surgery). The  $I^2$  statistic was used to examine the heterogeneity of effect sizes in the overall aggregations:  $I^2 \leq 25\%$  indicates low heterogeneity,  $I^2 \approx 50\%$  indicates moderate heterogeneity, and  $I^2 \geq 75\%$  indicates high heterogeneity.

Publication bias was evaluated with a combination of a funnel plot-based

method and the trim-and-fill method to estimate the number of missing studies and to calculate a corrected OR as if these studies were present.<sup>13</sup> The effect of potential outliers was examined by comparing the pooled estimate with estimates obtained after iterations using k-1 findings (each study is left out and the effect re-estimated). Studies were treated as statistical outliers if the k-1 estimate produced a 95% confidence interval that did not overlap with the 95% confidence interval of the aggregated estimate.

Statistical analyses were performed using SAS version 9.2 software (SAS Institute Inc). *P* values less than .05 were considered statistically significant.

## RESULTS

We identified 1029 articles, of which we selected 40 for further review on the basis of the inclusion and exclusion criteria described in the "Methods" section. Excluded studies did not include PCIs performed at centers without on-site surgery. We then excluded 23 additional studies that were case series of PCIs performed at centers without on-site surgery and that lacked a control group, an abstract that did not provide sufficient details, and a Japanese study that defined myocardial infarction differently.<sup>21,22</sup> Fifteen studies met our inclusion criteria (FIGURE 1). The included studies reported statistically adjusted effect estimates for the outcome of mortality, emergency CABG, or both (TABLE 1).

### Mortality

**Primary PCI.** The pooled OR for in-hospital mortality in patients undergoing primary PCI was derived from 124 074 patients. The average mortality rate across studies was 4.6% (range, 2.1%-11.3%) for sites without on-site surgery and 5.1% (range, 1.0%-12.2%) for sites with on-site surgery. Pooling all patients equally resulted in observed mortality rates of 4.6% and 7.2%, respectively. In-hospital mortality for patients at hospitals without on-site surgery was not different from hos-

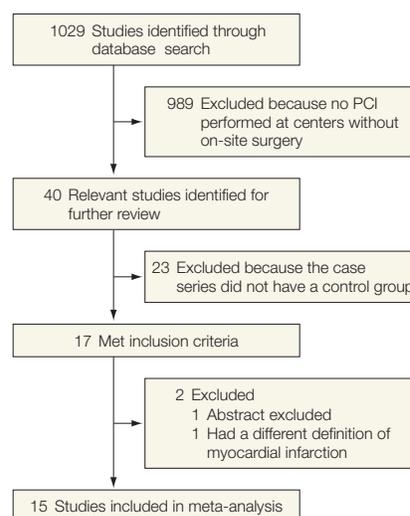
pitals having on-site surgery (OR, 0.96; 95% CI, 0.88-1.05) in both fixed-effects and random-effects models, with no observed heterogeneity ( $I^2=0\%$ ; FIGURE 2). The funnel plot was narrow, and the estimated effects are consistent across various studies (FIGURE 3).

**Nonprimary PCI.** The pooled OR for in-hospital mortality in patients undergoing nonprimary PCI was derived from 914 288 patients. Mortality was not significantly different for patients undergoing nonprimary PCI at facilities with and without on-site surgery (OR, 1.15; 95% CI, 0.93-1.41). The average mortality rate across studies was 0.9% (range, 0%-4.6%) for sites without on-site surgery and 0.8% (range, 0%-2.8%) for sites with on-site surgery. Pooling all patients equally resulted in observed rates of 1.4% and 2.1%, respectively. Moderate heterogeneity ( $I^2=46\%$ ) was identified in this group. After adjustment for publication bias, the mortality rate for nonprimary PCI was 25% higher at centers without on-site surgery compared with centers that had on-site surgery (OR, 1.25; 95% CI, 1.01-1.53;  $P=.04$ ; Figure 2 and TABLE 2).

### Emergency CABG

The incidence of emergency CABG for both primary and nonprimary PCI at centers without on-site surgery was low. The highest observed rate of emergency CABG surgery among the studies was 1.2% for primary PCI and 0.3% for nonprimary PCI; these occurred at facilities with on-site surgery. For primary PCI, the observed rate (pooling all patients equally) of emergency CABG surgery was 0.22% at centers without on-site surgery vs 1.03% at centers with on-site surgery; for nonprimary PCI, the rates were 0.17% and 0.29%, respectively. The OR for emergency CABG surgery after primary or nonprimary PCI performed at sites without on-site surgery vs that at centers with on-site surgery was 0.53 (95% CI, 0.35-0.79) for primary PCI and was 1.21 (95% CI, 0.52-2.85) for nonprimary PCI in the random-effects model

**Figure 1.** Study Flow



PCI indicates percutaneous coronary intervention. Abstracts were excluded because they do not provide enough information.

(FIGURE 4). Estimates of heterogeneity were low for these outcomes ( $I^2=20\%$  for primary PCI;  $I^2=5\%$  for nonprimary PCI). After adjustment for publication bias, the ORs were not substantially different. Transfer rates to hospitals with on-site surgery and the outcomes of transferred patients were not consistently reported and, hence, were not included in the analyses.

### Subset Analysis

We performed a subset analysis of 11 studies in which the study period included no years earlier than 1999. The results of this analysis gave ORs very similar to those in the primary analysis: For patients with STEMI, the OR of death was 0.97 (95% CI, 0.88-1.06); elective PCI, the OR for death was 1.15 (95% CI, 0.93-1.42); with STEMI the OR for emergency CABG surgery was 0.56 (95% CI, 0.37-0.84); and elective PCI, the OR for emergency CABG surgery was 1.32 (95% CI, 0.49-3.59).

## COMMENT

Several important clinical findings emerge from our meta-analysis. It demonstrated that mortality and the need

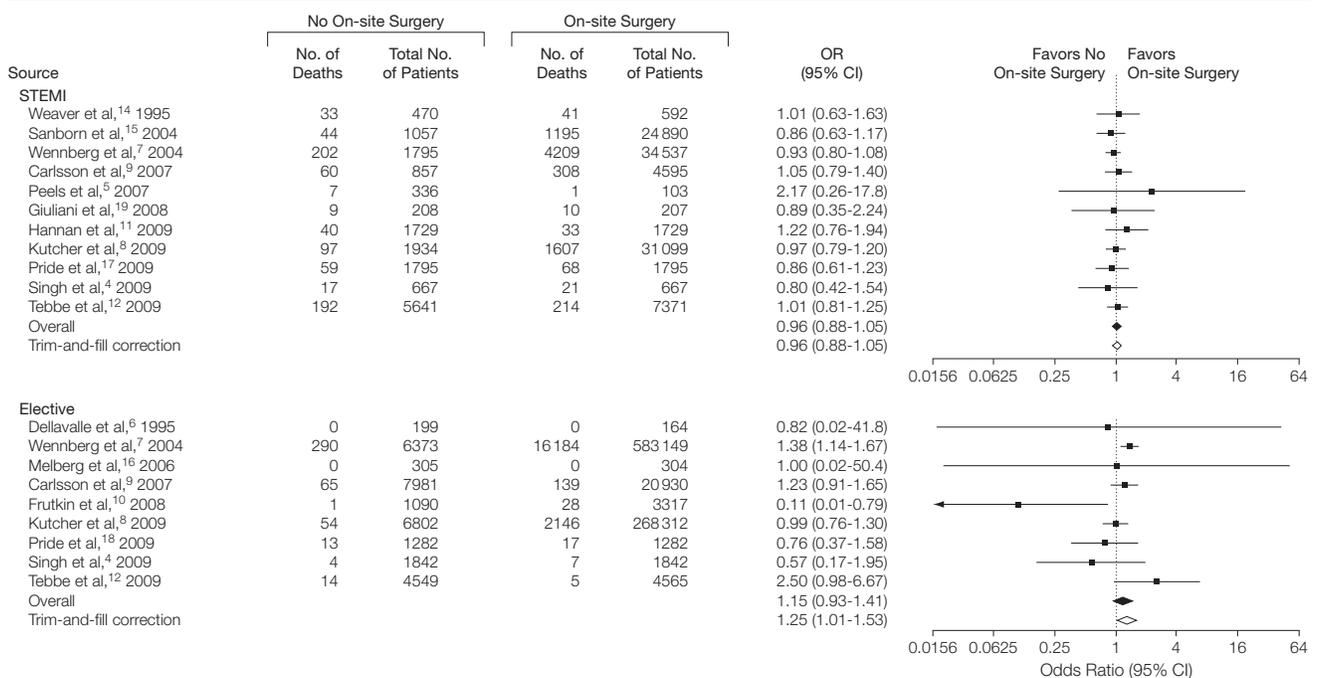
for emergency CABG surgery after primary PCI for STEMI were similar at centers with and without on-site surgical backup. The narrow funnel plot and consistent individual and combined effect estimates for mortality support the safety of performing primary PCI at these centers. No significant publication bias was demonstrated.

**Table 1.** Studies Included in the Meta-analysis

Source	Study	Study Period	Indication for PCI	Study Center Type	No. of Patients			
					STEMI		Elective or Non-STEMI	
					Without On-site Surgery	With On-site Surgery	Without On-site Surgery	With On-site Surgery
Dellavalle et al, <sup>6</sup> 1995	Dellavalle	1992-1994	Elective	Single			199	164
Weaver et al, <sup>14</sup> 1995	MITI	1988-1994	STEMI	Multi	470	592		
Sanborn et al, <sup>15</sup> 2004	NRMI	1998-2001	STEMI	Multi	1057	24 890		
Wennberg et al, <sup>7</sup> 2004	Medicare	1999-2001	All	Multi	1795	34 537	6373	583 149
Melberg et al, <sup>16</sup> 2006	Norwegian randomized	1997-2001	Elective	Single			305	304
Carlsson et al, <sup>9</sup> 2007	SCAAR	2000-2003	All	Multi	857	4595	7981	20 930
Peels et al, <sup>5</sup> 2007	Alkmaar, the Netherlands	2002-2005	STEMI	Single	336	103		
Frutkin et al, <sup>10</sup> 2008	MAHI	2003-2005	Elective	Single			1090	3317
Giuliani et al, <sup>19</sup> 2008	Italian	2005-2006	STEMI	Multi	208	207		
Hannan et al, <sup>11</sup> 2009	NY State PCIRS	2003-2006	STEMI	Multi	1729	1729		
Kutcher et al, <sup>8</sup> 2009	NCDR	2004-2006	All	Multi	1934	31 099	6802	268 312
Pride et al, <sup>17</sup> 2009	NRMI-STEMI	2004-2006	STEMI	Multi	1795	1795		
Pride et al, <sup>18</sup> 2009	NRMI-non-STEMI	2004-2006	Non-STEMI	Multi			1282	1282
Singh et al, <sup>4</sup> 2009	Mayo Clinic	1999-2007	All	Multi	667	667	1842	1842
Tebbe et al, <sup>12</sup> 2009	German, ALKK	2006	All	Multi	5641	7371	4549	4565

Abbreviations: ALKK, Arbeitsgemeinschaft Leitende Kardiologische Krankenhausärzte; MAHI, Mid America Heart Institute; MITI, Myocardial Infarction Triage and Intervention; NCDR, National Cardiovascular Data Registry; NRMI, National Registry of Myocardial Infarction; PCI, percutaneous coronary intervention; PCIRS, Percutaneous Coronary Intervention Reporting System; SCAAR, Swedish Coronary Angiography and Angioplasty Registry; STEMI, ST-segment elevation myocardial infarction.

**Figure 2.** Forest Plots Comparing In-hospital Mortality Following Percutaneous Coronary Intervention at Sites With and Without Surgery



Odds ratio (OR) estimates with 95% CIs of all studies for the outcomes of death by indication for percutaneous coronary intervention. In the case of 0 counts, ORs were calculated by adding 0.5 to all cell counts from the study to avoid division by 0. STEMI indicates ST-elevation myocardial infarction.

For nonprimary PCI overall, there was no difference in in-hospital mortality or the need for emergency CABG surgery in patients treated at centers with or without on-site surgery. In contrast to primary PCI, we noted moderate heterogeneity in mortality among studies and some evidence of publication bias. For further improvement in the outcomes at hospitals without on-site surgery, additional efforts should not only explore covariates linked to worse outcomes but also identify best practices. Outcome models that are effective for promoting successful outcomes after PCI have used, among other things, exporting of data into a national repository<sup>4,6-10,12,16,18</sup>, linkage of these hospitals to a tertiary care center for consultation, cross-training, and similar processes and structures of care of a patient undergoing PCI<sup>4,6,8,10,16</sup>, expeditious transfer for emergency CABG surgery<sup>4,8,10,16</sup>, and use of risk-adjustment tools for case selection, outcomes analyses and benchmarking of operators' performance, or both.<sup>4,6,10,12,16,18</sup> Studies that have adhered to such processes had more favorable outcomes (eFigure available at <http://www.jama.com>). Adherence to such standard processes of care has been demonstrated to be a successful strategy for successful outcomes in patients with coronary artery disease.<sup>23</sup> Patients admitted to centers without on-site surgery and angioplasty capabilities are less likely to receive guideline-recommended medications or to receive reperfusion therapy. However, no differences in guideline adherence or adverse outcomes were detected in hospitals with PCI capability.<sup>17,18</sup>

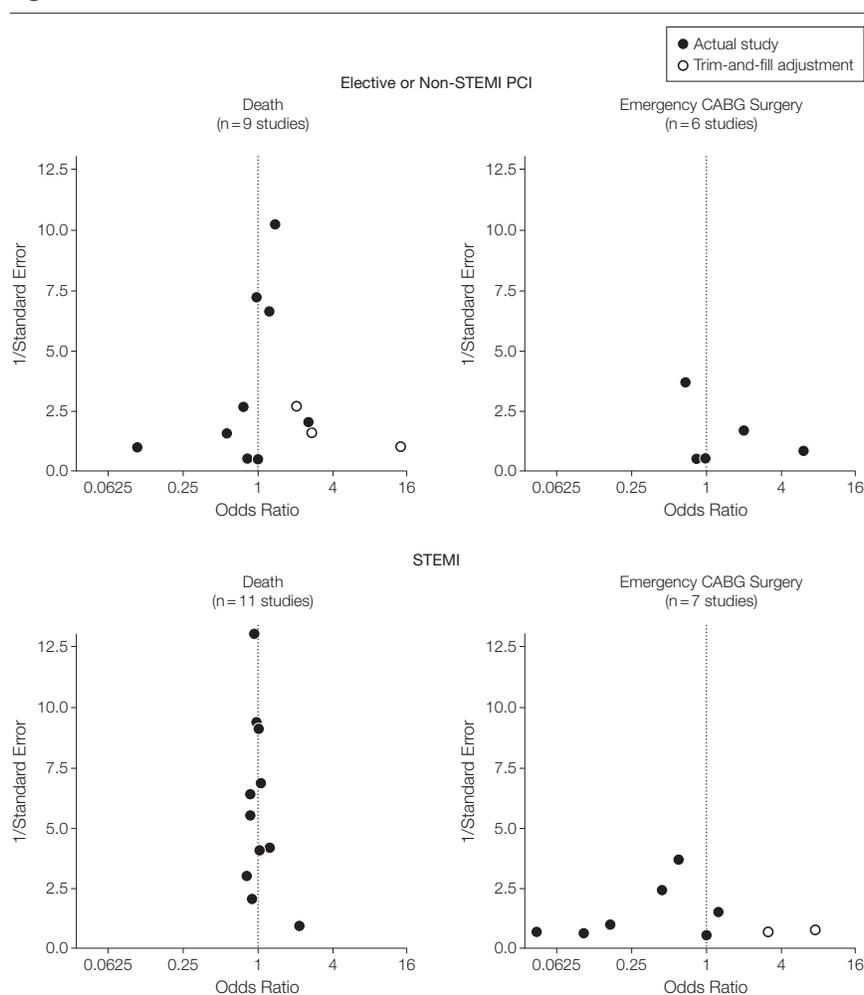
The relationship between outcomes and PCI volume of centers is inconsistent among studies, but Wennberg et al<sup>7</sup> reported worse outcomes for nonprimary PCI at low-volume centers without on-site surgery.<sup>24,25</sup> Because of inconsistent reporting and results, this important relationship was not examined in the present analysis but should be investigated in future studies.

The results of this meta-analysis are relevant to patient care and gain spe-

cial clinical relevance in light of the recent American College of Cardiology/American Heart Association guidelines that do not recommend PCI for elective indications and give a class IIb indication for primary PCI at centers without on-site surgery.<sup>1</sup> In-hospital mortality was not significantly different for patients undergoing nonprimary PCI at facilities with and without on-site surgery, but after adjustment for publication bias, the mortality rates for nonprimary PCI were approximately 25% higher at centers without on-site surgery. This finding is of concern, despite improved outcomes ob-

served in recent years in studies from national registries in Europe and the United States.<sup>8,9,26</sup> Most studies included in our analysis did not distinguish truly elective and low-risk PCI from treatment of higher-risk patients with unstable angina or non-STEMI or those needing rescue or facilitated PCI. More data for nonprimary PCI are required for definitive conclusions, especially data stratified on the basis of clinical and angiographic risk and operator or institutional PCI volumes, to better optimize the performance of PCI at centers without on-site surgery. Further work should identify processes that

**Figure 3.** Funnel Plot to Evaluate Publication Bias



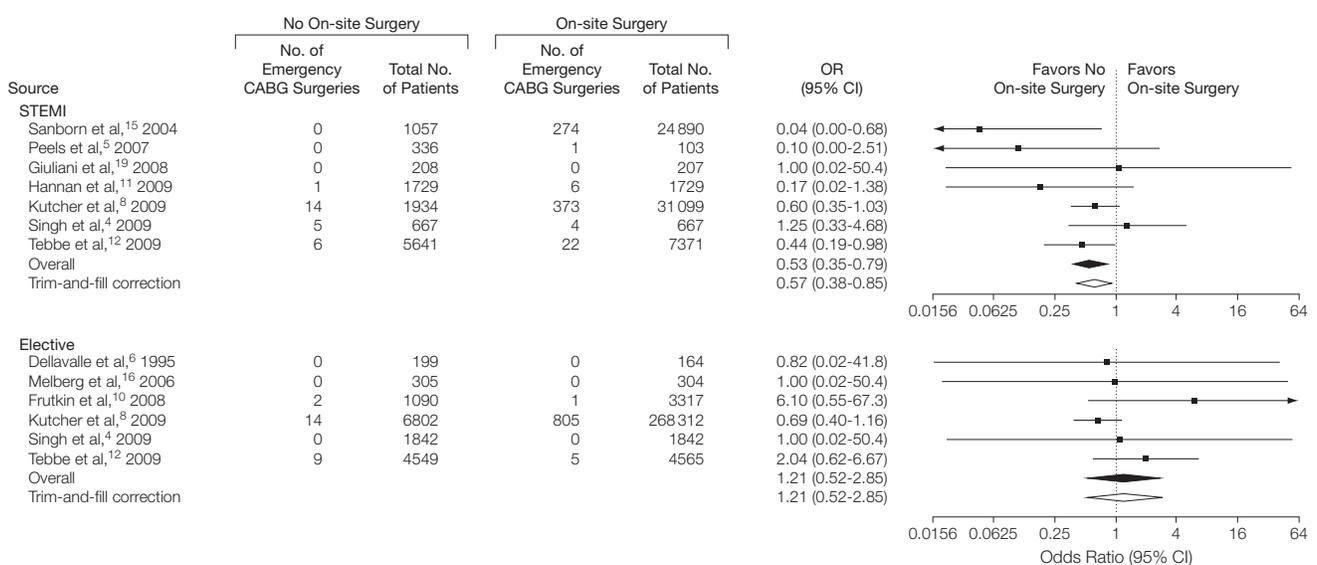
Studies comparing in-hospital mortality and emergency coronary artery bypass grafting (CABG) surgery after nonprimary (elective for patients without ST elevation myocardial infarction [STEMI]) and primary (patients with STEMI) percutaneous coronary intervention. Trim-and-based estimates of unpublished studies are also shown.

**Table 2.** Study Results Included in the Meta-Analysis

Study	Death			Emergency-CABG Surgery		
	Incidence, %		OR (95% CI)	Incidence, %		OR (95% CI)
	Without On-site Surgery	With On-site Surgery		Without On-site Surgery	With On-site Surgery	
<b>Primary PCI</b>						
Medicare	11.3	12.2	0.93 (0.80-1.08)			
SCAAR	7.0	6.7	1.05 (0.79-1.40)			
Mayo Clinic	2.5	3.1	0.80 (0.42-1.54)	0.7	0.6	1.25 (0.33-4.68)
NCDR	5.1	5.2	0.97 (0.79-1.20)	0.7	1.2	0.60 (0.35-1.03)
German, ALKK	3.4	2.9	1.01 (0.81-1.25)	0.1	0.3	0.44 (0.19-0.98)
MITI	7.0	7.0	1.01 (0.63-1.63)			
NRMI	4.2	4.8	0.86 (0.63-1.17)	0.0	1.1	0.04 (0.00-0.68)
Alkmaar, the Netherlands	2.1	1.0	2.17 (0.26-17.8)	0.0	1.0	0.10 (0.00-2.51)
Italian	4.3	4.9	0.89 (0.35-2.24)	0.0	0.0	1.00 (0.02-50.4)
NY State PCIRS	2.3	1.9	1.22 (0.76-1.94)	0.06	0.35	0.17 (0.02-1.38)
NRMI-STEMI	3.3	3.8	0.86 (0.61-1.23)			
<b>Nonprimary PCI</b>						
Medicare	4.6	2.8	1.38 (1.14-1.67)			
SCAAR	0.8	0.7	1.23 (0.91-1.65)			
Mayo Clinic	0.2	0.4	0.57 (0.17-1.95)	0.0	0.0	1.00 (0.02-50.4)
NCDR	0.8	0.8	0.99 (0.76-1.30)	0.2	0.3	0.69 (0.40-1.16)
German, ALKK	0.3	0.1	2.50 (0.98-6.67)	0.2	0.1	2.04 (0.62-6.67)
Dellavalle	0.0	0.0	0.82 (0.02-41.8)	0.0	0.0	0.82 (0.02-41.8)
Norwegian randomized	0.0	0.0	1.00 (0.02-50.4)	0.0	0.0	1.00 (0.02-50.4)
MAHI	0.09	0.8	0.11 (0.01-0.79)	0.2	0.03	6.10 (0.55-67.3)
NRMI-non-STEMI	1.0	1.3	0.76 (0.37-1.58)			

Abbreviations: ALKK, Arbeitsgemeinschaft Leitende Kardiologische Krankenhausärzte; CABG, coronary artery bypass grafting; MAHI, Mid America Heart Institute; MITI, Myocardial Infarction Triage and Intervention; NCDR, National Cardiovascular Data Registry; NRMI, National Registry of Myocardial Infarction; OR, odds ratio; PCI, percutaneous coronary intervention; PCIRS, Percutaneous Coronary Intervention Reporting System; SCAAR, Swedish Coronary Angiography and Angioplasty Registry; STEMI, ST-segment elevation myocardial infarction.

**Figure 4.** Forest Plot Comparing Emergency Coronary Bypass Graft Surgery Rates Following Percutaneous Coronary Intervention at Sites With and Without Surgery



Odds ratio (OR) estimates with 95% CIs of studies for the outcomes of emergency coronary artery bypass grafting (CABG) surgery by indication for percutaneous coronary intervention (PCI). In the case of 0 counts, ORs were calculated by adding 0.5 to all cell counts from the study to avoid division by 0.

improve the safety and outcomes of nonprimary PCI performed at centers without on-site surgery.

The rates of emergency CABG surgery were very low with wide confidence intervals. For primary PCI, the rates were lower at sites without on-site surgery, raising concern that borderline stable patients with suboptimal procedural results are being kept at their local facility rather than being transferred emergently to an outside surgical center.<sup>8</sup> If patients were being transferred, the in-hospital mortality rate for primary PCI would be expected to be higher at sites without on-site surgery; however, it was similar among sites with and without on-site surgery. Conversely, the higher risk-adjusted incidence of emergency CABG surgery at on-site PCI centers could reflect a lower threshold to opt for emergency surgery if there is any doubt about a suboptimal result. The rates of emergency CABG surgery for nonprimary PCI were higher than those for primary PCI but had wide confidence intervals because of the few patients (0.3%) who needed transfer. A study from Mayo Clinic demonstrated a transfer rate of 0.69%, and no patients undergoing elective PCI were transferred for emergency CABG surgery.<sup>4</sup> Most patients who needed transfer (80%) were patients with hemodynamic compromise, mechanical complications, or STEMI due to significant coronary artery disease requiring CABG surgery. The indications for transfer, transfer rates, and their outcomes were not universally reported and, hence, were not included in our analysis.

To our knowledge, this is the first study to systematically summarize in-hospital outcomes after PCI at centers with and without on-site surgery. We used a comprehensive search strategy and systematic review method, following recommendations from the MOOSE guidelines.<sup>13</sup> In our meta-analysis, we limited heterogeneity and potential sources of bias by including only high-quality studies that compared results of PCI at centers with and without on-

site surgery, excluding studies that just reported case series. Furthermore, our approach subdivided outcomes into several categories (primary vs nonprimary PCI; mortality and emergency CABG), thereby avoiding potential heterogeneity that may arise when a single summary estimate is used.

Our study had several methodological limitations. All but 1 study in our meta-analysis was observational; diverse study designs and patient characteristics make interpretation of aggregated estimates challenging, and causality could not be inferred. Additionally, it limits the relevance and reliability of the results. For more definitive conclusions, randomized designs by site (with or without on-site CABG surgery) with inclusion of low-risk, elective PCI is needed. For these analyses, we only had summary estimates, and we may not have adjusted for important patient-level covariates. On-site surgery may be a surrogate for other variables that could have favorable or adverse effects on outcome (eg, trainee operators, case mix, number of operators and their experience, skills of the nonmedical catheter laboratory team, private vs public institutions). However, these variables were not reported in the studies used for this analysis and thus could not be considered. Moreover, heterogeneity was moderate in the mortality analyses of nonprimary PCI. Variation in the definition of acute myocardial infarction and significant overlap in the indications for PCI did not allow us to separately analyze the results of truly low-risk, elective PCI. Hence, we aggregated the results into the nonprimary PCI category, which may not truly reflect the outcomes of elective PCI. Furthermore, very few studies reported a composite end point of death and emergency CABG surgery, precluding the chance to study whether one is being traded for another. We also restricted our search to English-language sources.

Our study method also had several strengths. The magnitude and consistency of the observed effects for primary PCI make the likelihood of bias

affecting this observation unlikely. Moreover, we rigorously controlled for publication bias and used random-effects models that are generally better suited when studies are only gathered from the published literature.

In conclusion, this meta-analysis provides evidence that rates of in-hospital mortality and emergency CABG surgery for primary and nonprimary PCI are similar at centers with and without on-site surgery. Additional outcome data are still needed, including rates and indications for urgent or emergency transfers, especially in patients undergoing nonprimary PCI at centers without on-site surgery.

**Author Contributions:** Dr Singh had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Study concept and design:** Singh, Holmes, Wharton, Kutcher, Rihal.

**Acquisition of data:** Holmes, Aversano.

**Analysis and interpretation of data:** Holmes, Dehmer, Lennon, Wharton, Kutcher, Aversano, Rihal.

**Drafting of the manuscript:** Singh, Holmes, Wharton, Rihal.

**Critical revision of the manuscript for important intellectual content:** Singh, Holmes, Dehmer, Lennon, Wharton, Kutcher, Aversano, Rihal.

**Statistical analysis:** Lennon.

**Administrative, technical, or material support:** Holmes, Rihal.

**Study supervision:** Singh, Holmes, Dehmer, Kutcher, Rihal.

**Conflict of Interest Disclosures:** All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

**Online-Only Material:** The eFigure is available at <http://www.jama.com>.

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It helps to write down half a dozen things which are worrying me. Two of them, say, disappear; about two nothing can be done, so it's no use worrying; and two perhaps can be settled.

—Winston Churchill (1874-1965)