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Complex or multivessel PCI is associated with higher 1-year mortality but better patient-centered outcomes when compared to CABG in patients with dementia

Khanjan B. Shah[1,✉], Lingwei Xiang[2], Samir K. Shah[3], MPH, Rachel R. Adler[2], Joel S. Weissman[2]

1. Division of Cardiovascular Medicine, University of Florida College of Medicine, Gainesville, FL, USA; 2. Center for Surgery and Public Health, Brigham and Women's Hospital, Boston, MA, USA; 3. Division of Vascular Surgery and Endovascular Therapy, University of Florida, Gainesville, FL USA

✉ Correspondence to: Khanjan.Shah@medicine.ufl.edu

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ABSTRACT

Objectives To compare outcomes of coronary revascularization with coronary artery bypass grafting (CABG) or complex or multivessel percutaneous coronary intervention (MV PCI) in patients with dementia.

Methods We compared outcomes of Medicare fee-for-service (FFS) beneficiaries 66 years or older with Alzheimer's disease and related dementias (ADRD) who underwent coronary artery bypass grafting (CABG) or MV PCI from January 1, 2017 to December 31, 2019. The primary clinical outcome was 1-year mortality, and secondary clinical outcomes were inpatient and 90-day complications and 90-day readmissions. Patient-centered outcomes were time-at-home ratio and discharge to higher level of care.

Results 8,939 patients with ADRD undergoing revascularization with CABG MV PCI met study criteria. Of these, 3,510 (39.3%) underwent CABG and 5,429 (60.7%) underwent MV PCI. Patients with ADRD who underwent MV PCI were more likely to be older (81.0 *vs.* 76.7, $P < 0.001$), women (44.1% *vs.* 29.4%, $P < 0.001$), frail (82.4% *vs.* 75.0%, $P < 0.001$), and have moderate to severe dementia (64.4% *vs.* 54.6%, $P < 0.001$). One-year mortality was higher among patients undergoing MV PCI (OR = 2.0, 95% CI: 1.8-2.3) but inpatient and 90-day major complications were lower (OR = 0.3, 95% CI: 0.3-0.3 and OR = 0.5, 95% CI: 0.4-0.5, respectively). Patients with ADRD undergoing MV PCI were less likely to be discharged to a higher level of care (OR = 0.2, 95% CI: 0.2-0.2) and had higher time-at-home ratios (Mean Difference 4.2, 95% CI: 2.4-6.0).

Conclusions Patients with ADRD undergoing MV PCI demonstrate higher 1-year mortality but lower short-term complications. Patient-centered outcomes of time-at-home ratio and risk for discharge to a higher level of care were more favorable with MV PCI compared to CABG. These data should be used by patients, their families, and physicians to facilitate goal-concordant care especially when optimization of patient-centered outcomes is desired.

Coronary artery disease (CAD) in patients with Alzheimer's Disease and Related Dementias (ADRD) is increasing due in part to shared risk factors, such as hypertension and diabetes.[1] As the population ages, more patients with ADRD will present with multivessel CAD.[1] Revascularization for multivessel CAD is traditionally achieved with either coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI). Both strategies come with considerable tradeoffs. For example, CABG is associated with improved long-term survival but requires longer hospital stays and rehabilitation.[2] In contrast, complex or multivessel percutaneous coronary intervention (hereafter, MV PCI) is minimally invasive with short recovery but may require repeat procedures for stent failure.[2]

Patients with ADRD are frequently excluded from clinical trials focused on understanding outcomes following revascularization for CAD.[2,3] As such, these patients are at risk for bias in both directions by healthcare teams – withholding care despite benefit or providing aggressive care despite harm. High-quality shared-de-

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cision making with patients and families is not possible without knowledge of population-specific clinical and patient-centered outcomes. Additionally, contemporary data focuses on clinical outcomes like mortality, which is important but may not represent the full picture of healthcare goals. A focus on patient-centered outcomes, such as time spent at home after a surgery, is necessary to help decision making especially in older patients with diverse healthcare goals.

We compared 1-year mortality and major inpatient and 90-day complications in patients with ADRD undergoing CABG or MV PCI. Furthermore, we investigated patient-centered outcomes, such as time-at-home ratio and discharge to a higher level of care. We hypothesized that patients with ADRD undergoing CABG would have worse 1-year mortality and time-at-home ratios compared to patients undergoing MV PCI.

METHODS

Data Source and Study Population

This study was approved by the Mass General Brigham institutional review board. We examined Medicare beneficiaries at least 66 years old who underwent inpatient CABG or MV PCI in short-term or critical access hospitals from January 1, 2017 to December 31, 2019, and with continuous fee-for-service (FFS) coverage 1-year prior to admission date and 1-year after discharge date or till death, allowing for a 1-month gap in both lookback and follow up periods, respectively. We obtained inpatient, outpatient, home health agency, skilled nursing facility (SNF), durable medical equipment (DME), Minimum Data Set (MDS), and carrier files from January 1, 2016 to December 31, 2018 and MedPAR from January 1, 2019 to December 31, 2020 for analysis. CABG and MV PCI was defined using International Classification of Disease, Tenth Revision (ICD-10) codes based on previously published work.[4,5] ICD-10 codes for MV PCI could be used as standalone for enrollment into the study, but ICD-10 codes for single vessel PCI required an additional ICD-10 code for percutaneous left-ventricular assist device and/or intra-aortic balloon pump to select patients appropriate for complex PCI. ADRD was defined using previously validated ICD-10 codes during admission or a 1-year lookback period.[6] Our codes identifying ADRD exclude codes for nonspecific and reversible conditions and have a positive predictive value of 77.1%.[6] We excluded patients (1) with ICD-10 codes for ST-elevation myocardial infarction or cardiogenic shock during the index admission, (2) who underwent concomitant valve procedure during index hospitalization, and (3) with missing geographic information.

Covariates and Endpoints

The primary clinical outcome was all-cause one-year mortality following CABG or MV PCI. Secondary clinical outcomes were (1) major postoperative complications (inpatient and 90-day), using a list we have employed previously,[7] (2) length of stay after revascularization (days between CABG or MV PCI date and discharge date), and (3) 90-day readmissions. Patient-centered outcomes were time-at-home ratio and discharge to higher level of care. Time-at-home ratio was calculated only for community dwelling patients as the time spent at home compared to time spent out of home (skilled nursing facilities, nursing home, hospitals, hospital-based hospice) from the date of revascularization to 365 days after surgery or the date of death or December 31, 2018, whichever came first.[8] Community dwelling was defined as no assessment in the MDS file for 180 days prior to index procedure.[9] Discharge to higher level of care was defined for all patients except those coming from a long-term acute care facility (LTAC). The hierarchy of discharge destinations was home<skilled nursing facility (SNF) < LTAC.

Patients were categorized into frail *vs* non-frail categories using a claims-based frailty index (cFI) and a cutoff of ≥ 0.250.[10] The cFI was also used to characterize patients with moderate to severe dementia with a cutoff of > 0.280.[11] The cFI is determined using 93 variables derived from ICD diagnosis, Current Procedural Terminology-4 (CPT-4), and Healthcare Common Procedure Coding System (HCPCS) codes and has been validated against physical performance tests as well as disabilities in instrumental and essential activities of daily living.[10]

Statistical Analysis

Continuous data were presented medians and interquartile range (IQR) and categorical data were described using frequencies and percentages. Unadjusted differences in outcomes were determined using Wilcoxon rank-sum tests and chi-squared tests for continuous variables and categorical variables. Generalized estimating equations multivariable logistic and linear regression models were used to generate adjusted odds ratios (OR)

for the effect of MV PCI on 1-year mortality, inpatient and 90-day complications, 90-day readmissions, discharge location, and home time ratios. Models were adjusted for demographic (age, sex, race, dual Medicare/Medicaid eligibility, patient residency) and clinical (Elixhauser comorbidity index score, admission urgency, and frailty) variables and accounted for hospital clustering using independent covariance structure. Kaplan Meier plot and all analyses were created and performed using SAS 9.4 (SAS, Cary, NC).

RESULTS

Baseline Characteristics

We identified 8,939 patients who met our inclusion and exclusion criteria between July 1, 2017 and December 31, 2019. The median age of the cohort was 79 years, 38% were women, and 81.3 were White (Table 1). 3,510 (39.3%) patients of the total cohort underwent CABG and 5,429 (60.7%) patients of the total cohort underwent

Table 1 Baseline characteristics.

	All, *n* = 8,939	Revascularization		*P*-value
		CABG (*n* = 3,510; 39.3%)	PCI (*n* = 5,429; 60.7%)	
Age, yrs	79.1 (74.1–83.9)	76.7 (72.6–80.9)	81.0 (75.5–85.7)	< 0.001
Sex				< 0.001
Male	5,511 (61.7%)	2,477 (70.67%)	3,034 (55.97%)	
Female	3,428 (38.37%)	1,033 (29.47%)	2,395 (44.17%)	
Race				0.18
Non-Hispanic White	7,265 (81.37%)	2,867 (81.77%)	4,398 (81.07%)	
Black (or African-American)	689 (7.77%)	250 (7.17%)	439 (8.17%)	
Other/Unknown	120 (1.37%)	56 (1.67%)	64 (1.27%)	
Asian/Native American	240 (2.77%)	99 (2.87%)	141 (2.67%)	
Hispanic	625 (7.07%)	238 (6.87%)	387 (7.17%)	
Frail	7,104 (79.57%)	2,633 (75.07%)	4,471 (82.47%)	< 0.001
Community dwelling[1]	5,890 (84.47%)	2,516 (90.77%)	3,374 (80.37%)	< 0.001
Admission Urgency				< 0.001
Other	3,947 (44.27%)	2,163 (61.67%)	1,784 (32.97%)	
Urgent/Emergent	4,992 (55.87%)	1,347 (38.47%)	3,645 (67.17%)	
Dual Eligibility	2,444 (27.37%)	793 (22.67%)	1,651 (30.47%)	< 0.001
Patient Geography				0.63
Metropolitan	6,617 (74.07%)	2,608 (74.37%)	4,009 (73.87%)	
Non-Metropolitan	2,322 (26.07%)	902 (25.77%)	1,420 (26.27%)	
Elixhauser in-hospital mortality index	11.0 (0–23)	7.0 (−2–19)	13.0 (1–26)	< 0.001
Cerebrovascular disease	1,626 (18.2%)	703 (20.0%)	923 (17.0%)	< 0.001
Obesity	2,419 (27.1%)	1,107 (31.5%)	1,312 (24.2%)	< 0.001
Diabetes with chronic complications	4,353 (48.7%)	1,726 (49.2%)	2,627 (48.4%)	0.01
Heart failure	4,632 (51.8%)	1,441 (41.1%)	3,191 (58.8%)	< 0.001
Hypertension, complicated	6,190 (69.2%)	2,253 (64.2%)	3,937 (72.5%)	< 0.001
Peripheral vascular disease	3,699 (41.4%)	1,484 (42.3%)	2,215 (40.8%)	0.17
Chronic pulmonary disease	3,335 (37.3%)	1,277 (36.4%)	2,058 (37.9%)	0.15
Renal failure	2,822 (31.6%)	981 (27.9%)	1,841 (33.9%)	< 0.001

Data are presented as median (IQR) or *n* (%). [1]Analysis restricted to patients who underwent revascularization before January 1, 2019. *Suppressed according to CMS data policy. CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention.

MV PCI. Patients with ADRD who underwent MV PCI were more likely to be older (81.0 *vs.* 76.7, $P < 0.001$), women (44.1% *vs.* 29.4%, $P < 0.001$), frail (82.4% *vs.* 75.0%, $P < 0.001$), and have moderate to severe dementia (64.4% *vs.* 54.6%, $P < 0.001$) as compared to mild dementia. The most common comorbid conditions in the overall cohort were hypertension (6,190; 69.2%), heart failure (4,632; 51.8%), and diabetes (4,353; 48.7%). Patients undergoing MV PCI were more likely to have comorbid conditions of hypertension, heart failure, and renal failure. Overall, 84.4% of the cohort was community dwelling although patients who underwent MV PCI were less likely than patients who underwent CABG to be community dwelling (80.3% *vs.* 90.7%, $P < 0.001$).

Unadjusted outcomes

2,407 (26.9%) patients with ADRD undergoing coronary revascularization died within 1 year. Patients who underwent MV PCI had significantly higher 1-year mortality compared to patients undergoing CABG (33.8% *vs.* 16.3%, $P < 0.001$) (Table 2,Figure 1). Patients who underwent MV PCI had significantly lower rates of inpatient and 90-day complications (26.8% *vs.* 51.1% and 52.7% *vs.* 64.8% respectively, $P < 0.001$), largely driven by pulmonary and cardiovascular complications. Patients who underwent MV PCI had significantly shorter hospital lengths of stays (4.2 *vs.* 8.7 days, $P < 0.001$), were less likely to be discharged to a higher level of care (35.1% *vs.* 61.0%, $P < 0.001$), and had similar time-at-home ratio (76.1 *vs.* 75.2, $P = 0.29$) (Table 2).

Adjusted outcomes

In an adjusted analysis, patients with ADRD who underwent MV PCI were more likely to die at 1-year (OR = 2.0, 95% CI: 1.8-2.3) compared to patients who underwent CABG (Table 3). Patients who underwent MV PCI were less likely to have major complications (OR = 0.3, 95% CI: 0.3-0.3 for inpatient and OR = 0.5, 95% CI: 0.4-0.5 at 90 days) but more likely to have 90-day readmissions (OR = 1.2, 95% CI: 1.0-1.3). In terms of patient-centered outcomes, patients with ADRD undergoing MV PCI were less likely to be discharged to a higher level of care (OR = 0.2, 95% CI 0.2-0.2) and had higher time-at-home ratios (Mean Difference 4.2, 95% CI: 2.4-6.0).

Sensitivity analyses with stratification by age, gender, and frailty demonstrated similar ORs for 1-year mortality, major complications, length of stay, and discharge to higher level of care (Table 4). Readmissions became nonsignificant for males, age ≥ 79 years, and non-frail, and home-time ratio became nonsignificant for non-frail (Table 4).

DISCUSSION

Our study of 8,939 Medicare FFS beneficiaries with ADRD undergoing revascularization with CABG or MV PCI showed an overall 1-year all-cause mortality of 26.9%. Patients with ADRD clearly represent a medically fragile cohort, and discussions regarding any revascularization should occur in the context of a nearly 1 in 3 odds of 1-year death. One-year mortality was signific-

Table 2 Unadjusted outcomes as stratified by revascularization type.

	All	Revascularization		*P*-value
		CABG	PCI	
1-Year Death	2,407 (26.9%)	571 (16.3%)	1,836 (33.8%)	< 0.001
90-Day Complication[1]	4,978 (57.6%)	2,249 (64.8%)	2,729 (52.7%)	< 0.001
Inpatient Complication	3,252 (36.4%)	1,795 (51.1%)	1,457 (26.8%)	< 0.001
90-Day Readmission[1]	3,089 (38.4%)	1,121 (34.0%)	1,968 (41.4%)	< 0.001
Discharge to Higher Level of Care[2]	2,991 (45.6%)	1,619 (61.0%)	1,372 (35.1%)	< 0.001
Discharge to Home[3]	3,090 (52.5%)	905 (36.0%)	2,185 (64.8%)	< 0.001
Hospital Length of Stay	5.9 ± 0.1	8.7 ± 0.1	4.2 ± 0.1	< 0.001
Home-time Ratio[3]	75.6 ± 0.4	76.1 ± 0.6	75.2 ± 0.6	0.29

Data are presented as mean ± SD or *n* (%). [1]Patients who died within the follow-up time frame and without event of interest were removed from analysis. [2]Patients who admitted from the highest level of care (hospital) were removed from analyses. [3]Analysis restricted to community dwelling patients who underwent PCI/CABG from 01/01/2017 to 12/31/2018. CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention.

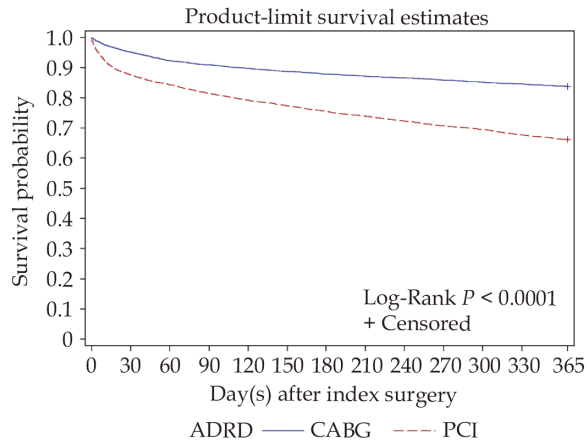

Figure 1 Kaplan-Meier estimates of one-year mortality by revascularization type.

antly higher in patients with ADRD undergoing MV PCI, even after controlling for differences in frailty and other comorbid conditions and demographic features. However, patient-centered outcomes of time-at-home ratio and discharge location are more favorable in patients undergoing MV PCI. As such, our data supports that a much more nuanced discussion of the ideal revascularization strategy in patients with ADRD is warranted. If these patients and their caregivers prioritize time at home as their most important outcome of interest, physicians may recommend MV PCI over CABG despite the increased 1-year mortality.

There are several potential explanations of our findings. First, higher 1-year mortality in patients with ADRD undergoing MV PCI may be related to acuity of patients in this group. Patients in the MV PCI group may have been turned down for CABG, which would represent a sicker overall cohort of patients (confounding by indication). Second, the higher rates of inpatient complications in the CABG group may be related to routine postsurgical and post-anesthesia complications. Third, higher rates of 90-day readmissions in the PCI group is consistent with existing data not focused on ADRD specifically and may be related to higher rates of repeat revascularization or medication-related bleeding after PCI.[12] Finally, better time-at-home ratios and discharge dispositions in the MV PCI group may be related to less need for rehabilitation following major surgery and fewer short-term complications with a minimally invasive revascularization approach.

This analysis adds to our understanding of revascularization with CABG or MV PCI in patients with ADRD in several ways. First, to our knowledge, this is the largest sample size of patients with ADRD undergoing revascularization with CABG of MV PCI. Physicians currently struggle with decision-making in this growing cohort of patients due to lack of data, and we hope our data will add meaningfully to the discussions. Second, our focus on patient-centered outcomes allows for a more complete understanding of outcomes following revascularization as caregivers may place more emphasis on these patient-centered outcomes rather than mortality alone.

Limitations

Our study has several important limitations. First, our analysis is based on administrative codes rather than direct clinical care; therefore, we were limited in full assessment of possible clinical confounders, detailed anatomical data on CAD, and pharmacological management. Nevertheless, we used validated definitions of important cohort characteristics such as ADRD. Second, due to

Table 3 Adjusted outcomes as stratified by revascularization type (CABG as reference).

Outcome	OR	*P*-value
1-Year Death	2.0 (1.8, 2.3)	< 0.001
90-Day Complication[1]	0.50 (0.4, 0.5)	< 0.001
Inpatient Complication	0.30 (0.3, 0.3)	< 0.001
90-Day Readmission[1]	1.20 (1.0, 1.3)	0.007
Discharge to Higher Level of Care[2]	0.20 (0.2, 0.2)	< 0.001
Discharge to Home[3]	5.5 (4.7, 6.3)	< 0.001
Hospital Length of Stay	−5.0 (−5.3, −4.8)	< 0.001
Home-time Ratio[3]	4.20 (2.4, 6.0)	< 0.001

[1]Patients who died within the follow-up time frame and without event of interest were removed from analysis. [2]Patients who admitted from the highest level of care (LTCH) were removed from analyses. [3]Analysis restricted to community-dwelling patients who underwent PCI/CABG from 01/01/2017 to 12/31/2018. CABG: coronary artery bypass grafting.

Table 4 Subgroup adjusted outcomes by age, sex, and frail (CABG as reference).

	Frail		Non-Frail	
Outcome	OR	*P*-value	OR	*P*-value
1−Year Death	2.0 (1.8, 2.3)	< 0.001	2.0 (1.5, 2.7)	< 0.001
90−Day Complication[1]	0.5 (0.5, 0.6)	< 0.001	0.3 (0.2, 0.4)	< 0.001
Inpatient Complication	0.3 (0.3, 0.3)	< 0.001	0.3 (0.2, 0.3)	< 0.001
90−Day Readmission[1]	1.2 (1.1, 1.4)	< 0.001	0.9 (0.7, 1.1)	0.22
Discharge to Higher Level of Care[2]	0.2 (0.2, 0.2)	< 0.001	0.2 (0.1, 0.2)	< 0.001
Discharge to Home[3]	5.7 (4.8, 6.7)	< 0.001	5.0 (3.7, 6.7)	< 0.001
	Mean Difference	*P*-value	Mean Difference	*P*-value
Hospital Length of Stay	−5.2 (−5.6, −4.9)	< 0.001	−4.3 (−4.7, −3.9)	< 0.001
Home−time Ratio[3]	4.8 (2.7, 6.9)	< 0.001	1.8 (−1.6, 5.3)	0.30
	Female		Male	
Outcome	OR	*P*-value	OR	*P*-value
1−Year Death	2.1 (1.8, 2.4)	< 0.001	1.9 (1.6, 2.3)	< 0.001
90−Day Complication[1]	0.5 (0.4, 0.5)	< 0.001	0.5 (0.4, 0.6)	< 0.001
Inpatient Complication	0.3 (0.3, 0.3)	< 0.001	0.3 (0.2, 0.3)	< 0.001
90−Day Readmission[1]	1.2 (1.1 1.4)	< 0.001	1.0 (0.8, 1.2)	0.97
Discharge to Higher Level of Care[2]	0.2 (0.2, 0.2)	< 0.001	0.2 (0.2, 0.2)	< 0.001
Discharge to Home[3]	5.4 (4.5, 6.4)	< 0.001	6.0 (4.8, 7.5)	< 0.001
	Mean Difference	*P*-value	Mean Difference	*P*-value
Hospital Length of Stay	−5.0 (−5.3, −4.6)	< 0.001	−5.2 (−5.7, −4.7)	< 0.001
Home−time Ratio[3]	3.5 (1.2, 5.8)	0.003	5.6 (2.6, 8.7)	< 0.001
	Age ≥ 79 yrs		Age < 79 yrs	
Outcome	OR	*P*-value	OR	*P*-value
1−Year Death	1.9 (1.6, 2.2)	< 0.001	2.2 (1.9, 2.6)	< 0.001
90−Day Complication[1]	0.4 (0.3, 0.4)	< 0.001	0.6 (0.5, 0.6)	< 0.001
Inpatient Complication	0.2 (0.2, 0.3)	< 0.001	0.4 (0.3, 0.4)	< 0.001
90−Day Readmission[1]	1.0 (0.9, 1.2)	0.89	1.3 (1.1, 1.5)	< 0.001
Discharge to Higher Level of Care[2]	0.2 (0.1, 0.2)	< 0.001	0.3 (0.2, .03)	< 0.001
Discharge to Home[3]	6.3 (5.2, 7.7)	< 0.001	4.4 (3.7, 5.3)	< 0.001
	Mean Difference	*P*-value	Mean Difference	*P*-value
Hospital Length of Stay	−5.2 (−5.6, −4.8)	< 0.001	−4.9 (−5.3, −4.5)	< 0.001
Home−time Ratio[3]	4.0 (1.3, 6.8)	0.004	3.7 (1.4, 6.1)	0.002

[1]Patients who died within the follow-up time frame and without event of interest were removed from analysis. [2]Patients who admitted from the highest level of care (LTCH) were removed from analyses. [3]Analysis restricted to community-dwelling patients who underwent PCI/CABG from 01/01/2017 to 12/31/2018. CABG: coronary artery bypass grafting.

limitations of our dataset, we are unable to stratify patients by type of sedation or anesthesia used, which could have implications on inpatient outcomes. Third, due to the retrospective nature of our study, there is a risk for unmeasured confounding. Finally, our study is specific to Medicare FFS patients and therefore may not be generalizable to other patient populations, such as younger patients.

Conclusions

In conclusion, among FFS Medicare beneficiaries with ADRD who undergo revascularization for CAD, patients undergoing MV PCI demonstrate higher 1-year mortality. Importantly, however, patients with ADRD

undergoing MV PCI demonstrate better patient-centered outcomes of time-at-home ratio and discharge disposition. These data should be used by patients, their families, and physicians to facilitate goal-concordant care especially when maximization of patient-centered outcomes is desired.

DISCLOSURE

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Conflict of Interest

None.

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