

## **SUPPLEMENTAL MATERIAL:**

**Supplemental Methods:** Covariates included in the multivariable model

**Supplemental Table 1:** Baseline characteristics of patients included and excluded in the primary analysis

**Supplemental Table 2:** 30-day death and major bleeding by operator volume

**Supplemental Table 3:** Cumulative incidence of death and MACE over 1-year follow-up by subgroup

**Supplemental Table 4:** 1-year recurrent MI and unplanned revascularization by operator volume

**Supplemental Table 5:** Association between operator volume, analyzed continuously, and outcomes

**Supplemental Table 6:** Operator volume in 2014 by years of experience

## **Supplemental Appendix 1: Covariates included in multivariable models**

Age (>70 and ≤70 years); cardiogenic shock; prior heart failure; peripheral vascular disease; chronic lung disease; estimated glomerular filtration rate (calculated using the Modification of Diet in Renal Disease equation); New York Heart Association functional class; presentation with ST-segment elevation myocardial infarction (STEMI) (only for overall population); ethnicity; body mass index (≤30 and >30 kg/m<sup>2</sup>); diabetes; dyslipidemia; hypertension; cerebrovascular disease; current/recent smoker; prior coronary artery bypass grafting; prior myocardial infarction; prior percutaneous coronary intervention (PCI); cardiomyopathy or left ventricular systolic dysfunction; pre-PCI left ventricular ejection fraction; year of PCI; lesion length; multivessel disease; chronic total occlusion; bifurcation lesion; in-stent restenosis; at least one previously treated lesion within 1 month with in-stent thrombosis; lesion in graft; lesion complexity (high vs. non); Lesion location: left main/proximal left anterior descending coronary artery vs. mid/distal left anterior descending coronary artery vs. other; discharge P2Y<sub>12</sub> inhibitor; discharge aspirin; discharge beta blocker; discharge statin.

**Supplemental Table 1:** Baseline characteristics of patients included and excluded in the primary analysis

	Patients excluded (n = 574,189)	Patients included (n = 723,644)
<b>Hospital characteristics</b>		
Hospital region		
Northeast	102,338 (17.8%)	104,044 (14.4%)
Midwest	158,022 (27.5%)	204,514 (28.3%)
South	221,528 (38.6%)	316,948 (43.8%)
West	92,291 (16.1%)	98,114 (13.6%)
Urban location	331,615 (57.8%)	395,016 (54.6%)
No. of beds	404 (274, 587)	393 (261, 576)
Annual PCI volume	685 (428, 1084)	663 (406, 1083)
Teaching hospital*	280,808 (48.9%)	333,131 (46.0%)
Private/community hospital	511,745 (89.1%)	641,075 (88.6%)
<b>Patient characteristics</b>		
Age	73 (68, 79)	74 (69, 80)
Male	367,130 (63.9%)	448,322 (62.0%)
White	510,502 (88.9%)	662,486 (91.6%)
Admit source		
Emergency dept	205,099 (35.7%)	251,165 (34.7%)
Transfer in	82,398 (14.4%)	129,335 (17.9%)

	Patients excluded (n = 574,189)	Patients included (n = 723,644)
Other	286,091 (49.8%)	342,418 (47.3%)
BMI	28 (25, 32)	29 (25, 32)
GFR	68 (53,86)	67 (52, 85)
Prior MI	205,866 (35.9%)	196,693 (27.2%)
Prior CHF	95,661 (16.7%)	111,603 (15.4%)
HF within 2 weeks	71,962 (12.5%)	97,340 (13.5%)
LV systolic dysfunction	73,956 (12.9%)	90,579 (12.5%)
Cardiogenic shock within 24 hours	14,883 (2.6%)	21,785 (3.0%)
Cardiac arrest within 24 hours	8,388 (1.5%)	12,573 (1.7%)
Diabetes	233,720 (40.7%)	269,926 (37.3%)
Cerebrovascular disease	96,591 (16.8%)	122,238 (16.9%)
Peripheral vascular disease	96,392 (16.8%)	115,744 (16.0%)
Hypertension	507,111 (88.3%)	626,220 (86.5%)
Chronic lung disease	100,870 (17.6%)	133,221 (18.4%)
Current/recent smoker	77,787 (13.6%)	100,217 (13.9%)
Dyslipidemia	485,785 (84.6%)	583,235 (80.6%)
Prior PCI	316,611 (55.1%)	246,607 (34.1%)
Prior CABG	145,769 (25.4%)	163,621 (22.6%)
Admission symptoms		
No symptoms	49,452 (8.6%)	55,855 (7.7%)

	Patients excluded (n = 574,189)	Patients included (n = 723,644)
Atypical chest pain	15,519 (2.7%)	23,541 (3.3%)
Stable angina	99,873 (17.4%)	122,145 (16.9%)
Unstable angina	237,984 (41.5%)	280,997 (38.8%)
NSTEMI	107,109 (18.7%)	146,333 (20.2%)
STEMI	64,126 (11.2%)	94,616 (13.1%)
PCI status		
Elective	268,669 (46.8%)	321,495 (44.4%)
Urgent	231,056 (40.2%)	294,611 (40.7%)
Emergency	72,615 (12.7%)	104,729 (14.5%)
Salvage	1,629 (0.3%)	2,517 (0.4%)
Discharge Medications		
Aspirin	537,463 (96.5%)	671,417 (96.1%)
P2Y <sub>12</sub> inhibitor	541,518 (96.3%)	674,862 (95.7%)
Statin	494,365 (90.1%)	609,710 (88.4%)
Beta blocker	465,700 (85.2%)	568,723 (83.0%)
<b>Lesion characteristics</b>		
Lesion segment		
Left main	18,702 (3.3%)	23,045 (3.2%)
Proximal LAD	94,300 (16.4%)	126,496 (17.5%)
pRCA/mLAD/pLCx	215,680 (37.6%)	276,985 (38.3%)
Other	243,998 (42.5%)	295,063 (40.8%)

	Patients excluded (n = 574,189)	Patients included (n = 723,644)
Previously treated lesion	89,297 (15.6%)	58,792 (8.1%)
Vein graft lesion	50,050 (8.7%)	55,062 (7.6%)
Chronic total occlusion	15,614 (20.3%)	17,545 (17.5%)
Bifurcation lesion	64,755 (11.3%)	80,112 (11.1%)
Lesion length	16 (12, 23)	16 (12, 23)
No. lesions attempted in lab visit		
1	417,783 (72.8%)	527,321 (72.9%)
2	124,050 (21.6%)	155,520 (21.5%)
≥ 3	32,356 (5.6%)	40,803 (5.6%)
Radial access	73,825 (12.9%)	87,714 (12.1%)
Unfractionated heparin	286,408 (50.0%)	367,617 (50.9%)
Bivalirudin	354,402 (61.8%)	434,174 (60.0%)
Glycoprotein IIb/IIIa inhibitor	110,020 (19.2%)	159,510 (22.1%)
Drug eluting stent	422,819 (73.6%)	509,776 (70.5%)
Fluoroscopy time (minutes)	12 (8, 20)	12 (8, 19)
Contrast volume (mL)	175 (125, 230)	180 (130, 235)
IVUS performed	11,805 (21.0%)	13,358 (20.8%)

\*, residency/fellowship program; BMI, body mass index; GFR, glomerular filtration rate, calculated by the Modification of Diet in Renal Disease equation; MI, myocardial infarction; CHF, congestive heart failure; HF, heart failure; LV, left ventricular; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; NSTEMI, non-ST segment elevation myocardial infarction; STEMI, ST segment elevation myocardial infarction.

**Supplement Table 2: 30-day death and major bleeding by operator volume**

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
<b>Death</b>		
All patients		
High vs. low volume	0.92 (0.88-0.97)*	0.91 (0.86-0.96)*
Intermediate vs. low volume	1.00 (0.95-1.06)	0.95 (0.90-1.01)
STEMI only		
High vs. low volume	0.93 (0.87-0.99)*	0.86 (0.79-0.92)*
Intermediate vs. low volume	0.93 (0.87-1.00)*	0.87 (0.80-0.94)*
UA/NSTEMI only		
High vs. low volume	1.07 (1.00-1.16)	0.97 (0.91-1.05)
Intermediate vs. low volume	1.08 (1.00-1.17)	1.03 (0.95-1.12)
Stable angina only		
High vs. low volume	0.92 (0.73-1.17)	0.92 (0.64-1.05)
Intermediate vs. low volume	1.00 (0.77-1.29)	0.94 (0.72-1.22)
<b>Major bleeding</b>		
All patients		
High vs. low volume	0.95 (0.90-1.01)	0.96 (0.91-1.12)

Intermediate vs. low volume	1.01 (0.96-1.08)	1.00 (0.94-1.06)
STEMI only		
High vs. low volume	1.03 (0.93-1.13)	1.00 (0.91-1.11)
Intermediate vs. low volume	1.07 (0.97-1.18)	1.05 (0.95-1.16)
UA/NSTEMI only		
High vs. low volume	0.94 (0.87-1.01)	0.90 (0.84-0.97)*
Intermediate vs. low volume	0.94 (0.87-1.01)	0.92 (0.85-0.99)*
Stable angina only		
High vs. low volume	0.94 (0.80-1.11)	0.87 (0.74-1.03)
Intermediate vs. low volume	1.04 (0.88-1.24)	1.02 (0.86-1.21)

\*  $p < 0.05$ . MI, myocardial infarction; OR, hazard ratio; CI, confidence interval; STEMI, ST segment elevation MI; UA, unstable angina; NSTEMI, non-ST segment elevation MI. Low-volume operators performed < 50 PCIs/year; intermediate-volume operators performed 50-100 PCIs/year; high-volume operators performed > 100 PCIs/year



**Supplemental Table 3:** Cumulative incidence of death and MACE over 1-year follow-up by subgroup

	Cumulative incidence (95% CI)			Log-rank p-value
	Low-volume	Intermediate-volume	High-volume	
<b>Death</b>				
Overall	9.5 (9.3-9.7)	9.9 (9.7-10.0)	9.8 (9.7-9.9)	0.03
STEMI	18.9 (18.2-19.7)	18.8 (18.4-19.3)	18.7 (18.4-19.1)	0.73
UA/NSTEMI	8.7 (8.4-8.9)	9.2 (9.0-9.4)	9.5 (9.4-9.6)	< 0.001
Stable angina	4.7 (4.4-5.1)	4.5 (4.3-4.7)	4.8 (4.6-4.9)	0.22
CTO	16.0 (14.4-17.6)	14.9 (14.0-15.8)	12.3 (11.8-12.9)	< 0.001
Bifurcation	10.6 (9.8-11.3)	10.2 (9.8-10.6)	10.7 (10.5-11.0)	0.21
Left main	18.5 (16.3-20.7)	19.3 (18.1-20.6)	18.3 (17.6-19.0)	0.13
<b>MACE</b>				
Overall	15.9 (15.6-16.1)	16.2 (16.0-16.3)	16.5 (16.4-16.6)	0.004
STEMI	24.7 (23.9-25.6)	24.3 (23.9-24.8)	24.5 (24.1-24.9)	0.50
UA/NSTEMI	15.9 (15.5-16.3)	16.3 (16.1-16.5)	16.8 (16.7-17.0)	< 0.001
Stable angina	10.4 (9.8-10.9)	10.0 (9.7-10.3)	10.7 (10.5-11.0)	0.003
CTO	22.6 (20.8-24.5)	21.4 (20.3-22.5)	18.8 (18.1-19.5)	< 0.001
Bifurcation	16.4 (15.5-17.3)	16.6 (16.1-17.1)	17.5 (17.1-17.8)	0.01
Left main	27.3 (24.7-29.9)	26.4 (25.1-27.8)	26.8 (25.9-27.6)	0.80

CI, confidence interval; STEMI, ST segment elevation MI; UA, unstable angina; NSTEMI, non-ST segment elevation MI; CTO, chronic total occlusion. Low-volume operators performed < 50 PCIs/year;

intermediate-volume operators performed 50-100 PCIs/year; high-volume operators performed > 100 PCIs/year

**Supplemental Table 4: 1-year recurrent MI and unplanned revascularization by operator volume**

	Recurrent MI		Unplanned revascularization	
	Unadjusted HR (95% CI)	Adjusted HR (95% CI)	Unadjusted HR (95% CI)	Adjusted HR (95% CI)
Overall				
High vs. low volume	1.05 (1.01-1.09)*	0.98 (0.95-1.02)	1.06 (1.02-1.09)*	1.03 (0.99-1.06)
Intermediate vs. low volume	1.01 (0.97-1.05)	0.98 (0.95-1.02)	1.01 (0.97-1.04)	1.01 (0.97-1.04)
STEMI only				
High vs. low volume	0.98 (0.89-1.07)	0.96 (0.88-1.05)	0.98 (0.91-1.06)	0.96 (0.89-1.03)
Intermediate vs. low volume	0.95 (0.86-1.05)	0.95 (0.86-1.04)	0.95 (0.88-1.03)	0.95 (0.88-1.03)
UA/NSTEMI only				
High vs. low volume	1.02 (0.97-1.06)	0.96 (0.92-1.01)	1.03 (0.99-1.07)	1.00 (0.97-1.04)
Intermediate vs. low volume	0.98 (0.94-1.03)	0.97 (0.92-1.01)	0.99 (0.95-1.03)	1.00 (0.96-1.04)
Stable angina only				
High vs. low volume	1.06 (0.98-1.16)	1.02 (0.93-1.11)	1.09 (1.01-1.17)*	1.06 (0.99-1.14)
Intermediate vs. low volume	1.06 (0.98-1.17)	1.05 (0.95-1.15)	1.00 (0.94-1.08)	1.01 (0.94-1.08)
Chronic total occlusion				
High vs. low volume	0.88 (0.73-1.06)	0.94 (0.77-1.13)	1.01 (0.95-1.18)	1.02 (0.86-1.20)
Intermediate vs. low volume	0.99 (0.81-1.22)	1.02 (0.83-1.25)	0.96 (0.81-1.14)	0.98 (0.82-1.17)
Bifurcation lesion				
High vs. low volume	1.10 (0.99-1.23)	1.03 (0.93-1.14)	1.10 (1.01-1.21)*	1.07 (0.98-1.16)
Intermediate vs. low volume	1.04 (0.93-1.17)	1.01 (0.91-1.13)	1.03 (0.94-1.13)	1.04 (0.94-1.13)

Left main lesion				
High vs. low volume	0.91 (0.75-1.10)	0.89 (0.74-1.08)	0.87 (0.74-1.03)	0.89 (0.75-1.05)
Intermediate vs. low volume	0.84 (0.68-1.04)	0.94 (0.68-1.04)	0.80 (0.66-0.95)*	0.83 (0.69-0.99)*

\*  $p < 0.05$ . HR, hazard ratio; MI, myocardial infarction; other abbreviations per Supplemental Table 1.

Low-volume operators performed < 50 PCIs/year; intermediate-volume operators performed 50-100

PCIs/year; high-volume operators performed > 100 PCIs/year

**Supplemental Table 5:** Association between operator volume, analyzed continuously, and 1-year outcomes

	Unadjusted HR (95% CI)	Adjusted HR (95% CI)
All patients		
MACE	1.01 (1.00-1.02)	1.00 (0.99-1.00)
Post-discharge MACE	1.02 (1.01-1.03)*	1.01 (1.00-1.01)
Death	1.00 (0.99-1.01)	0.99 (0.98-1.00)*
Post-discharge death	1.03 (1.02-1.04)*	1.00 (0.99-1.01)
MI	1.02 (1.01-1.04)*	1.00 (0.99-1.01)
Unplanned revascularization	1.03 (1.02-1.05)*	1.02 (1.01-1.03)*
STEMI		
MACE	1.00 (0.99-1.01)	0.99 (0.97-1.00)
Post-discharge MACE	1.02 (1.00-1.03)*	1.00 (0.99-1.01)
Death	1.00 (0.98-1.02)	0.99 (0.97-1.00)
Post-discharge death	1.03 (1.00-1.05)*	1.01 (0.99-1.03)
MI	1.01 (0.98-1.04)	1.00 (0.97-1.02)
Unplanned revascularization	1.01 (1.00-1.03)	1.00 (0.99-1.02)
UA/NSTEMI		
MACE	1.02 (1.01-1.03)*	1.00 (0.99-1.01)
Post-discharge MACE	1.02 (1.01-1.03)*	1.00 (1.00-1.01)
Death	1.02 (1.01-1.04)*	0.99 (0.99-1.01)
Post-discharge death	1.04 (1.02-1.05)*	1.01 (0.99-1.02)

MI	1.02 (1.01-1.03)*	0.99 (0.98-1.01)
Unplanned revascularization	1.03 (1.01-1.04)*	1.01 (1.00-1.03)*
Stable angina		
MACE	1.03 (1.00-1.05)*	1.01 (0.99-1.03)
Post-discharge MACE	1.03 (1.01-1.04)*	1.01 (1.00-1.03)
Death	1.01 (0.98-1.04)	0.99 (0.96-1.01)
Post-discharge death	1.01 (0.98-1.04)	0.99 (0.97-1.02)
MI	1.02 (1.00-1.05)	1.00 (0.98-1.02)
Unplanned revascularization	1.05 (1.03-1.08)*	1.04 (1.02-1.06)*

\*  $p < 0.05$ ; all abbreviations per Supplemental Tables 1 and 2. HRs represent the change in hazard per 50 unit PCI increase in average annual volume.

**Supplemental Table 6:** Operator volume in 2014 by years of experience

	<b>Years of experience, 2009-2013</b>		
<b>Operator volume, 2014</b>	<b>0-1 Year (n = 652 operators)</b>	<b>2-4 years (n = 1469 operators)</b>	<b>&gt; 4 years (n = 4403 operators)</b>
<b>Low (&lt; 50 PCIs)</b>	382 (58.6%)	480 (32.7%)	1343 (30.5%)
<b>Intermediate (50-100 PCIs)</b>	172 (26.4%)	499 (34.0%)	1491 (33.9%)
<b>High (&gt; 100 PCIs)</b>	98 (15.0%)	490 (33.4%)	1569 (35.6%)

$p < 0.001$