Comparison of Inhospital Mortality, Length of Hospitalization, Costs, and Vascular Complications of Percutaneous Coronary Interventions Guided by Ultrasound Versus Angiography

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Despite the valuable role of intravascular ultrasound (IVUS) guidance in percutaneous coronary interventions (PCIs), its impact on clinical outcomes remains debatable. The aim of the present study was to compare the outcomes of PCIs guided by IVUS versus angiography in the contemporary era on inhospital outcomes in an unrestricted large, nationwide patient population. Data were obtained from the Nationwide Inpatient Sample from 2008 to 2011. Hierarchical mixed-effects logistic regression models were used for categorical dependent variables like inhospital mortality, and hierarchical mixed-effects linear regression models were used for continuous dependent variables like length of hospital stay and cost of hospitalization. A total of 401,571 PCIs were identified, of which 377,096 were angiography guided and 24,475 (weighted n = 119,102) used IVUS. In a multivariate model, significant predictors of higher mortality were increasing age, female gender, higher baseline co-morbidity burden, presence of acute myocardial infarction, shock, weekend and emergent admission, or occurrence of any complication during hospitalization. Significant predictors of reduced mortality were the use of IVUS guidance (odds ratio 0.65, 95% confidence interval 0.52 to 0.83; p <0.001) for PCI and higher hospital volumes (third and fourth quartiles). The use of IVUS was also associated with reduced inhospital mortality in subgroup of patients with acute myocardial infarction and/or shock and those with a higher co-morbidity burden (Charlson's co-morbidity index ≥2). In one of the largest studies on IVUS-guided PCIs in the drug-eluting stent era, we demonstrate that IVUS guidance is associated with reduced inhospital mortality, similar length of hospital stay, and increased cost of care and vascular complications compared with conventional angiography-guided PCIs. **© 2015 Elsevier Inc. All rights reserved.** **(Am J Cardiol 2015;115:1357−1366)**

Intravascular ultrasound (IVUS), secondary to its excellent spatial resolution, provides valuable complementary information to angiography on cross-sectional coronary anatomy and plaque burden and composition. Furthermore, IVUS guidance is useful in selecting appropriate treatment strategy, stent sizing, and optimal deployment, especially in complex lesions. Despite the valuable role of IVUS guidance in percutaneous coronary interventions (PCIs), its impact on clinical outcomes remains controversial. The initial studies performed in the bare-metal stent (BMS) era demonstrated that IVUS-guided PCI significantly reduced the risk of restenosis

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See page 1365 for disclosure information.

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http://dx.doi.org/10.1016/j.amjcard.2015.02.037

Table 1
Baseline characteristics of the studied population

Demographic variable	Angiography guided PCI	IVUS guided PCI	Overall	P-value
Total no. of PCI (Unweighted NO.)	377,096	24,475	401,571	
Total no. of PCI (weighted no.)	18,594,82	119,102	19,785,84	
Patient level variables				
Age(Continuous Variable)	64.3±0.02	64.1±0.08	64.3±0.01	0.012
Age (years)				<0.001
18-34	0.6	0.6	0.6	
35-49	11.9	11.2	11.8	
50-64	38.0	38.5	38.1	
65-79	37.0	38.8	37.1	
≥80	12.6	10.9	12.5	
Gender				<0.001
Male	66.4	64.5	66.3	
Female	33.6	35.5	33.7	
Race*				<0.001
White	64.9	66.2	65.0	
Non-white	16.6	17.8	16.7	
Missing	18.4	16.1	18.3	
Charlson/Deyo comorbidity index[†]				<0.001
0	18.7	25.3	19.1	
1	39.4	37.6	39.3	
≥2	41.9	37.1	41.6	
Comorbidities[‡]				
Obesity	13.4	13.9	13.5	<0.001
History of hypertension	72.1	73.7	72.2	<0.001
History of diabetes	34.0	32.8	34.0	<0.001
History of congestive heart failure	0.5	0.4	0.5	0.489
History of chronic pulmonary disease	15.7	15.5	15.7	0.106
Peripheral vascular disease	10.6	10.5	10.6	0.743
Renal failure	16.9	16.4	16.9	<0.001
Neurological disorder or paralysis	3.6	3.3	3.6	<0.001
Anemia or Coagulopathy	8.7	8.5	8.7	0.028
Hematological or Oncological malignancy	1.5	1.5	1.5	0.125
Weight loss	0.6	0.6	0.6	0.221
Rheumatoid arthritis or other collagen vascular disease	1.9	1.9	1.9	0.174
Depression, psychosis or substance abuse	8.5	8.9	8.5	<0.001
Median household income category for patient's zip code[§]				<0.001
1. 0-25th percentile	27.1	24.4	26.9	
2. 26-50th percentile	27.6	25.3	27.5	
3. 51-75th percentile	24.0	24.3	24.0	
4. 76-100th percentile	19.1	23.8	19.4	
Primary Payer				<0.001
Medicare / Medicaid	55.8	55.7	55.8	
Private including HMO	35.0	37.1	35.1	
Self pay/no charge/other	9.0	6.9	8.9	
Hospital characteristics				
Hospital bed size				<0.001
Small	6.9	6.9	6.9	
Medium	18.8	22.1	19.0	
Large	73.3	70.6	73.2	
Hospital Location				
Rural	6.6	5.6	6.5	
Urban	92.4	94.0	92.5	
Hospital Region				<0.001
Northeast	20.3	19.5	20.3	
Midwest or North Central	28.0	22.6	27.7	
South	41.5	35.8	41.2	
West	9.9	21.9	10.6	
Hospital Teaching status				<0.001
Non-teaching	43.9	42.4	43.8	
Teaching	55.1	57.1	55.2	
Admission types				<0.001
Emergent/Urgent	74.5	69.0	74.2	

Table 1
(*continued*)

Demographic variable	Angiography guided PCI	IVUS guided PCI	Overall	P-value
Elective admission	24.6	29.9	24.9	
Admission day				<0.001
Weekdays	83.3	87.1	83.5	
Weekend	16.7	12.9	16.5	
No. of Vessel stents¶				<0.001
Single Vessel Single Stent	50.3	50.7	50.3	
Single Vessel multiple stents	17.2	22.3	17.5	
Bifurcation Stenting	2.5	3.6	2.6	
Multivessel Stenting	15.8	20.5	16.1	
Type of Stent¶				
Bare Metal Stent	29.2	22.7	28.8	<0.001
Drug Eluting Stent	73.1	79.9	73.5	<0.001
AMI	46.3	33.0	45.5	<0.001
Shock	1.4	1.0	1.3	<0.001
Length of stay (days) (Mean±SE)	2.8±0.01	2.55±0.02	2.78±0.01	<0.001
Cost of Hospitalization($)(Means ± SE)	18,019±18	19,779±14	18,111±18	<0.001
Disposition				<0.001
Home	95.2	96.9	95.3	
Facility/others	3.6	2.4	3.6	
Death	0.8	0.4	0.8	<0.001

* Race was missing in 18% of the study population and hence excluded in the multivariable analysis.
† Charlson/Deyo comorbidity index was calculated as per Deyo classification.
‡ Variables are AHRQ comorbidity measures.
§ This represents a quartile classification of the estimated median household income of residents in the patient's ZIP Code. These values are derived from ZIP Code-demographic data obtained from Claritas. The quartiles are identified by values of 1 to 4, indicating the poorest to wealthiest populations. Because these estimates are updated annually, the value ranges vary by year. http://www.hcupus.ahrq.gov/db/vars/zipinc_qrtl/nisnote.jsp.
¶ All the procedure and diagnosis were identified by using International Classification of Disease (ICD-9) codes. 36.06 Insertion of non-drug-eluting coronary artery stent (bare metal stent), 36.07 insertion of drug-eluting coronary artery stent, 410.xx acute myocardial infarction, 785.5x shock,00.40 procedure on single vessel, 00.41 procedure on two vessels, 00.42 procedure on three vessels, 00.43 procedure on four or more vessels, 00.44 procedure on vessel bifurcation, 00.45 insertion of one vascular stent, 00.46 insertion of two vascular stents, 00.47 insertion of three vascular stents, 00.48 insertion of four or more vascular stents.

Table 2
Complications*

Complications	Angiography guided PCI	IVUS guided PCI	Overall	P-value
Overall any complication	5.5	5.5	5.5	0.538
Vascular complications	1.7	2	1.8	<0.001
Postoperative hemorrhage requiring transfusion	0.5	0.7	0.5	<0.001
Vascular injury	1.2	1.4	1.3	<0.001
Cardiac complications	1.4	1.8	1.5	<0.001
Iatrogenic cardiac complications	1.4	1.7	1.4	<0.001
Pericardial complications	0.1	0.1	0.1	<0.001
Requiring CABG	0.01	0.01	0.01	0.012
Respiratory complications (Post-op resp failure)	1.5	1	1.5	<0.001
Postop-Stroke/TIA/Stroke effects	0.2	0.2	0.2	0.372
Renal and metabolic complications	0.24	0.15	0.2	<0.001
Postoperative DVT/PE	0.3	0.3	0.3	0.930
Postop infectious complications	0.5	0.4	0.5	0.01

CABG = coronary artery bypass graft surgery; DVT = deep venous thrombosis; TIA = transient ischemic attack; PE = pulmonary embolism.
* Details in supplementary Table 2.

and target vessel revascularization with no effect on mortality and myocardial infarction (MI).[1,2] However, the studies evaluating IVUS-guided PCI in the drug-eluting stent (DES) era are limited and have yielded conflicting results. Additionally, most studies have been underpowered to detect meaningful differences in clinical outcomes with IVUS-guided PCI. However, there is recent evidence that suggests IVUS-guided PCI in the DES era may significantly reduce the risk of death and stent thrombosis compared with angiography guidance.[3−8] The aim of the present study was to compare the outcome PCIs guided by IVUS versus those guided by angiography in the contemporary era on inhospital outcomes in an unrestricted large, nationwide patient population.

Table 3
Multivariate predictors of In-hospital Mortality

Variables	Odds Ratio	LL	UL	P-value
Presence of any complications	5.80	5.25	6.41	<0.001
Age (10 year increment)	1.63	1.56	1.71	<0.001
Female	1.12	1.03	1.22	0.007
AMI	3.70	3.24	4.23	<0.001
Shock	15.40	13.86	17.12	<0.001
Charlson/Deyo comorbidity index*				
0	Referent	Referent	Referent	
1	1.81	1.36	2.42	<0.001
≥2	2.81	2.11	3.75	<.001
Median household income category for patient's zip code†				
1. 0-25th percentile	Referent	Referent	Referent	
2. 26-50th percentile	1.00	0.89	1.12	0.968
3. 51-75th percentile	0.97	0.86	1.10	0.620
4. 76-100th percentile	0.94	0.82	1.09	0.418
Procedure				
Angiography	Referent	Referent	Referent	
IVUS	0.65	0.52	0.83	<0.001
Primary Payer				
Medicare / Medicaid	Referent	Referent	Referent	
Private including HMO	0.86	0.75	0.97	0.018
Self pay/no charge/other	1.27	1.07	1.51	0.007
Teaching vs non-teaching hospital	1.02	0.91	1.14	0.717
Weekend vs Weekdays admission	1.14	1.04	1.26	0.007
Emergent/urgent admission vs elective	1.58	1.36	1.84	<.001
Hospital Region				
Northeast	Referent	Referent	Referent	
Midwest or North Central	1.17	0.98	1.39	0.083
South	1.45	1.23	1.71	<.001
West	1.17	0.96	1.43	0.128
hospital Volume (Quartile)				
1st Quartile (1-313)	Referent	Referent	Referent	
2nd Quartile (314- 539)	1.00	0.88	1.13	0.937
3rd Quartile (540 - 947)	0.86	0.75	0.99	0.039
4th Quartile (948- 3420)	0.75	0.63	0.90	0.002
c-Index	0.92			

HMO = Health Maintenance Organization.
* Charlson/Deyo comorbidity index was calculated as per Deyo classification.
† Please refer Table 1.

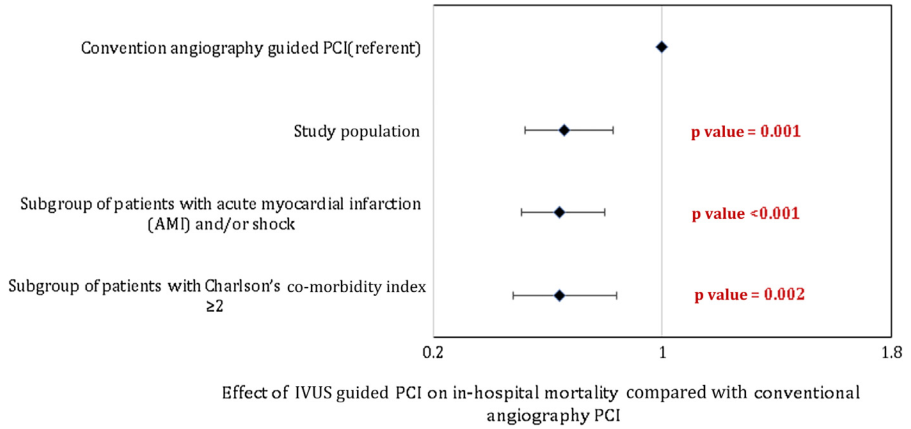

Figure 1. Effect of IVUS on inhospital mortality.

Methods

Data were obtained from the Nationwide Inpatient Sample (NIS). NIS is a part of a family of databases developed for the Healthcare Cost and Utilization Project and is sponsored by the Agency for Healthcare Research and Quality (AHRQ). NIS contains all discharge data from >1,000 short-term and

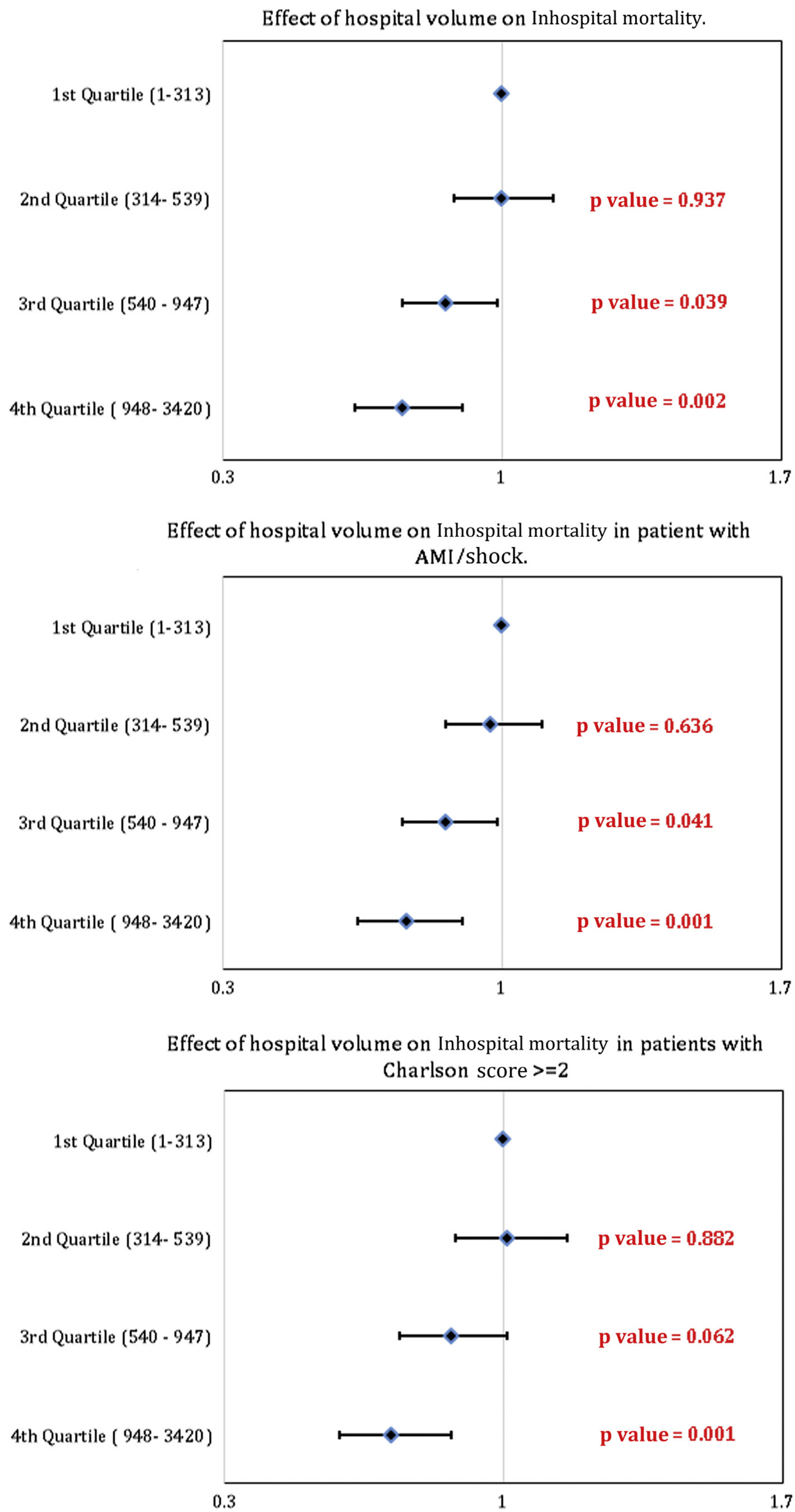

Figure 2. Effect of hospital volume on inhospital mortality.

Table 4
Multivariate analysis in-hospital mortality in different subgroups

Variables	AMI and/or Shock				Charlson Score >= 2			
	Odds ratio	LL	UL	P-value	Odds ratio	LL	UL	P-value
Presence of any complications	9.00	8.22	9.84	<.001	4.90	4.37	5.48	<.001
Age (10 year increment)	1.61	1.54	1.69	<.001	1.60	1.52	1.68	<.001
Female	1.12	1.03	1.21	0.006	1.05	0.95	1.15	0.347
AMI		Referent Group			3.40	2.93	3.94	<.001
Shock					13.01	11.55	14.67	<.001
Charlson/Deyo comorbidity index*								
0					Referent Group			
1	Referent	Referent	Referent					
≥2	1.66	1.51	1.83	<.001				
Median household income category for patient's zip code								
1. 0-25th percentile	Referent	Referent	Referent		Referent	Referent	Referent	
2. 26-50th percentile	1.03	0.93	1.15	0.559	0.98	0.86	1.11	0.713
3. 51-75th percentile	0.96	0.86	1.09	0.539	1.01	0.87	1.16	0.934
4. 76-100th percentile	1.01	0.87	1.16	0.925	0.99	0.86	1.15	0.932
Procedure								
Angiography	Referent	Referent	Referent		Referent	Referent	Referent	
IVUS	0.64	0.51	0.80	<.001	0.64	0.48	0.84	0.002
Primary Payer								
Medicare / Medicaid	Referent	Referent	Referent		Referent	Referent	Referent	
Private including HMO	0.82	0.72	0.93	0.002	0.87	0.75	1.01	0.075
Self pay/no charge/other	1.28	1.08	1.51	0.004	1.15	0.94	1.41	0.174
Teaching vs non-teaching hospital	0.98	0.88	1.10	0.747	1.01	0.89	1.14	0.920
Weekend vs Weekdays admission	1.16	1.06	1.27	0.001	1.13	1.01	1.26	0.029
Emergent/urgent admission vs elective	1.59	1.35	1.88	<.001	1.59	1.33	1.92	<.001
Hospital Region								
Northeast	Referent	Referent	Referent		Referent	Referent	Referent	
Midwest or North Central	1.20	1.01	1.43	0.037	1.18	0.99	1.40	0.067
South	1.39	1.17	1.65	<.001	1.43	1.21	1.69	<.001
West	1.22	1.00	1.49	0.049	1.14	0.92	1.40	0.231
hospital Volume (Quartile)								
1st Quartile (1-313)	Referent	Referent	Referent		Referent	Referent	Referent	
2nd Quartile (314- 539)	0.97	0.86	1.10	0.636	1.01	0.88	1.16	0.882
3rd Quartile (540 - 947)	0.86	0.75	0.99	0.041	0.87	0.74	1.01	0.063
4th Quartile (948- 3420)	0.76	0.64	0.90	0.001	0.72	0.59	0.87	0.001
c-Index	0.83				0.89			

HMO = Health Maintenance Organization.
* Charlson/Deyo comorbidity index was calculated as per Deyo classification.

non-Federal hospitals each year, which approximates a 20% stratified sample of US community hospitals. Data from the NIS have previously been used to identify, track, and analyze national trends in health care use, patterns of major procedures, access, disparity of care, trends in hospitalizations, charges, quality, and outcomes.[9–14] Annual data quality assessments are performed for internal validity of the database. To maintain the external validity, database is compared with the following data sources: the American Hospital Association Annual Survey Database, the National Hospital Discharge Survey from the National Center for Health Statistics, and the MedPAR inpatient data from the Centers for Medicare and Medicaid Services.[15]

We analyzed data from NIS from 2008 to 2011 using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) procedure codes of 36.06 for non–drug-eluting coronary artery stents and 36.07 for drug-eluting coronary artery stents in any of the procedural fields. Subjects ≥18 years were included. PCIs performed under IVUS guidance were identified by *ICD-9-CM* code 00.24. We excluded PCIs with fractional flow reserve guidance (*ICD-9-CM*: 00.59) or where both fractional flow reserve and IVUS were used. The remaining observations were categorized as angiography-guided (AO) PCIs.

We defined severity of co-morbid conditions using Deyo modification of Charlson's co-morbidity index (CCI).[16] This index contains 17 co-morbid conditions with differential weights. The score ranges from 0 to 33, with higher scores corresponding to greater burden of co-morbid diseases (Supplementary Table 1). Hospitals were categorized as teaching if they had an American Medical Association–approved residency program, were a member of the Council of Teaching Hospitals, or had a full-time equivalent interns and resident-to-patient ratio of ≥0.25. Annual hospital volume was determined on a year-to-year basis using the unique hospital identification number to calculate the total number of procedures performed by a particular institution in a given year.

Table 5
Multivariate predictors of length of hospital stay and cost of Hospitalization

Variables	Length of stay				Cost of Hospitalization			
	Days	LL	UL	P-value	USD ($)	LL	UL	P-value
Presence of any complications	2.65	2.53	2.76	<.001	7544	7307	7781	<.001
Age (10 year increment)	0.18	0.17	0.20	<.001	186	146	226	<.001
Female	0.24	0.22	0.26	<.001	-29	-87	29	0.331
AMI	0.50	0.44	0.56	<.001	1800	1616	1983	<.001
Shock	3.89	3.65	4.13	<.001	10757	10141	11372	<.001
Charlson/ Deyocomorbity index*								
0	Referent	Referent	Referent		Referent	Referent	Referent	
1	0.19	0.15	0.22	<.001	463	369	558	<.001
≥ 2	1.11	1.04	1.17	<.001	2231	2040	2422	<.001
Median household income category for patient's zip code†								
1. 0-25th percentile	Referent	Referent	Referent		Referent	Referent	Referent	
2. 26-50th percentile	-0.10	-0.15	-0.06	<.001	-4	-168	160	0.964
3. 51-75th percentile	-0.10	-0.16	-0.05	<.001	-257	-451	-63	0.010
4. 76-100th percentile	-0.15	-0.23	-0.07	<.001	-99	-557	360	0.673
Procedure								
Angiography	Referent	Referent	Referent		Referent	Referent	Referent	
IVUS	-0.01	-0.08	0.05	0.687	2302	1912	2693	<.001
Primary Payer								
Medicare / Medicaid	Referent	Referent	Referent		Referent	Referent	Referent	
Private including HMO	-0.19	-0.21	-0.16	<.001	-97	-202	8	0.072
Self pay/no charge/other	-0.07	-0.12	-0.02	0.005	-587	-808	-366	<.001
Teaching vs non-teaching hospital	0.01	-0.10	0.12	0.867	374	-233	980	0.228
Weekend vs Weekdays admission	0.51	0.47	0.55	<.001	1273	1159	1386	<.001
Emergent/urgent admission vs elective	0.94	0.86	1.01	<.001	2010	1676	2345	<.001
Hospital Region								
Northeast	Referent	Referent	Referent		Referent	Referent	Referent	
Midwest or North Central	-0.21	-0.37	-0.05	0.009	-290	-1810	1229	0.708
South	-0.01	-0.18	0.17	0.947	-1103	-2472	266	0.115
West	-0.32	-0.50	-0.15	0.000	816	-609	2240	0.262
hospital Volume (Quartile)								
1st Quartile (1-313)	Referent	Referent	Referent		Referent	Referent	Referent	
2nd Quartile (314- 539)	-0.09	-0.17	-0.02	0.014	-1994	-2669	-1319	<.001
3rd Quartile (540 - 947)	-0.23	-0.34	-0.12	<.001	-2557	-3272	-1841	<.001
4th Quartile (948- 3420)	-0.43	-0.56	-0.30	<.001	-3309	-4152	-2467	<.001

AMI = acute myocardial infarction, HMO = Health Maintenance Organization, IVUS = intravascular ultrasound.
* Charlson/Deyo comorbidity index was calculated as per Deyo classification.
† Please refer Table 1.

The primary outcome was all-cause inhospital mortality. Procedural complications were identified by Patient Safety Indicators (PSIs), version 4.4, March 2012, which have been established by the AHRQ to monitor preventable adverse events during hospitalization. These indicators are based on *ICD-9-CM* codes and Medicare severity diagnosis-related groups, and each PSI has specific inclusion and exclusion criteria.[16,17] Procedural complications not included in PSI were identified using *ICD-9-CM* codes (Supplementary Table 2). This methodology of identifying patients who underwent procedures, co-morbid conditions, and associated complications has previously been used in several studies.[11,13]

Other outcomes studied were the length of hospital stay (LOS) and cost of hospitalization. LOS included admissions with observational and inpatient status. To estimate the cost of hospitalization, the NIS data were merged with cost-to-charge ratios available from the Healthcare Cost and Utilization Project. We estimated the cost of each inpatient stay by multiplying the total hospital charge with cost-to-charge ratios. Adjusted cost for each year was calculated in terms of the 2011 cost, after adjusting for inflation according to the latest consumer price index data released by the US government on January 16, 2013.[18,19]

Stata IC 11.0 (Stata-Corp, College Station, Texas) and SAS 9.3 (SAS Institute Inc., Cary, North Carolina) were used for analyses, which accounted for the complex survey design and clustering. All analyses were performed using hospital-level discharge weights provided by the NIS to minimize biases.

Hierarchical mixed-effects models were generated to identify the independent multivariate predictors of inhospital mortality, LOS, and cost of hospitalization. Three-level hierarchical models (with patient-level factors nested within hospital-level factors) were created with the unique hospital identification number incorporated as random effects within the model. Subgroup analysis was also performed in subgroup of patients with acute myocardial infarction (AMI) and/or shock and those with Charlson's comorbidity index ≥2.

Table 6
Propensity score match cohort

	Angiography guided PCI	IVUS guided PCI	P-value
Overall	23,465	23,465	
Age(years)	64.4±0.07	64.2±0.07	0.043
Female	34.62	35.38	0.082
AMI	31.9	32.8	0.046
Shock	0.6	0.92	<.001
Charlson/Deyo comorbidity index*			0.209
0	24.6	25.3	
1	38.0	37.6	
>=2	37.4	37.2	
Median household income category for patient's zip code†			0.280
1. 0-25th percentile	24.2	24.9	
2. 26-50th percentile	25.8	25.8	
3. 51-75th percentile	24.9	24.8	
4. 76-100th percentile	25.1	24.6	
Primary Payer			0.053
Medicare / Medicaid	56.8	55.7	
Private including HMO	36.5	37.3	
Self pay/no charge/other	6.7	6.9	
Hospital Teaching status			0.556
Non-teaching	42.2	42.5	
Teaching	57.8	57.6	
Admission day			<0.001
Weekdays	88.3	87.2	
Weekend	11.7	12.8	
Admission types			0.146
Emergent/Urgent	70.6	70.0	
Elective admission	29.4	30.0	
Hospital Region			<.001
Northeast	19.8	19.6	
Midwest or North Central	22.8	22.6	
South	38.5	36.7	
West	18.9	21.1	
Hospital Volume (Quartile)			0.046
1st Quartile (1-313)	23.4	23.9	
2nd Quartile (314- 539)	24.9	25.3	
3rd Quartile (540 - 947)	21.1	20.1	
4th Quartile (948- 3420)	30.6	30.6	
Outcomes			
Death	0.55	0.4	0.019
Length of stay(days)	2.5± 0.01	2.54± 0.01	0.213
Cost of Hospitalization($)	17,208± 64	19,702± 72	<.001

* Charlson/Deyo comorbidity index was calculated as per Deyo classification.

† Please refer Table 1.

We used propensity-scoring method to establish matched cohorts to control for imbalances of patient and hospital characteristics between the 2 different treatment groups that may have influenced treatment outcome. A propensity score was assigned to each hospitalization. This was based on multivariate logistic regression model that examined the impact of 12 variables (patient demographics, co-morbidities, and hospital characteristics) on the likelihood of treatment assignment. Patients with similar propensity score in the 2 treatment groups were matched using a 1 to 1 scheme without replacement using greedy algorithm.[20]

Variables with >10% missing data (such as race) were not included in the multivariate models. All interactions were thoroughly tested. Collinearity was assessed using variance inflation factor.

Results

A total of 401,571 PCIs were identified, of which 377,096 were AO PCIs and 24,475 used IVUS (IVUS PCIs). Table 1 demonstrates the baseline characteristics of the study population. The mean age of the study population was 64.3 ± 0.02 years with majority (88%) of the patients >50 years; 66% were men and 65% were whites. There were significant differences between the baseline characteristics of the 2 groups (Table 1). More patients in the AO PCI group had CCI score ≥2, diabetes, AMI, low household income (less than twenty-fifth percentile), emergent admissions, weekend admissions, and use of BMS, whereas IVUS PCIs outnumbered in patients with hypertension, high household income (more than seventy-fifth percentile), elective admissions, weekday admissions, multivessel stenting, bifurcation stenting, multiple stents in a single vessel, and use of DES. DES was implanted in nearly 73.5% of the PCIs in this study population.

The mean LOS for the population was 2.78 ± 0.01 days (2.5 ± 0.02 days for IVUS and 2.80 ± 0.01 days for AO PCIs, p <0.001). Overall cost of hospitalization was $18,111 ± 18 ($19,779 ± 14 for IVUS and $18,019 ± 18 for AO, p <0.001). The mortality rate was lower in patients receiving IVUS (0.4% in IVUS group vs 0.8% in angiography group, p <0.001). The overall complications rate was similar in the 2 groups (5.5%); however, vascular and iatrogenic cardiac complications were more frequent in the IVUS group (2% vs 1.7%, p <0.001, and 1.7% vs 1.4%, p <0.001; Table 2).

In a multivariate model, significant predictors of higher mortality were increasing age, female gender, higher baseline co-morbidity burden (high CCI score), presence of AMI or shock, weekend and emergent admission, or occurrence of any complication during hospitalization (Table 3). Significant predictors of reduced mortality were use of IVUS guidance for PCI (odds ratio [OR] 0.65, 95% CI 0.52 to 0.83; p <0.001; Figure 1) and higher hospital volumes (third and fourth quartiles; Figure 2). Similar results were obtained in a multivariate analysis performed in a subgroup of patients with AMI and/or shock and those with higher comorbidity burden (CCI score ≥2; Table 4 and Figures 1 and 2. Multivariate predictors of increased LOS and cost of hospitalization are listed in Table 5. The use of IVUS did not significantly alter the LOS; however, it was associated with slightly higher hospitalization costs compared with AO PCIs ($2302; 95% CI $1912 to $2693; p <0.001).

Propensity score match analysis is listed in Table 6. In this analysis, multiple patient- and hospital-level variables that could have affected treatment selection were adjusted for. These variables included age, gender, AMI, shock, CCI, median household income, primary payer, admission day, admission type, hospital teaching status, hospital region, and hospital volume. The propensity score matching analysis also showed a reduction in inhospital mortality, increase in cost of hospitalization, and no change with LOS associated with using IVUS.

Discussion

In one of the largest studies on IVUS-guided PCIs in the DES era, we demonstrate that IVUS-guided PCI is associated with reduced inhospital mortality, no effect on the LOS, and minimal increase in the cost of care compared with conventional angiography-guided PCIs. Overall complication's rate (identified by PSIs) was similar in the 2 groups, however, the use of IVUS was associated with a higher rate of vascular and cardiac complications.

The use of IVUS (class IIa recommendation as per the American College of Cardiology/American Hospital Association PCI guidelines for use in angiographically intermediate coronary stenosis) has been previously associated with improved procedural and clinical outcomes.[2,21,22] Published studies have noted IVUS to reduce restenosis and repeat revascularization rates after BMS implantation without any significant impact on post-PCI MI or mortality.[2] Although the restenosis rates have dramatically improved since introduction of DES, stent thrombosis remains a serious concern. Most stent thrombosis occurs in the first 30 days after stent implantation mostly because of technical and procedural factors. Although IVUS-guided PCI has not been shown to affect restenosis rates in DES, it has been posited to reduce stent thrombosis rates, thus, positively influencing mortality outcomes after DES implantation.

The Angiography versus IVUS Optimization study failed to show any significant effect of IVUS-guided PCI on stent thrombosis or mortality outcomes.[4] A recently published cohort study based on the pan-London (United Kingdom) PCI registry also did not show any significant difference in inhospital mortality between the IVUS-guided PCI group (13 of 1,831 patients [0.7%]) and the angiography-guided PCI group (177 of 37,090 patients [0.5%]; $p = 0.12$).[23] In the current era of improved PCI outcomes and consequential rarity of stent thrombosis and inhospital deaths, these studies were possibly underpowered to detect significant difference in mortality. This hypothesis is supported by a recent (largest till date) randomized trial: The Assessment of Dual Antiplatelet Therapy With Drug-Eluting Stents and another meta-analysis (which included this trial), which suggest that IVUS guidance may reduce stent thrombosis and cardiac mortality in the DES era in contradiction to the earlier smaller studies.[5–7,24,25] Most of these differences were because of reduction in stent thrombosis and periprocedural MIs, which may occur during the same hospitalization.[7]

Besides defining accurate coronary anatomy, IVUS further affords the additional utility of appropriate stent sizing and postimplantation stent optimization in terms of expansion and apposition. Thus, superior outcomes with IVUS-guided PCI might conceptually be in part a result of earlier recognition of periprocedural complications like stent fracture, malapposition, or underexpansion. The acute (inpatient or <30 days) benefits of IVUS-guided PCIs have also been reported from the CathPCI Registry and the MATRIX registry.[8,26] Similar to our study, the CathPCI registry demonstrated the use of IVUS to be associated with higher rates of major bleeding (OR 1.23; interquartile range 1.09 to 1.38; $p < 0.001$) but lower rates of inhospital death (OR 0.66; interquartile range 0.44 to 0.98; $p = 0.04$).[8] The use of IVUS was associated with a higher rate of cardiac complications compared with AO PCIs in our study; this could be because of poor interpretation of IVUS data that occasionally results in overdilation of stents, perforations, and cardiac tamponade. Similarly, the MATRIX registry (patients treated with sirolimus-eluting stents) showed that IVUS group had significantly less death/MI at 30 days compared with AO (1.5% vs 4.6%, $p < 0.01$).[26] Our study represents the largest comparative analysis between IVUS- and angiography-guided PCI in the current DES era, which adds to the growing literature on beneficial effects of IVUS on reducing adverse outcomes after PCI.

Our study is also unique in including all-comers real-world data from patients admitted with AMI and cardiogenic shock. A subgroup analysis of these higher risk populations showed similar results with IVUS-guided PCI independently predicting superior mortality outcomes after PCI. This is in contrast to a few previously published studies like the Korea Acute Myocardial Infarction Registry that did not support the routine use of IVUS during PCI in the setting of AMI.[24]

The utility of IVUS guidance has been debated in the past because of minimal clinical benefit observed in the previous small studies and because of significant reduction in restenosis rates after the introduction of DES into clinical practice. This issue is further complicated because of financial reasons, higher costs of catheters, and low reimbursement. Our analysis, thus, suggests a very low rate of utilization of IVUS (6%) compared with AO (93.5% of the cases). The higher cost and time required for this procedure may, however, be offset by a reduction in mortality as seen in larger studies such as ours. Newer and improved technologies such as Optical Coherence Tomography and Infrared techniques may also contribute to possible similar improved outcomes.

The study limitations are inherent to the post hoc analysis of an administrative database. The design of our study further restricts any inference of causality or temporal associations. Compared with previous studies, we lack information on coronary anatomy, lesion characteristics, and stent sizes. Likewise, we lack data on procedural details (IVUS utilization preintervention vs postintervention or both) that could shed more light on the mechanism of observed benefits in our study. In addition, we did not have postdischarge data on mortality as the NIS does not track individual patients over time. However, the impact of IVUS-guided PCIs on these individual characteristics with longer follow-ups has been previously demonstrated in several studies. We aimed to analyze a larger unrestricted population to appraise rare events associated with PCIs, such as inhospital mortality, which were not well captured by previous smaller studies. Although acknowledging these limitations, the present study has important strengths including the largest sample size and the use of standardized definitions of preventable adverse events that are established by the AHRQ. Our results need to be replicated in larger randomized trials with detailed angiographic analysis to better understand the pathophysiological underpinnings of positive outcomes afforded by IVUS guidance.

Disclosures

None of the other authors have any disclosures relevant to the content of the manuscript.

Supplementary Data

Supplementary data related with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.amjcard.2015.02.037.

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