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Key Words: magnetic resonance imaging ■ pulmonary embolism ■ pulmonary perfusion.

Research Correspondence

Contemporary Patterns of Fractional Flow Reserve and Intravascular Ultrasound Use Among Patients Undergoing Percutaneous Coronary Intervention in the United States

Insights From the National Cardiovascular Data Registry

To the Editor: The use of fractional flow reserve (FFR) and intravascular ultrasound (IVUS) to assess intermediate coronary stenoses (defined as 40% to 70% stenosis) has been associated with improved procedural and clinical outcomes (1,2) in patients undergoing percutaneous coronary intervention (PCI). Both technologies received a Class IIa recommendation for use in angiographically intermediate coronary stenoses in the recently published 2011 American College of Cardiology/American Hospital Association PCI guidelines (3). We undertook an analysis of the CathPCI Registry data in order to better understand current patterns of use of both FFR and IVUS associated with PCI of intermediate lesions, and how their use might relate to procedural and patient-based outcomes.

The CathPCI Registry is an initiative of the American College of Cardiology Foundation and the Society for Cardiovascular Angiography and Interventions and has been previously described (4). We analyzed data for patients undergoing PCI of intermediate coronary stenoses (defined as a percent diameter stenosis ≥40% and ≤70%). Patients were excluded if PCI was performed for a nonintermediate stenosis (n = 373,320), if they underwent diagnostic angiography only (n = 1,977), or if they underwent both FFR and IVUS (n = 778). We examined data starting from April 2009 when version 4 of the CathPCI Registry data collection form began to be implemented, as IVUS and FFR use for PCI of intermediate stenoses were not collected in earlier versions.

Descriptive statistics on the study population were grouped by lesion assessment (angiography only [AO], FFR, or IVUS). Categorical variables were presented as percentages, and continuous variables were presented as medians along with the interquartile range (IQR). Comparisons between groups were performed using Pearson chi-square tests for categorical variables and the Kruskal-Wallis test or Wilcoxon test for continuous variables. Logistic regression with generalized estimating equations to account for within hospital clustering was used to compare in-hospital mortality and procedural success adjusting for baseline patient characteristics in the CathPCI Registry mortality risk model. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, North Carolina).

Data for 61,874 attempted coronary interventions of intermediate coronary stenoses performed between April 2009 and September 2010 were available for analysis. Among these, FFR was used in 3,763 (6.1%) patients, IVUS was used in 12,589 (20.3%) patients, and 45,522 (73.6%) patients had lesions assessed by AO (Table 1). Compared with patients who underwent AO, patients undergoing FFR were more likely to be younger ($p < 0.0001$) and more frequently male ($p < 0.0001$), with slightly lower rates of diabetes ($p = 0.017$) and hypertension ($p = 0.0003$), and higher rates of dyslipidemia ($p < 0.0001$). Patients undergoing IVUS were younger ($p < 0.0001$) and less frequently male ($p < 0.0001$), with slightly lower rates of diabetes ($p < 0.0001$) and similar rates of hypertension ($p = 0.75$) and dyslipidemia ($p = 0.31$).

Patients undergoing FFR were more likely to have had their procedure performed in a university hospital ($p < 0.0001$) compared with private and community hospitals ($p < 0.0001$) and in a hospital with a fellowship or residency training program ($p < 0.0001$).

Patients who underwent FFR were less likely to present with an acute coronary syndrome (ST-segment elevation myocardial infarction, non–ST-segment elevation myocardial infarction, and unstable angina; $p < 0.0001$). Patients who underwent IVUS were more likely to undergo stress testing prior to the procedure ($p < 0.0001$). Patients undergoing FFR were more likely to have had a prior stress test that had negative or equivocal findings ($p < 0.0001$).

Patients undergoing FFR and/or IVUS were less likely to have multivessel disease ($p < 0.0001$), and more likely to have a lesion deemed high risk ($p < 0.0001$). Both the FFR and IVUS cohorts had longer fluoroscopy times ($p < 0.0001$) and more contrast use ($p < 0.0001$) as compared with the AO group.

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Table 1 Patient and Procedural Characteristics

	Angiography Only (n = 45,522)		FFR (n = 3,763)		p Value	IVUS (n = 12,589)		p Value
Median age, yrs	45,522	65.0 (57–73)	3,763	63.0 (55–71)	<0.0001	12,589	64.0 (56–72)	<0.0001
Male, %	28,836	63.35	2,571	68.32	<0.0001	7,439	59.09	<0.0001
Median creatinine clearance*	41,556	64.01 (47.1–82.4)	3,475	69.82 (52.9–87.9)	<0.0001	11,753	65.36 (48.9–83.5)	<0.0001
Diabetes, %	16,796	36.90	1,315	34.95	0.017	4,363	34.66	<0.0001
Hypertension, %	39,047	85.78	3,147	83.63	0.0003	10,788	85.69	0.745
Dyslipidemia, %	38,487	84.55	3,278	87.11	<0.0001	10,690	84.92	0.313
Hospital profit type, %								
Government	557	1.22	61	1.62	<0.0001	135	1.07	0.383
Private/community	39,206	86.13	3,015	80.12		10,856	86.23	
University	5,759	12.65	687	18.26		1,598	12.69	
Fellowship, internship, or residency program, %	23,098	50.74	2,194	58.30	<0.0001	6,447	51.21	0.349
Admission symptom presentation,† %								
Non–acute coronary syndrome	19,844	43.59	1,767	49.96	<0.0001	5,459	43.36	0.647
Acute coronary syndrome	25,678	56.41	1,996	53.04		7,130	56.64	
Stress or imaging study performed	19,109	41.98	1,877	49.88	<0.0001	6,232	49.50	<0.0001
Outcome of stress or imaging study, %								
Positive	15,396	84.22	1,400	77.61	<0.0001	4,918	83.91	0.365
Negative	1,783	9.75	237	13.14		611	10.42	
Equivocal	687	3.76	123	6.82		223	3.80	
Lesion risk, %								
Non-high/non-C	29,671	65.18	2,264	60.16	<0.0001	7,729	61.39	<0.0001
High/C	15,799	34.71	1,496	39.76		4,853	38.55	
Multivessel disease, %	20,610	45.27	1,486	39.49	<0.0001	4,463	35.45	<0.0001
Median fluoroscopy time, min	44,872	9.60 (6.1–15.6)	3,739	12.6 (8.8–19)	<0.0001	12,459	10.9 (7.3–16.5)	<0.0001
Median contrast volume, ml	45,403	175 (125–230)	3,758	200 (154–260)	<0.0001	12,553	180 (140–240)	<0.0001

Values are n, %, and median (interquartile range [IQR]). *Cockroft-Gault calculation. †Acute coronary syndrome includes ST-segment elevation myocardial infarction, non–ST-segment elevation myocardial infarction, and unstable angina. Non–acute coronary syndrome includes no symptoms, atypical chest pain, and stable angina. Each p value compares the associated group with angiography only.
FFR = fractional flow reserve; IVUS = intravascular ultrasound.

After adjusting for comorbid conditions, the use of IVUS was associated with higher rates of major bleeding (odds ratio [OR]: 1.23; IQR: 1.09 to 1.38; $p < 0.001$), lower rates of in-hospital death (OR: 0.66; IQR: 0.44 to 0.98; $p = 0.04$), and no difference in procedural success (OR: 1.10; IQR: 0.97 to 1.26; $p = 0.14$) compared with AO. No difference between the FFR and AO groups was seen in adjusted comparisons of mortality (OR: 1.07; IQR: 0.53 to 2.15; $p = 0.857$), major bleeding (OR: 0.95; IQR: 0.76 to 1.19; $p = 0.683$), or procedural success (OR: 0.97; IQR: 0.76 to 1.25; $p = 0.836$).

This analysis demonstrates that despite a wealth of data demonstrating the utility of these technologies in the evaluation of intermediate coronary stenoses (1,2), IVUS (20.3%) and FFR (6.1%) are used in only a small minority of such cases. The use of IVUS was likely more common than FFR due to its demonstrated utility in determining appropriate stent sizing, as well as the post-implantation evaluation of stent expansion and apposition. A number of factors probably contributed to these low rates of use, such as the fact that the catheters used to perform these lesion assessments are costly and are poorly reimbursed, if at all. In fact, routine use may provide a financial disincentive, as the cost of the procedure increases with the use of the catheters and the reimbursement decreases with less frequent stent implantation.

After adjustment for comorbidities, IVUS appears to be associated with lower rates of in-patient mortality, a finding consistent with prior data (5). It was also associated with higher rates of major bleeding, whereas FFR showed no such correlations. Neither technology was associated with differences in procedural success.

We were unable to explicitly examine cases where either of these technologies was used to deem a lesion physiologically insignificant and PCI was deferred, as these cases are not captured in the CathPCI Registry dataset. The CathPCI Registry dataset only records outcomes occurring in the hospital stay during which PCI was performed. Given that these data were analyzed retrospectively, outcomes associated with the use of IVUS and FFR are observational and causality cannot be inferred.

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Key Words: fractional flow reserve ■ intermediate coronary stenosis ■ intravascular ultrasound ■ percutaneous coronary intervention.

Letters to the Editor

Why Permanent Pacemaker Implantation After Transcatheter Aortic Valve Implantation Does Not Affect Long-Term Clinical Outcome

With interest, we took notice of the paper by Buellesfeld et al. (1) investigating the impact of permanent pacemaker implantation on clinical outcome after transcatheter aortic valve implantation (TAVI) (1). The authors state that periprocedural permanent pacemaker (PPM) implantation does not affect rate of death, stroke, and/or myocardial infarction at 12 months compared with patients with pre-existing PPM or patients without any PPM. Because the findings of present study seem to contrast with earlier observations from the MOST (Mode Selection Trial) study and the DAVID (Dual Chamber and VVI Implantable Defibrillator) trial, we have some concerns regarding the study design (2,3).

First of all, Buellesfeld et al. (1) do not provide a power calculation regarding the study size. Given the relatively low number of patients, it is likely that the study is under-powered to detect differences in the primary endpoint of all-cause mortality. It is plausible than an endpoint combining all-cause mortality with hospitalization for worsening of heart failure would have resulted in different outcome between the groups. Indeed, the MOST and DAVID trials, using similar endpoints, demonstrated that chronic right ventricular pacing is associated with occurrence of heart failure (2,3).

Second, the PPM implantation strategy in the present study seems rather liberal and early, with almost three-quarters of implantations occurring within 3 days after TAVI. As early atrioventricular conduction disorders post-TAVI are known to recover over time (4–6), a considerable number of patients would have received a PPM unnecessarily. Although scarce, there is some evidence that during longer follow-up of TAVI-related PPM implantations, patients show no or limited pacemaker dependency (7) (unpublished data van der Boon RM, van Mieghem NM, Theuns DA, et al., 2012). Due to alterations in pacing mode, these patients are not exposed to the unbeneficial effects of chronic right ventricle pacing.

We recently compared the impact of TAVI-induced left bundle branch block (LBBB) on all-cause mortality during long-term follow-up. In a cohort of 679 patients, all-cause mortality was significantly higher among patients with TAVI-induced LBBB compared with patients without LBBB. Interestingly, the mortality rate among patients receiving PPM after TAVI was comparable to that of patients without TAVI-induced LBBB. This discrepancy could be explained by the low percentage of cumulative ventricular pacing in the PPM group (8).

In conclusion, in the present study by Buellesfeld et al. (1), patient classification might be problematic as the post-TAVI PPM patients are principally heterogeneous and are not all exposed to the risks of (continuous) right ventricular pacing, which might explain the findings of the current study. We agree with the authors that larger-scaled studies are needed to further investigate the impact of PPM after TAVI.

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