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Adoption and Effectiveness of Internal Mammary Artery Grafting in Coronary Artery Bypass Surgery Among Medicare Beneficiaries

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Objectives The aim of this study was to assess the pattern of the adoption of internal mammary artery (IMA) grafting in the United States, test its association with clinical outcomes, and assess whether its effectiveness differs in key clinical subgroups.

Background The effect of IMA grafting on major clinical outcomes has never been tested in a large randomized trial, yet it is now a quality standard for coronary artery bypass graft (CABG) surgery.

Methods We identified Medicare beneficiaries $\geq$66 years of age who underwent isolated multivessel CABG between 1988 and 2008, and we documented patterns of IMA use over time. We used a multivariable propensity score to match patients with and without an IMA and compared rates of death, myocardial infarction (MI), and repeat revascularization. We tested for variations in IMA effectiveness with treatment $\times$ covariate interaction tests.

Results The IMA use in CABG rose slowly from 31% in 1988 to 91% in 2008, with persistent wide geographic variations. Among 60,896 propensity score-matched patients over a median 6.8-year follow-up, IMA use was associated with lower all-cause mortality (adjusted hazard ratio: 0.77, $p < 0.001$), lower death or MI (adjusted hazard ratio: 0.77, $p < 0.001$), and fewer repeat revascularizations over 5 years (8% vs. 9%, $p < 0.001$). The association between IMA use and lower mortality was significantly weaker ($p \leq 0.008$) for older patients, women, and patients with diabetes or peripheral arterial disease.

Conclusions Internal mammary artery grafting was adopted slowly and still shows substantial geographic variation. IMA use is associated with lower rates of death, MI, and repeat coronary revascularization. (J Am Coll Cardiol 2014;63:33–9)

Coronary artery bypass graft (CABG) surgery was generally performed with saphenous veins as conduits until the pivotal study of Loop et al. (1) reported improved long-term outcomes from using the internal mammary artery (IMA) as a conduit. Their single-center, nonrandomized comparison of 5,931 patients reported a 38% reduction in the risk of death over 10 years of follow-up from use of the IMA. Similar results were subsequently reported by others with observational data (2–5). The only randomized trial of IMA grafting enrolled just 80 patients and lacked statistical power to assess its effect on hard cardiac outcomes (6). Perhaps because there has never been a large, definitive randomized trial, adoption of IMA grafting has been slow and uneven in the United States (7–11). The National Quality Forum in 2004 adopted use of an IMA graft as a measure of the quality of CABG (12), which is now reported publicly by several states. In this study, we sought to document the patterns of adoption of IMA use in coronary revascularization procedures performed in Medicare beneficiaries and assess the association of IMA grafting with long-term outcomes in a "real-world" population of patients undergoing CABG.

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Methods

The overall study population consisted of Medicare beneficiaries who underwent CABG between 1988 and 2008 who were included in the 20% sample of Part A data. We identified patients with the International Classification of

Abbreviations and Acronyms

CABG = coronary artery bypass graft surgery

CI = confidence interval

DES = drug-eluting stent(s)

HR = hazard ratio

ICD9-CM = International Classification of Diseases, Ninth Revision-Clinical Modification

IMA = internal mammary artery

MI = myocardial infarction

PAD = peripheral arterial disease

PCI = percutaneous coronary intervention

p_{int} = p value for the treatment × covariate interaction test

Diseases, Ninth Revision, Clinical Modification (ICD9-CM) procedure codes for multivessel CABG (36.12, 36.13, 36.14, 36.16, or 36.11 plus 36.15) and identified IMA grafts by procedure codes 36.15 or 36.16. We excluded patients who had single-vessel CABG, concomitant cardiac procedures (such as valve replacement) at the time of CABG, evidence of a prior coronary revascularization (a Medicare hospital stay for CABG or percutaneous coronary intervention [PCI] since 1988 or a prior condition code of V.15.1, V45.81, or V45.82 in the index admission), were of unknown race, or who had end-stage renal disease receiving chronic dialysis.

We used the subset of this overall population who received CABG between 1992 and 2008 to assess the association of IMA use with clinical outcomes, because data on some key characteristics needed for risk adjustment were not available before 1992. To permit a 1-year look-back period and document the presence of comorbid conditions, we restricted this portion of the study population to individuals 66 years of age or older who had both Part A and Part B Medicare coverage and who were not enrolled in a Medicare Advantage Managed Care Program (in which diagnosis and procedure codes are not available) in the year before the procedure. Part B data from 1992 through 1997 were available from only a 5% sample of beneficiaries rather than the 20% sample available from 1998 through 2008. We defined comorbid conditions with outpatient and inpatient encounters in the year before the index procedure. We considered a comorbidity to be present if it was recorded as a primary or secondary diagnosis code on an inpatient admission or outpatient encounter.

We developed a multivariable logistic regression in the analysis subset to identify baseline clinical factors that predicted receipt of an IMA graft and assessed the discrimination of the model with the C-statistic (13). We used the results of this analysis to assign each patient a propensity score indicating the probability that the individual would receive an IMA graft. We then applied a greedy pair-matching algorithm (14) to match each patient who did not receive an IMA graft with another patient who did. The algorithm first matched patients at 7 digits of the propensity score, then matched the remaining patients at 6 digits, and so forth, down to a 2-digit match (i.e., to agreement of 0.01 or better). We additionally required that patients match on the calendar year they underwent CABG (to control further for any secular trends in outcome) and to be the same age within 1 year.

Patients were followed until death or December 31, 2008. We identified all-cause mortality from the Medicare Denominator file; admissions for acute myocardial infarction (MI) in Part A data by an ICD9-CM primary hospital discharge diagnosis code of 410.x; repeat CABG in Part A data by ICD9-CM procedure codes 36.1x; and PCIs by ICD9-CM procedure codes 36.01, 36.02, 36.05, 36.06, 36.07 and, after October 2005, 00.66. For the endpoints of MI and repeat procedures, patients were censored if they entered a Medicare Advantage Plan or lost Part A coverage, because data on hospital stay would no longer be available.

We described event-free survival data with the Kaplan-Meier method (15), and we compared outcomes in the matched population by IMA status with the Cox proportional hazards model. We initially performed the comparison among the propensity score-matched cohort without additional adjustment for baseline clinical characteristics, and we subsequently adjusted for the baseline characteristics shown in Table 1, because they might provide additional prognostic information. We tested for interactions among each of 4 pre-specified clinical characteristics (age, sex, diabetes, and peripheral arterial disease); treatment with an IMA graft; and mortality with a model that contained treatment, the selected covariate, and their interaction. We repeated the interaction tests in models that contained other baseline characteristics.

Results

A total of 374,918 patients in the study population underwent isolated multivessel CABG between 1988 and 2008 and 260,119 (69%) patients received at least 1 IMA graft. Overall, use of the IMA graft during CABG increased steadily over time (Fig. 1), from 31% in 1988 to 91% in 2008. There was an additional increase in use of the IMA after its adoption in late 2004 as a quality measure for CABG (12) (Fig. 1). The use of IMA grafting differed substantially among different regions of the United States (Fig. 2), and although these differences narrowed over time, they were still evident in 2008. Use of IMA grafts was highest among patients age 66 to 70 and lowest among patients age 86 years and older (Fig. 3), and the difference in IMA use by age narrowed progressively over time. By contrast, rates of IMA grafting among women were slightly lower than among men throughout the study period (Fig. 3).

In the subset of 186,451 patients who underwent isolated multivessel CABG between 1992 and 2008 for which baseline clinical data on comorbid conditions were available, there were several significant differences between patients who received an IMA graft and those who did not (Table 1). In addition to differences in age, geographic region, and year of procedure, patients who received an IMA graft were more often male and white but less likely to have diabetes. In a multivariable logistic regression model, the strongest independent predictors of receiving an IMA graft were