ORIGINAL RESEARCH

Heterogeneity of Treatment and Outcomes Among Asians With Coronary Artery Disease in the United States

Lakshman Manjunath, MD; Sukyung Chung, PhD; Jiang Li, PhD, MPH; Harsh Shah, MPH; Latha Palaniappan, MD, MS; Celina M. Yong (ID), MD, MBA, MSc

BACKGROUND: Prior data demonstrate significant heterogeneity regarding coronary artery disease risk factors and outcomes among Asians in the United States, but no studies have yet examined coronary artery disease treatment patterns or outcomes among disaggregated Asian American subgroups.

METHODS AND RESULTS: From a total of 772 882 patients with known race/ethnicity and sex who received care from a mixed-payer healthcare organization in Northern California between 2006 and 2015, a retrospective analysis was conducted on 6667 adults with coronary artery disease. Logistic regression was used to examine medical and procedural therapies and outcomes by race/ethnicity, with adjustment for age, sex, income, and baseline comorbidities. Compared with non-Hispanic whites, Chinese were more likely to undergo stenting (50.9% versus 60.8%, odds ratio [OR] 1.39 [95% CI, 1.04–1.87], p=0.005), whereas Filipinos were more likely to receive bypass surgery (6.9% versus 20.5%, OR 2.65 [95% CI, 1.75–4.01], $P<0.0001$). After stenting, Chinese, Filipinos, and Japanese were more likely than non-Hispanic whites to be prescribed clopidogrel (86.2%, 83.0%, and 91.4% versus 74.5%, ORs 1.86 [95% CI, 1.13–3.04], 1.86 [95% CI, 1.01–3.44], and 4.37 [95% CI, 1.02–18.67], respectively, $P<0.0001$). Lastly, Chinese and Asian Indians were more likely than non-Hispanic whites to be diagnosed with a myocardial infarction within 1 year postangiography (15.6% and 17.4% versus 11.2%, ORs 1.49 [95% CI, 1.02–2.19] and 1.68 [95% CI, 1.21–2.34], respectively, $P<0.0001$).

CONCLUSIONS: Disaggregation of Asian Americans with coronary artery disease into individual racial/ethnic subgroups reveals significant variability in treatment patterns and outcomes. Further investigation into these differences may expose important opportunities to mitigate disparities and improve quality of care in this diverse population.

Key Words: Asian ■ coronary artery disease ■ outcomes ■ race/ethnicity ■ treatment

Asians are the fastest growing ethnic group in the United States.[1] Today, they account for more than 22 million people living in the nation, a figure that has doubled since the turn of the century.[2,3] Collectively, they represent a wide variety of migration histories, cultures, lifestyles, and socioeconomic backgrounds. Yet despite the extraordinary growth of this diverse population, ethnic-specific data on Asian Americans has been sparse, primarily due to the historical lack of specificity of the term "Asian" in major federal health surveys and only recent classification of Asians into individual subgroups.[4,5] This knowledge gap is especially large for research in cardiovascular disease, a leading cause of morbidity and mortality among this population.[6]

In recent years, the disaggregation of Asian Americans in public health analyses has led to important observations regarding differences in cardiovascular disease prevalence and outcomes among Asian subgroups, particularly for patients with coronary

CLINICAL PERSPECTIVE

What Is New?

- Prior public health analyses have shown important differences in coronary artery disease risk factors, prevalence, and outcomes among Asian subgroups in the United States.
- This is the first large observational study to investigate whether there are differences in treatment practices and outcomes among disaggregated Asian American subgroups with coronary artery disease, compared with non-Hispanic whites.

What Are the Clinical Implications?

- In this analysis, we identified substantial heterogeneity in treatment patterns and outcomes among Asian American subgroups with coronary artery disease compared with non-Hispanic whites.
- Further investigation into treatment variation may expose important opportunities to improve the quality of care among Asian Americans with coronary artery disease.

Nonstandard Abbreviations and Acronyms

AF	atrial fibrillation
CABG	coronary artery bypass grafting
CAD	coronary artery disease
CHF	congestive heart failure
COPD	chronic obstructive pulmonary disease
CPT	current procedural terminology
GPI	generic product identifier
HTN	hypertension
ICD	*International Classification of Diseases*
NDC	national drug code
NHW	non-Hispanic white
PVD	peripheral vascular disease
TIA	transient ischemic attack

artery disease (CAD).[4,7–9] Epidemiologic data have shown that Asian Indians and Filipinos have a higher risk of CAD whereas Chinese patients have a lower risk compared with non-Hispanic whites (NHWs).[5] Apart from an increased prevalence, both Asian Indians and Filipinos have also been shown to have a higher proportionate mortality burden from coronary events.[7] Asian Indians in the United States seem to be especially vulnerable to CAD, with several studies demonstrating an earlier onset of acute coronary syndromes, increased severity of CAD at initial presentation, more frequent hospitalizations for ischemic heart

disease, and higher CAD-related mortality in younger patients,[4,9–11] with differences in disease course compared with NHWs likely conditional on the presence and severity of CAD. Taken together, these findings illustrate the marked heterogeneity in the natural history and outcomes of CAD among Asian Americans and necessitate research into actionable mechanisms that mediate these differences.

To our knowledge, no studies have yet compared treatment patterns and how they may relate to outcomes in CAD among multiple disaggregated Asian American subgroups. Therefore, the main aims of this analysis are to describe the proportion of patients undergoing diagnostic evaluation for CAD, determine the prevalence of CAD as defined by diagnostic angiography, and analyze differences in procedural and postprocedural treatment and outcomes among the six largest Asian American subgroups in the United States (Chinese, Asian Indians, Filipinos, Vietnamese, Koreans, and Japanese).

METHODS

The study population consisted of adult patients (age 18 years or older) who were active members of the Palo Alto Medical Foundation, a mixed-payer health care organization serving populations in Northern California between 2006 and 2015. Details regarding the characteristics of this health organization have been previously reported.[7] Patients within the study population represented one of the following self-identified race/ethnicity groups: NHW, Black, Hispanic, American Indian/Alaskan Native/Pacific Islander, Asian, or Other, with "Asian" further self-specified as either Asian Indian, Chinese, Filipino, Korean, Vietnamese, or "Other Asian." Patients who were multiracial/multiethnic or who did not have a known race/ethnicity or sex were excluded from the study. The Stanford Institutional Review Board approved this study and the need for informed consent was waived due to the retrospective study design. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Diagnostic Testing and CAD Prevalence

All data for this study were obtained through analysis of Current Procedural Terminology (CPT) and *International Classification of Diseases* (*ICD*) codes. Among all patients with known race/ethnicity and sex from the initial study population, CPT codes were used to identify those who underwent stress testing and/or coronary angiography. Within the subset of patients who received coronary angiography, *ICD* 9th and 10th Revision (*ICD-9* and *ICD-10*) codes were used to

identify those who had a diagnosis of CAD. In order to focus on the comparison between Asian Americans and NHWs, race/ethnicity groups outside of these categories were excluded from the analysis (ie, Hispanic, Black, American Indian, and "Other"). Patients who had a diagnosis of CAD only before the date of the first coronary angiogram and patients who had no follow-up encounter within 1 year after diagnosis of CAD were excluded from the analysis. Patients with CAD who either had at least 1 follow-up encounter or who died within 1 year after diagnosis served as the final cohort. Any patient with no follow-up within 1 year was excluded (Figure 1).

Demographics and Comorbidities among Patients With CAD

Among the final cohort, data regarding demographic information (age, sex, and household median income) and the presence of comorbid conditions (hypertension, diabetes mellitus, chronic obstructive pulmonary disease, atrial fibrillation, transient ischemic attack, and peripheral vascular disease) were analyzed.

Treatment and Outcomes for CAD

Among the final cohort, the number of patients who underwent procedural therapy (stenting and/or coronary artery bypass grafting [CABG]) was determined using CPT codes. Among those who underwent stenting, the number of patients who received clopidogrel or prasugrel was determined by reviewing medication names, national drug code identification numbers, and generic product identifier codes on medication orders. Clinical outcomes within 1 year after initial coronary angiography included mortality, stroke, transient ischemic attack, myocardial infarction, and major bleeding. Postangiogram myocardial infarction was defined as any myocardial infarction coded from day 8 through 365 after coronary angiography. To avoid potential late coding of the indication for the initial angiogram, we excluded postangiogram coding from day 1 to 8.

Statistical Analysis

Logistic regression was used to the examine the proportion who underwent stress testing by race/ethnicity and coronary angiography by race/ethnicity, with adjustment for age and sex. Among those who underwent angiography, the prevalence of CAD was calculated, and logistic regression was used to compare these results by race/ethnicity. Means, standard deviations, and frequency distributions of the demographic and clinical characteristics of those with CAD were determined. These results were then compared across race/ethnicity groups using ANOVA for continuous variables and chi-square tests for categorical

variables. Logistic regression was used to examine the relationships of medical and procedural therapies and outcomes for patients with CAD by race/ethnicity, with adjustment for age, sex, income, and baseline comorbidities. Baseline was defined as the time of first coronary angiography. Details regarding clinical, procedural, and medication definitions are outlined in Tables S1 through S3.

RESULTS

Diagnostic Testing and CAD Prevalence

A total of 772 882 patients with known race/ethnicity and sex were identified from the initial study population. Among the 219 150 (28.3%) Asians in this group, the highest proportion represented Asian Indians (38.5%), followed by Chinese (28.4%), Filipinos (9.6%), Japanese (4.2%), Koreans (3.2%), and Vietnamese (2.1%), with "Other Asian" accounting for the remainder of patients (14.1%).

Of the 772 882 patients included, 45 540 (5.89%) underwent stress testing and 8571 (1.11%) underwent coronary angiography. The proportion receiving each type of test varied substantially by race/ethnicity (*P*<0.0001 for each, respectively). Higher proportions of NHW patients underwent diagnostic testing for CAD than Asians overall (stress testing: 6.8% of NHWs versus 4.7% of all Asians [Chinese 5.5%, Asian Indian 4.4%, Filipino 6.2%, Japanese 6.0%, Korean 3.3%, Vietnamese 4.2%, Other Asian 2.6%]; coronary angiography: 1.4% of NHWs versus 0.6% of all Asians [Chinese 0.5%, Asian Indian 0.5%, Filipino 1.1%, Japanese 1.1%, Korean 0.4%, Vietnamese 0.4%, Other Asian 0.4%]). After adjustment for age and sex, Asian Indians and Filipinos, but not other subgroups, were more likely to undergo stress testing compared with NHW patients (adjusted odds ratios [ORs] 1.20 [CI 1.16–1.25] and 1.19 [CI 1.13–1.37], respectively, *P*<0.0001). All Asian subgroups apart from Filipinos were less likely to receive coronary angiography compared with NHW patients (adjusted ORs 0.48–0.87 [95% CI, 0.34–0.97], *P*<0.0001).

After coronary angiography, 6667 patients (79.2%) received a diagnosis of CAD. Prevalence of CAD was highest in Chinese (83.3%), Filipinos (82.4%), and Asian Indians (81.3%), though this was not significantly different from NHWs.

Comorbidities Among Patients With CAD

Among patients with CAD, there was significant heterogeneity by race/ethnicity with regard to age and comorbidities at the time of diagnosis (*P*<0.0001 for each, respectively). Mean age at initial coronary angiography was 66.8 years, and compared with NHWs, all Asian subgroups apart from Japanese were younger at the time of diagnosis of CAD (68.1 years versus
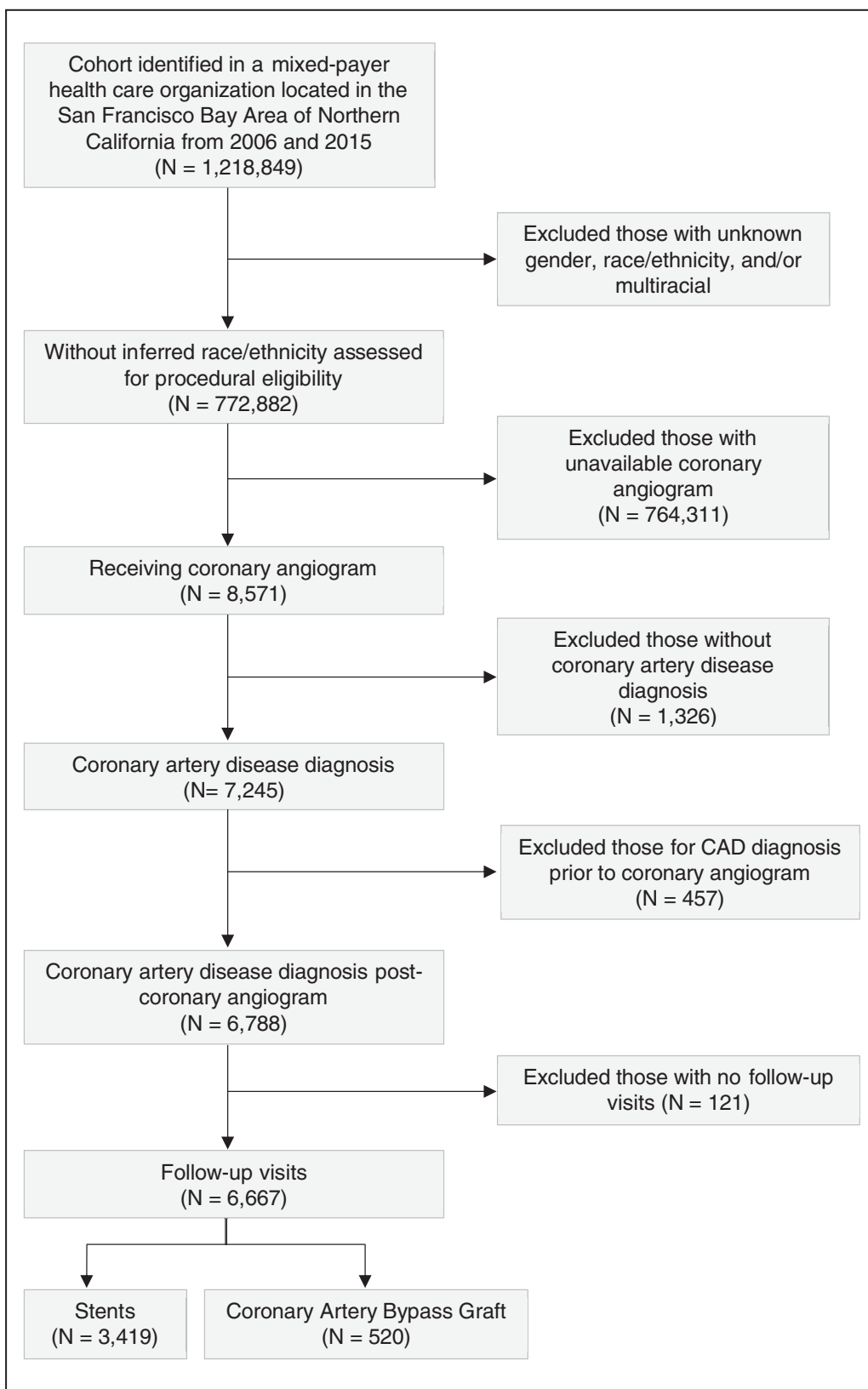
Figure 1. Cohort diagram.
Of the 1 218 849 patients treated at the healthcare organization between 2006 and 2015, 6667 patients with known sex and race/ethnicity ultimately underwent coronary angiography, were diagnosed with coronary artery disease, and had follow-up or death within 1 year after initial angiogram. Among the final cohort, 3419 underwent stenting and 520 underwent coronary artery bypass grafting. CAD indicates coronary artery disease.

60.2–64.5 years, respectively) (Table 1). Filipinos had the highest proportions of hypertension (78.0%) and diabetes mellitus (53.3%). Notably, the proportion of Filipinos with diabetes mellitus was more than double that of NHWs (53.3% versus 23.8%) (*P*<0.0001).

Procedural Therapies

Of the 6667 patients who received a diagnosis of CAD after coronary angiography, 3419 (51.3%) received a stent and 520 (7.8%) underwent CABG. After adjustment for age, sex, income, and comorbidities, Chinese were most likely to undergo stenting compared with NHWs (60.8% versus 50.9%, adjusted OR 1.39 [95% CI, 1.04–1.87], *P*=0.005) (Figure 2). Filipinos had the highest proportion who underwent CABG, which was nearly 3-fold higher than the proportion of NHWs (20.5% versus 6.9%, respectively, adjusted OR 2.65 [95%, CI 1.75–4.01], *P*<0.0001).

Medical Therapies for CAD

Among the 3419 patients who underwent stenting after coronary angiography, 2566 (75.1%) received clopidogrel and 337 (9.9%) received prasugrel (Table 2). After adjustment, Chinese, Filipinos, and Japanese were more likely to be prescribed clopidogrel compared with NHWs (86.2%, 83.0%, and 91.4% versus 74.5%, adjusted ORs 1.86 [95% CI, 1.13–3.04], 1.99 [95% CI, 1.01–3.44], and 4.37 [95% CI, 1.02–18.67], respectively, *P*<0.0001). There were no significant differences in prasugrel prescription by race/ethnicity (*P*=0.11).

One-Year Outcomes

Chinese and Asian Indians were more likely to be diagnosed with a myocardial infarction within 1 year following coronary angiography compared with NHWs (15.6% and 17.4% versus 11.2%, adjusted ORs 1.5 [95% CI, 1.02–2.19] and 1.7 [95% CI, 1.21–2.34], respectively, *P*<0.0001). The absolute percentage of Filipinos who were diagnosed with a myocardial infarction within 1 year following coronary angiography was higher than that of NHWs (13.9% versus 11.2%); however, this did not reach statistical significance after adjustment. Figure 3 illustrates the cumulative hazard plot of myocardial infarction from days 8 through 365 postangiogram by racial/ethnic group. There were no significant differences by race/ethnicity in postangiogram 1-year mortality, stroke, transient ischemic attack, or major bleeding after adjustment for demographic and clinical characteristics.

DISCUSSION

Using a decade of clinical data from a large, mixed-payer healthcare organization in Northern California

serving racially/ethnically diverse populations, we found substantial variation in therapeutic interventions and outcomes among Asian American subgroups with CAD. Compared with the NHW population, Chinese patients were more likely to undergo stenting and Filipinos were more likely to undergo CABG as procedural therapies for CAD. After receiving a stent, Chinese, Filipino, and Japanese patients were more likely to be prescribed clopidogrel compared with the NHW population. Finally, Asian Indians and Chinese patients were more likely to be diagnosed with a myocardial infarction within 1 year following initial coronary angiography compared with NHW counterparts. To our knowledge, the present study is the first analysis that has characterized CAD treatment and outcome data from multiple Asian subgroups in the United States.

Over the past several decades, the relatively few studies that have examined treatment patterns or outcomes among Asian Americans with CAD have used predominantly aggregated cohorts, largely due to a lack of available subgroup granularity for comparative analysis.[12–16] In the era of fibrinolytic therapy for ST-elevation myocardial infarction, for example, data from the National Registry for Myocardial Infarction showed that Asian Americans and Pacific Islanders experienced longer "door-to-drug" times compared with white patients, despite adjustment for risk factors.[12] Research from the late 1990s showed that after acute coronary syndromes, male Asian Americans and Pacific Islanders were more likely to undergo CABG and had a trend toward higher mortality compared with NHW patients.[13] Data from the CRUSADE initiative illustrated that Asian Americans undergoing therapy for non–ST–elevation myocardial infarction carry significantly higher bleeding risk even after adjustment for risk factors and body mass index, suggesting the potential for ethnic variability in antithrombotic susceptibility.[14] Lastly, more recent studies have shown that Asian Americans suffer worse in-hospital mortality after acute myocardial infarction and acute coronary syndromes compared with NHW patients, despite rapid times to percutaneous coronary intervention and higher implantation of drug-eluting stents.[15,16] Collectively, although these data underscore general disparities among Asian Americans with CAD, the aggregation of multiple subgroups masks significant heterogeneity and leads to an incomplete understanding of CAD and outcomes in this population.

Our results raise a number of important questions surrounding the mechanisms that mediate differences in care and outcomes among certain Asian American subgroups suffering from CAD. The increased likelihood of Chinese patients to receive stenting compared with NHW patients, for example, may be due to the possibility that Chinese patients present with less severe coronary disease that is more amenable

Table 1. Diagnostic Testing and Patient Characteristics

Race/Ethnicity	Non-Hispanic White	Chinese	Asian Indian	Filipino	Japanese	Korean	Vietnamese	Other Asian	P Value
Number of patients (n)	4885	250	316	195	75	18	15	96	
Demographics									
CAD diagnosis, %	78.9	83.3	81.3	82.4	78.6	79.2	79.0	80.3	0.5490
Male, %	67.0	79.2	77.5	61.3	68.0	61.1	66.7	77.1	<0.0001
Median income (in $10 000)	10.3	12.2	12.0	9.4	10.8	9.9	10.2	11.3	<0.0001
Comorbidities									
HTN, %	67.4	64.8	60.1	78.0	77.3	66.7	53.3	66.7	0.0017
DM, %	23.8	26.8	37.3	53.3	37.3	33.3	40.0	35.4	<0.0001
COPD, %	16.0	8.4	9.2	17.4	13.3	5.6	20.0	8.3	0.0005
AF, %	15.4	8.8	5.1	11.3	14.7	5.6	13.3	8.3	<0.0001
CHF, %	16.8	12.8	15.8	19.5	22.7	0.0	13.3	11.5	0.1146
Stroke, %	9.5	7.2	5.4	9.7	10.7	0.0	6.7	7.3	0.1864
TIA, %	3.9	0.8	1.6	1.0	2.7	0.0	6.7	2.1	0.024
PVD, %	14.6	6.8	7.3	11.8	14.7	0.0	6.7	6.3	<0.0001

Proportion of Asian American and non-Hispanic white patients with a diagnosis of CAD after angiography by race/ethnicity. Among those with a diagnosis of CAD after angiography, the distribution of comorbid conditions and demographic information (sex and income) are listed by race/ethnicity. Among all patients with known sex and race/ethnicity, the proportion that underwent diagnostic testing (stress tests and/or coronary angiography) are listed by race/ethnicity. AF indicates atrial fibrillation; CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; HTN, hypertension; PVD, peripheral vascular disease; and TIA, transient ischemic attack.
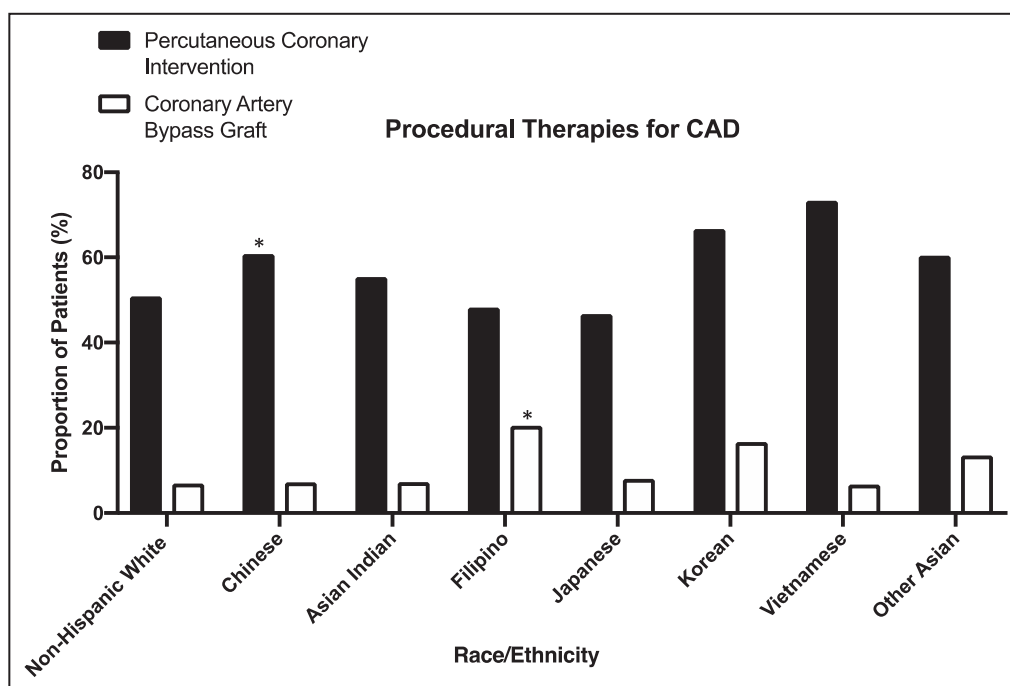
Figure 2. Procedural therapy for coronary artery disease by race/ethnicity using Non-Hispanic whites as the comparison group.
After adjustment for age, sex, income, and comorbidities, Chinese were more likely to undergo stenting (60.8% vs 50.9%, adjusted odds ratio [OR] 1.39 [95% CI, 1.04–1.87], P=0.005), and Filipinos were more likely to undergo coronary artery bypass grafting (20.5% vs 6.9%, adjusted OR 2.65 [CI, 1.75–4.01], P<0.0001) compared with non-Hispanic whites. *Statistically significant differences. CAD indicates coronary artery disease.

to percutaneous intervention. Conversely, Chinese patients may undergo more stenting because they might decline recommendations for surgery due to health literacy or cultural biases against more invasive procedures.[17] Studies that examine the severity of CAD at presentation and investigate both the medical and sociocultural barriers to undergoing CABG among Chinese American patients may be able to address the increased likelihood of stenting in this group.

Although a high prevalence of diabetes mellitus, hypertension, and metabolic syndrome is well documented in Filipino Americans, there is some evidence that these traditional risk factors are insufficient to explain the increased risk for coronary events in this population.[8,18–24] An observational report by Ryan et al[24] using outcome data from the late 1990s showed that classification as a Filipino American was an independent predictor of triple vessel disease, higher mortality

Table 2. Medication Prescription by Race/Ethnicity

Medication Name	Clopidogrel (%)	Adjusted Odds Ratio (95% CI)	Prasugrel (%)	Adjusted Odds Ratio (95% CI)
Race/ethnicity				
NHW	74.5	1.00	10.4	1.00
Chinese*	86.2	1.86 (1.13–3.04)	3.3	0.30 (0.12–0.76)
Asian Indian	82.3	1.43 (0.94–2.18)	8.0	0.57 (0.30–1.07)
Filipino*	83.0	1.86 (1.01–3.44)	7.5	0.64 (0.28–1.43)
Japanese*	91.4	4.37 (1.02–18.67)	5.7	0.33 (0.04–2.51)
Korean	75.0	1.54 (0.33–7.24)	0.0	0.00
Vietnamese	90.9	3.58 (0.45–28.30)	0.0	0.00
Other Asian	67.2	0.61 (0.32–1.13)	6.9	0.66 (0.23–1.89)

Medication treatment differences by race/ethnicity among patients who received a stent using non-Hispanic whites (NHWs) as the comparison group. After adjustment for age, sex, income, and comorbidities, Chinese, Filipinos, and Japanese were more likely to be prescribed clopidogrel compared with NHWs.
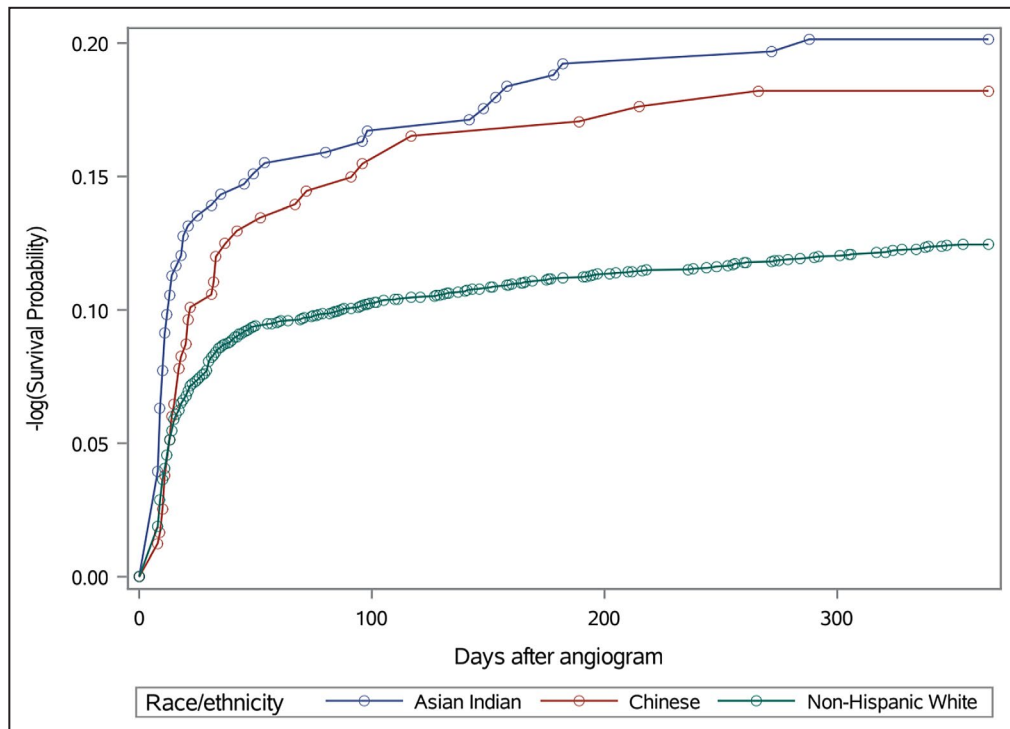*Statistically significant differences.

Figure 3. Cumulative survival plot of myocardial infarction within 1 year of initial coronary angiography.
After adjustment for age, sex, income, and comorbidities, Chinese and Asian Indians were more likely to be diagnosed with a myocardial infarction within 1 year following coronary angiography compared with NHWs (15.6% and 17.4% vs 11.2%, adjusted odds ratios [ORs] 1.49 [CI, 1.02–2.19] and 1.68 [CI, 1.21–2.34], respectively, $P<0.0001$). Note that only racial/ethnic groups who were significantly different from NHWs are demonstrated here. NHW indicates non-Hispanic white.

after catheterization laboratory intervention, and increased need for late reintervention. Our analysis extends these findings further by demonstrating a nearly 3-fold higher proportion of Filipino patients undergoing CABG compared with NHW counterparts despite adjustment for comorbid risk factors, age, and income, an observation that likely reflects accelerated triple vessel disease in this population. In light of this finding, the trend toward a higher likelihood of myocardial infarction within 1 year after initial coronary angiography among Filipino patients, although not statistically significant, should not be dismissed. In addition to identifying potential genetic drivers for these disparities, future work should also investigate the role of modifiable social factors such as medication adherence and physical activity levels, both of which remain suboptimal in Filipino American populations.[25,26]

The differences regarding medication prescriptions after coronary stenting among Asian Americans in our analysis may provide insight into the observed differences in CAD outcomes, particularly among Chinese Americans. Multiple systematic reviews and meta-analyses have documented the association between CYP219 polymorphism and adverse cardiovascular outcomes among patients receiving clopidogrel therapy, ultimately leading to a black box warning issued by the Food and Drug Administration that recommends consideration of alternate antiplatelet medications or higher dosing strategies for clopidogrel in patients whom are identified as poor metabolizers.[27–30] Despite the high prevalence of poor metabolizers in the Chinese population (up to 14%), our analysis demonstrates that, compared with NHW patients, Chinese Americans were both more likely to receive clopidogrel and had higher risk of myocardial infarction within 1 year after initial coronary angiography.[30] Thus, whether or not the poor outcomes seen among Chinese Americans with CAD might relate to potentially inappropriate clopidogrel use remains an important area of future investigation. Moreover, even though not recommended routinely,[31] these results should encourage providers to consider CYP219 genotype testing for patients with suspected clopidogrel resistance—a practice that has been demonstrated to be both feasible and cost-effective.[31,32]

Lastly, the vulnerability of the Asian Indian population to CAD is again exposed in the present study, as evidenced by the nearly 60% higher proportion of Asian Indian patients diagnosed with a myocardial infarction within 1 year after initial coronary angiography

compared with NHW counterparts. In the context of CAD, Asian Indians in the United States resemble Filipino Americans in that the severity of their disease and correspondingly poor outcomes are not fully accounted for by their increased burden of traditional risk factors.[4,7–11,33] Several biological mechanisms that may explain our findings include aspirin or other antiplatelet resistance, smaller observed epicardial coronary artery diameter compared with other race/ethnicities (which may contribute to faster atherosclerosis and increased difficulty of successful percutaneous coronary intervention), and a whole host of genetic factors that are implicated in accelerated CAD.[33–35] Meanwhile, nonbiologic mechanisms remain equally important and include Asian Indians' tendency for lower levels of physical inactivity, higher rates of adverse psychosocial factors (ie, depression and stress at work or home), and higher instances of perceived interpersonal discrimination when seeking healthcare services.[36–40] Although aggressive management of modifiable risk factors is essential for Asian Indians with CAD, additional work to characterize and understand nontraditional and social risk factors will be necessary to further reduce outcome disparities in this population.

There are several limitations of this study. The study population derived from a single geographic area and certain subgroups had substantially smaller sample sizes (ie, Korean and Vietnamese populations), which limits generalizability. Data were gathered using *ICD-10* and CPT information, both of which are subject to coding errors. In an attempt to mitigate misattribution of postangiogram myocardial infarction to simple delays in coding, we specifically chose to examine only myocardial infarctions after day 8 postangiogram, but this would underestimate any true infarcts that occurred immediately postangiogram. This will be particularly important to examine in future studies given the importance of early stent thrombosis due to clopidogrel resistance among Asian subgroups. In addition, there are multiple residual confounders that were not accounted for. Traditional CAD risk factor data that we did not have access to included smoking status, obesity, family history, rates of physical inactivity, and rates of hyperlipidemia. However, adjusting for multiple cardiovascular comorbidities that share the same traditional risk factors may mitigate this limitation (ie, macrovascular conditions such as stroke and peripheral vascular disease). Furthermore, although acculturation has been associated with the development of cardiovascular disease and increased cardiovascular disease risk factors, we were unable to characterize migration status in our study population.[41,42] Lastly, there are many unmeasured lifestyle and social factors that might have contributed to the disparities seen in our study, including dietary habits, psychological influences, and environmental factors.[37]

CONCLUSIONS

In conclusion, we found marked heterogeneity in the treatment patterns and outcomes among Asian American subgroups with CAD. These findings demonstrate the compelling need to disaggregate Asians in both research and clinical practice if we are to gain a better understanding of the biologic and cultural factors that influence disparate outcomes among these patients and potential opportunities to intervene upon them.

REFERENCES

1. Colby SL, Ortman JM. United States Census Bureau. Projections of the size and composition of the U.S. Population: 2014 to 2060. 2015 March Available at: https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf. Accessed August 15, 2019.

2. Lopez G, Ruiz NG, Patten E. Pew Research Center. Key facts about Asian Americans, a diverse and growing population. 2017. Available at: https://www.pewresearch.org/fact-tank/2017/09/08/key-facts-about-asian-americans/. Accessed: August 15, 2019.

3. United States Census Bureau. United States Census Bureau. American Fact Finder. May 2010. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk#. Accessed August 15, 2019.

4. Wang EJ, Wong EC, Dixit AA, Fortmann SP, Linde RB, Palaniappan LP. Type 2 diabetes: identifying high risk Asian American subgroups in a clinical population. *Diabetes Res Clin Pract*. 2011;93:248–254.

5. Palaniappan L, Wang Y, Fortmann SP. Coronary heart disease mortality for six ethnic groups in California, 1990–2000. *Ann Epidemiol*. 2004;14:499–506.

6. Palaniappan LP, Araneta MR, Assimes TL, Barrett-Connor EL, Carnethon MR, Criqui MH, Fung GL, Venkat Narayan KM, Patel H, Taylor-Pilliae RE, et al. Call to action: cardiovascular disease in Asian Americans: a science advisory from the American Heart Association. *Circulation*. 2010;122:1242–1252.

7. Jose PO, Frank AT, Kapphahn KI, Goldstein BA, Eggleston K, Hastings KG, Cullen MR, Palaniappan LP. Cardiovascular disease mortality in Asian Americans. *J Am Coll Cardiol*. 2014;64:2486–2494.

8. Joshi P, Islam S, Pais P, Reddy S, Dorairaj P, Kazmi K, Pandey MR, Haque S, Mendis S, Rangaraian S, et al. Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *JAMA*. 2007;297:286–294.

9. Holland AT, Wong EC, Lauderdale DS, Palaniappan LP. Spectrum of cardiovascular diseases in Asian-American racial/ethnic subgroups. *Ann Epidemiol*. 2011;21:608–614.

10. Rosengren A, Wallentin L, Simoons M, Gitt AK, Behar S, Battler A, Hasdai D. Age, clinical presentation, and outcome of acute coronary syndromes in the Euroheart acute coronary syndrome survey. *Eur Heart J*. 2006;27:789–795.

11. Klatsky AL, Tekawa I, Armstrong MA, Sidney S. The risk of hospitalization for ischemic heart disease among Asian Americans in northern California. *Am J Public Health*. 1994;84:1672–1675.

12. Qian F, Ling FS, Deedwania P, Hernandez AF, Fonarow GC, Cannon CP, Peterson ED, Peacock WF, Kaltenbach LA, Laskey WK, et al. Care and outcomes of Asian-American acute myocardial infarction patients: findings from the American Heart Association Get With The Guidelines-Coronary Artery Disease program. *Circ Cardiovasc Qual Outcomes*. 2012;5:126–133.

13. Wang TY, Chen AY, Roe MT, Alexander KP, Newby LK, Smith SC, Bangalore S, Gibler WB, Ohman EM, Peterson ED. Comparison of baseline characteristics, treatment patterns, and in-hospital outcomes of Asian versus non-Asian white Americans with non-ST-segment elevation acute coronary syndromes from the CRUSADE quality improvement initiative. *Am J Cardiol*. 2007;100:391–396.

14. Taira DA, Seto TB, Marciel C. Ethnic disparities in care following acute coronary syndromes among Asian Americans and Pacific Islanders during the initial hospitalization. *Cell Mol Biol*. 2001;47:1209–1215.

15. Bradley EH, Herrin J, Wang Y, McNamara RL, Webster TR, Magid DJ, Blaney M, Peterson ED, Canto JG, Pollack CV, et al. Racial and ethnic differences in time to acute reperfusion therapy for patients hospitalized with myocardial infarction. *JAMA*. 2004;292:1563–1572.

16. Yong CM, Ungar L, Abnousi F, Asch SM, Heidenreich PA. Racial differences in quality of care and outcomes after acute coronary syndrome. *Am J Cardiol*. 2018;121:1489–1495.

17. Lee HY, Rhee TG, Kim NK, Ahluwalia JS. Health literacy as a social determinant of health in Asian American immigrants: findings from a population-based survey in California. *J Gen Intern Med*. 2015;30:1118–1124.

18. Araneta MR, Barrett-Connor E. Ethnic differences in visceral adipose tissue and type 2 diabetes: Filipino, African-American, and white women. *Obes Res*. 2005;13:1458–1465.

19. Araneta MR, Wingard DL, Barrett-Connor E. Type 2 diabetes and metabolic syndrome in Filipina-American women : a high-risk nonobese population. *Diabetes Care*. 2002;25:494–499.

20. Klatsky AL, Armstrong MA. Cardiovascular risk factors among Asian Americans living in northern California. *Am J Public Health*. 1991;81:1423–1428.

21. Palaniappan LPWE, Shin JJ, Fortmann SP, Lauderdale DS. Asian Americans have greater prevalence of metabolic syndrome despite lower body mass index. *Int J Obes*. 2011;35:393–400.

22. Tanchoco CCCA, Duante CA, Litonjua AD. Prevalence of metabolic syndrome among Filipino adults aged 20 years and over. *Asia Pac J Clin Nutr*. 2003;12:271–276.

23. Ye J, Rust G, Baltrus P, Daniels E. Cardiovascular risk factors among Asian Americans: results from a National Health Survey. *Ann Epidemiol*. 2009;19:718–723.

24. Ryan C, Shaw R, Pliam M, Zapolanksi AJ, Murphy M, Valle HV, Myler R. Coronary heart disease in Filipino and Filipino-American patients: prevalence of risk factors and outcomes of treatment. *J Invasive Cardiol*. 2000;12:134–139.

25. Taira DA, Gelber RP, Davis J, Gronley K, Chung RS, Seto TB. Antihypertensive adherence and drug class among Asian Pacific Americans. *Ethn Health*. 2007;12:265–281.

26. Bhimla A, Gadegbeku CA, Tan Y, Zhu L, Aczon F, Ma GX. A study of physical activity determinants among high-risk hypertensive Filipino and Korean Americans. *Int J Environ Res Public Health*. 2019;16:1156.

27. Sorich MJ, Rowland A, McKinnon RA, Wiese MD. CYP2C19 genotype has a greater effect on adverse cardiovascular outcomes following percutaneous coronary intervention and in Asian populations treated with clopidogrel: a meta-analysis. *Cir Cardiovasc Genet*. 2014;7:895–902.

28. Mao L, Jian C, Changzhi L, Dan H, Suihua H, Wanyi T, Wei W. Cytochrome CYP2C19 polymorphism and risk of adverse clinical events in clopidogrel-treated patients: a meta-analysis based on 23,035 subjects. *Arch Cardiovasc Dis*. 2013;106:517–527.

29. Zhang L, Yang J, Zhu X, Wang X, Peng L, Li X, Cheng P, Yin T. Effect of high-dose clopidogrel according to CYP2C19*2 genotype in patients undergoing percutaneous coronary intervention- a systematic review and meta-analysis. *Thromb Res*. 2015;135:449–458.

30. Partnership B-MSSP. PLAVIX (clopidogrel bisulfate) tablets, for oral use. Bristol-Myers Squibb/Sanofi Pharmaceuticals Partnership. September 2016. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/020839s062s064lbl.pdf. Accessed September 1, 2019.

31. Reese ES, Daniel Mullins C, Beitelshees AL, Onukwugha E. Cost-effectiveness of cytochrome P450 2C19 genotype screening for selection of antiplatelet therapy with clopidogrel or prasugrel. *Pharmacotherapy*. 2012;32:323–332.

32. Johnson SG, Shaw PB, Delate T, Kurz DL, Gregg D, Darnell JC, Aquilante CL. Feasibility of clinical pharmacist-led CYP2C19 genotyping for patients receiving non-emergent cardiac catheterization in an integrated health system. *Pharm Pract (Granada)*. 2017;15:946.

33. Ardeshna DR, Bob-Manuel T, Nanda A, Shrma A, Skelton WP, Skelton M, Khouzam RN. Asian-Indians: a review of coronary artery disease in this understudied cohort in the United States. *Ann Transl Med*. 2018;6:12.

34. Makaryus AN, Jauhar R, Tortez LM, Pekmezaris R. Comparison of the diameters of the major epicardial coronary arteries by angiogram in Asian-Indians versus European Americans <40 years of age undergoing percutaneous coronary artery intervention. *Am J Cardiol*. 2017;120:924–926.

35. Chadha DS, Sumana B, Karthikeyan G, Jayaprasad V, Arun SS. Prevalence of aspirin resistance in Asian-Indian patients with stable coronary artery disease. *Catheter Cardiovasc Interv*. 2016;88:E126–E131.

36. Daniel M, Wilbur J, Fogg LF, Miller AM. Correlates of lifestyle: physical activity among South Asian Indian immigrants. *J Community Health Nurs*. 2013;30:185–200.

37. Volgman AS, Palaniappan LS, Aggarwal NT, Gupta M, Khandelwal A, Krishnan AV, Lichtman JH, Mehta LS, Patel HN, Shah KS, et al. Atherosclerotic cardiovascular disease in South Asians in the United States: epidemiology, risk factors, and treatments: a scientific statement from the American Heart Association. *Circulation*. 2018;138:e1–e34.

38. Shah BM, Shah S, Kandula N, Gadgil MD, Kanaya AM. Psychosocial factors associated with subclinical atherosclerosis in South Asians: the MASALA Study. *J Immigr Minor Health*. 2016;18:1317–1327.

39. Misra R, Hunte H. Perceived discrimination and health outcomes among Asian Indians in the United States. *BMC Health Serv Res*. 2016;16:567.

40. Joshi P, Islam S, Pais P, Reddy S, Dorairaj P, Kazmi K, Pandey MR, Haque S, Mendis S, Rangarajan S, et al. Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *JAMA*. 2007;297:286–294.

41. Marmot MG, Syme SL. Acculturation and coronary heart disease in Japanese-Americans. *Am J Epidemiol*. 1976;104:225–247.

42. Taylor VM, Yasui Y, Tu SP, Neuhouser ML, Li L, Woodall E, Acorda E, Cripe SM, Hislop TG. Heart disease prevention among Chinese immigrants. *J Community Health*. 2007;32:299–310.