Phase III: Disparities in Access to Selected Advanced Medical Procedures in the Medicare Population

Prepared For:

Advanced Medical Technology Association (AdvaMed)

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Executive Summary

Racial and ethnic healthcare disparities in access to advanced interventions have persisted for decades in U.S. healthcare, making clear the need for increased attention and policy action to reduce these disparities.

In this third of our series of reports on disparities in the use of advanced interventions in the Medicare program, we examined whether measurable disparities in access were detectable for racial minorities, women, and by dual-eligibility for Medicaid status. In addition, we focused on how to interpret those differences after accounting for patient clinical and utilization history as well as provider and geographic factors.

The analysis targeted five interventions: cardiac ablation for patients with atrial fibrillation or arrhythmias; angioplasty for patients with acute myocardial infarction or angina; transaortic valve replacement (TAVR) for patient with aortic stenosis; mechanical thrombectomy for patients with ischemic stroke; and, thrombolysis for patients with ischemic stroke. Our key findings were:

1. Significant disparities in access exist, particularly for Black and dual-eligible Medicare beneficiaries even after accounting for the effects of provider and beneficiaries' county of residence fixed effects (FE) in addition to patient demographic, clinical, and utilization histories (Figure ES.1).
    - Across all five interventions, the size of the disparity between Black and White Medicare beneficiaries was between 21% and 40% of the overall utilization rate for the service.
    - Dual-eligible beneficiaries likewise were consistently less likely to receive these interventions than non-dual beneficiaries.
    - Gender disparities in the full models were typically smaller than for race and dual-eligibility and only detectable for cardiac ablation and angioplasty.

2. The disparities observed in the use of these interventions were largest for Black and dually-eligible Medicare beneficiaries. The largest disparities for Other race beneficiaries were in angioplasty and TAVR, while for women they were in cardiac ablation and angioplasty.

3. Accounting for provider effects and county effects either had no impact or increased the estimates of disparity for Black Medicare beneficiaries relative to White beneficiaries; in contrast, accounting for geography using county FE had no or only small impacts on the magnitude of disparity estimates across the demographic attributes of interest.

Figure ES.1: Adjusted Disparity Estimate as a Percentage of the Overall Average Medicare Utilization Rate, 2018-2019

Intervention	Model	Black (%)	Dual-Eligible (%)
Cardiac Ablation	Provider FE	-36.0 ***	-43.2 ***
	County FE	-35.3 ***	-52.0 ***
Angioplasty	Provider FE	-21.8 ***	-10.7 ***
	County FE	-24.2 ***	-13.6 ***
TAVR	Provider FE	-40.1 ***	-38.5 ***
	County FE	-39.7 ***	-43.1 ***
Mechanical Thrombectomy	Provider FE	-35.5 **	-14.4 *
	County FE	-21.8 **	-33.0 ***
Thrombolysis	Provider FE	-31.6 ***	-27.4 ***
	County FE	-28.7 ***	-43.0 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.
Note: Negative values represent lower utilization rates relative to the reference population: for Race, the reference is White Medicare beneficiaries; for dual-eligibility the reference is non-dual Medicare beneficiaries. The percentage is calculated as: 100 times (a) the adjusted estimate in percentage points from the provider FE and county FE models for each procedure and attribute then (b) divided by the Medicare average utilization rate for the procedure. The significance levels refer to the coefficient estimates for the patient attribute in the respective regressions.

I. Introduction

Racial and ethnic health and healthcare disparities have been documented by researchers for years.[1,2,3] In recent years the healthcare community has renewed its attention on these issues, in part, due to recent social justice movements and the impact of major public health crises, such as the COVID-19 pandemic on people of color.

AdvaMed is a trade association that represents medical device, diagnostic product, and digital health technology companies in their efforts to help patients achieve healthier lives and healthier economies around the world. The October 2023 edition of AdvaMed's *Principles on Health Equity* highlighted four key propositions.[4]

1. **Promoting Inclusion and Equity in Health Care**. This principle emphasizes equitable access to unbiased, quality healthcare regardless of location, advocating for fair treatment in health encounters while urging providers to recognize and address biases in patient interactions. AdvaMed, along with its members, aims to disseminate information promoting unbiased patient treatment and support legislation fostering equitable patient care and improved access to healthcare facilities, particularly in underserved communities.
2. **Partnering in Education with Stakeholders**. Knowing about technology should not depend on where the patient lives, their resources, their gender or race. AdvaMed aims to ensure widespread awareness of novel medical technologies with potential benefits for individuals. Efforts include development of informational materials for patients and education of healthcare providers, especially those catering to individuals of diverse backgrounds. Collaboration with medical professionals, policy changes to improve accessibility, and partnerships with organizations supporting underserved communities are integral to achieving this goal.
3. **Patient Access to Innovative Technology**. Everyone should have access to new medical technology that can make their lives better regardless of insurance status. Patients should also have equitable access to infrastructure advancements that improve their ability to access care. AdvaMed will advocate to promote timely access to technology to benefit patient outcomes.
4. **Promoting Research Equity in the MedTech Industry**. This principle proposes to advance the evidence base by making research recruitment and clinical trials more inclusive of underserved communities. This will require working with different groups to build trust, encouraging more

[1] Williams, D. R., & Collins, C. (1995). U.S. Socioeconomic and Racial Differences in Health: Patterns and Explanations. *Annual Review of Sociology, 21*, 349-386.

[2] Gornick ME, Eggers PW, Reilly TW, et al. (1996). Effects of race and income on mortality and use of services among Medicare beneficiaries. *New England Journal of Medicine, 335*(11):791–799.

[3] Institute of Medicine. 2003. Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care. Washington, DC: The National Academies Press. https://doi.org/10.17226/12875.

[4] https://www.advamed.org/member-center/resource-library/principles-on-health-equity/ and https://www.advamed.org/wp-content/uploads/2023/10/Principles-on-Health-Equity.pdf

people to take part in research, and supporting patient participation and retention. It will also require work to increase diversity among clinical investigators.

The principles articulate the role of AdvaMed and its members in promoting health equity and educating providers and policymakers on the existence of disparities in access to innovative technologies, the reasons for these access barriers among some groups of patients, and supporting policy solutions.

The need for increased focus and policy action on health disparities is clear. Recent studies demonstrate that disparities in access to innovative technology and advanced procedures have been stubbornly persistent. For example, Best and colleagues assessed changes in racial disparities between White and Black patients for nine surgical procedures, including angioplasty, spinal fusion, carotid endarterectomy, appendectomy, colorectal resection, coronary artery bypass grafting, total hip arthroplasty, total knee arthroplasty, and heart valve replacement.[5] They found racial disparities in all nine procedures either remained similar over time or, in 3 of the 9, worsened between 2012 and 2017.

This report estimates disparities in access to five advanced technologies in the Medicare program for racial minorities, women, and people dually enrolled in Medicare and Medicaid (dual-eligibles):

- Cardiac ablation (cardiovascular) for atrial fibrillation or other arrhythmias.
- Angioplasty (cardiovascular) for acute myocardial infarction or angina.
- Transaortic valve replacement (cardiovascular) for aortic stenosis.
- Mechanical thrombectomy (neurovascular) for ischemic stroke.
- Thrombolysis (neurovascular) for ischemic stroke.

This study aims to help AdvaMed educate stakeholders and engage in activities consistent with its stated health equity principles by documenting utilization differences to the types of technologies developed by member companies and uncovering potential reasons for these patterns. The analysis aimed to answer the following questions:

1. How large are disparities in access to these services after we account for provider differences in utilization of these services?
2. How large are disparities in access to these services after we account for the patient's county of residence?
3. What do the patterns of disparity across the provider and county models tell us about the potential sources of disparity?

The remainder of the report is organized as follows: The next section briefly summarizes the methods, including analyses and data sources (with additional detail included in Appendix A). We then present the results separately for each service, with a summary of findings across services. We conclude with a brief discussion of the findings and conclusion section.

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[5] Best MJ, McFarland EG, Thakkar SC, Srikumaran U. (2021). Racial Disparities in the Use of Surgical Procedures in the US. *JAMA Surg, 156*(3):274–281. doi:10.1001/jamasurg.2020.6257

II. Methods

The Phase III analysis examined differences in the utilization rate for five interventions for specific conditions: cardiac ablation (atrial fibrillation or arrhythmia), angioplasty (AMI or angina), TAVR (aortic stenosis), mechanical thrombectomy (ischemic stroke), and thrombolysis (ischemic stroke). We defined an indicated population for each condition (e.g., patients with atrial fibrillation or arrhythmia) and assessed whether the procedure of interest occurred on that claim. Therefore, these utilization rates and estimates of disparity are conditional upon having used services and received a qualifying diagnosis.[6]

We used a regression framework that controlled initially for patient demographic attributes plus clinical (comorbid conditions) and utilization (past inpatient and outpatient service use). We then examined the change in disparity resulting from accounting for shared provider and geographic (beneficiary county of residence) factors. The remainder of this section describes the analytic choices surrounding the data and variables used.[7]

A. Data

The analysis used the Medicare 5% Standard Analytic File for calendar years 2018 and 2019. Patient demographic information as well as information about dual-eligibility for Medicaid and county of residence came from the Medicare Beneficiary Summary File. Information used to identify the subset of cases that were likely candidates to receive the intervention (as well as the associated service provider) were based on the inpatient, outpatient, and carrier claims data. To examine the history of service use for the 2018 cases, we also used the 2017 versions of these data.

B. Study Population

The study population was limited to adult Medicare fee-for-service (FFS) beneficiaries (18 years of age or older) in 2018 or 2019. FFS coverage was defined as at least one month of either Part A or Part B Medicare coverage. We used a mix of ICD-10-CM diagnosis, ICD-10-PCS procedure, and MS-DRG codes to identify the indicated patient population (i.e., patients with the diagnosis of interest) and whether those patients received the service of interest. The algorithm is included in Appendix A.

We focused on the first claim in the year (index diagnosis) with each Medicare beneficiary allowed to contribute one observation per year. This approach allowed a common index event for the indicated population to be used to assess comorbidities identified prior to the index admission. It also captures patients "mid-stream" in their current service history. That is, for some patients this index service will be their first diagnosis ever while for others it may be within a series of on-going contacts. This approach

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[6] The population is also limited in the specificity of the indicated population by the diagnostic information available. In the case of TAVR, the procedure is recommended for patients with severe symptomatic aortic stenosis. However, claims data only provide information about diagnosis of aortic stenosis without additional indication of severity. Thus, in this report we use the term "indicated population" to mean the population evaluated in this study (i.e., all patients with a diagnosis of aortic stenosis) even though the true population of cases that are clinically indicated is narrower.

[7] See Appendix A for additional details on the data sources and variables.

also limited the impact of differential access by race and other conditions by not overweighting additional visits for patients that may present multiple times per year.

C. Outcome Variables

We examined the rates of utilization for the set of cardiovascular and neurovascular procedures: cardiac ablation (indicated population is arrhythmia or atrial fibrillation), angioplasty (acute myocardial infarction or angina), transaortic valve replacement (aortic stenosis), mechanical thrombectomy (ischemic stroke), and thrombolysis (ischemic stroke).

The outcome of interest was whether the Medicare beneficiaries in the eligible population for the specific condition (e.g., aortic stenosis) received the procedure of interest (e.g., TAVR). Those that received the service were marked as 1's and those that did not were marked as 0's. The pool of cases was limited to the patients in the indicated population (i.e., had the diagnosis of interest).[8]

D. Independent Variables

The analysis classified patients according to beneficiary age, race/ethnicity, gender, and dual-eligibility status in the year. The sample was limited to adults, and age was categorized as 18-44, 45-64, 65-74, 75-84 and 85 and older. Race/ethnicity was grouped as White non-Hispanic, Black non-Hispanic, and Other race.[9] Dual-eligibility was determined for the member during the patient's year of coverage (any dual-eligibility in the year v. no dual-eligibility observed). We also identify each patient's county of residence in the month of the index claim.

We identified patient comorbidities using diagnoses on claims for the 12 months prior to and inclusive of the index service.[10] We then mapped diagnoses to condition categories in the CMS Hierarchical Condition Category system. The full regression analysis (Appendix C) used all 79 condition categories; the descriptive results (Appendix B) summarized information on the 15 most common comorbid conditions across the services. We also summarized prior service use to account for the level of interaction with the healthcare system. The measures included indications for the 12 months prior to the index service, any inpatient admission, any hospital outpatient visit, number of inpatient admissions, and number of outpatient visits.

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[8] We use the term "indicated population" here for consistency across all procedures. There is imprecision in the use of the term given the type of data available. For example, TAVR is indicated only for patients with severe symptomatic aortic stenosis; likewise, the ischemic stroke procedures may not be appropriate for patients admitted past a time interval following an ischemic stroke. However, given the limitations of claims data, this is the indicated population for this analysis. Future studies with more robust data sources (e.g., electronic medical records with lab results) may address this limitation.

[9] For simplicity, we will use "Black" and "White" instead of Black non-Hispanic and White non-Hispanic to describe the race of Medicare beneficiaries. The Other race category includes the following race categories (as coded by CMS): Asian, Hispanic, Native American, Other (as coded by CMS) and Unknown.

[10] The study sample is limited to patients enrolled in Medicare FFS. The history information may be incomplete for the 12-month prior period to the extent that patients were enrolled in Medicare Advantage or were new to Medicare FFS (e.g., aged into Medicare).

E. Analysis

We conducted an initial regression analysis for each intervention's indicated population that included the demographic, clinical, and utilization factors noted above. Each regression used a linear probability model (LPM). The model fit an ordinary least squares (OLS) regression for the outcome. By using a linear model, the analysis was able to accommodate the fixed effect (FE) specifications and include more covariates, even when certain combinations of attributes may have had very few cases.

We then implemented two additional regressions using the same outcome framework. The first accounted for provider FE, and the second accounted for county FE. The provider FE model leverages the variation in characteristics of beneficiaries served by a given provider (variation within a provider's patient panel). The provider FE model estimates the disparity in utilization while holding provider characteristics constant. The county FE model leverages the variation in beneficiary characteristics within a given county, although there could still be factors unique to a county that influence the disparity in service use. Using this framework, the model accounts for these unique county factors and estimates the within-county disparity.

To facilitate comparison of results across the models, we scale the estimates of disparity from each model to the overall utilization rate of the procedure. For example, a 1 percentage point difference between Black and White Medicare beneficiaries is a larger effect when the overall utilization rate for the intervention is 2% than when it is 10%. To scale the disparity estimates, we divided the regression coefficient for the model by the population average utilization rate for the procedure in 2018-2019 and then multiplied by 100 to represent this as a percentage. Negative values represent lower utilization relative to the reference population and positive values indicated higher utilization (e.g., lower or higher utilization for Black Medicare beneficiaries relative to White Medicare beneficiaries).

III. Results

A. Cardiac Ablation

In 2018, the indicated population for cardiac ablation consisted of mostly White beneficiaries (88.0%), followed by Black beneficiaries (6.5%) and Other race (5.5%), and male (51%) (Figure 1). Over 93 percent of the indicated population was 65 and older, and 19 percent of cases were dually-eligible. Index cases from 2019 followed the same demographic distribution.

The service-using population was about 2 percentage points more likely to be White race in each year, with most of that difference coming from the share of Black beneficiaries (decreased by 1.8 percentage points in 2018 and 2.4 percentage points in 2019). The service-using population was much more likely to be male, age less than 75 years, and not dually-eligible.

The average utilization rate for cardiac ablation across the two years was 1.74% (Figure 2). Black Medicare beneficiaries had utilization rates that were 0.448 percentage points lower than for White beneficiaries (Figure 2, column 1). That difference is about one-quarter of the average utilization rate overall. The difference between dual-eligible and non-dual-eligible beneficiaries was more than twice as large (-0.941), resulting in a use rate that was almost half that of non-dual-eligibles. Access rates for women were lower than for men (-0.207), a difference that is about 12% of the overall utilization rate. The differences for Other race beneficiaries were smaller (about 6%) but not statistically distinguishable from White beneficiaries, likely due to the smaller sample size.

We compared the baseline LPM model results described above to two additional models intended to remove time-invariant differences across physicians (provider FE model) and then counties (county FE model). Including provider FE asks, what is the average disparity when we look at patients treated by the same provider? In this framework, the estimate of disparity for Black Medicare beneficiaries increased to -0.627. That is, compared to a model that only controls for patient attributes, the Black v. White disparity increased by about 36% of the population-wide utilization rate (Figure 2, column 2). For women and dual-eligibles, the disparity in utilization rates decreased but remained statistically significant. The estimate of disparity for Other race beneficiaries decreased but was still not distinguishable from utilization rates for White beneficiaries.

The county FE model controls for unique factors attributable to patient geography. The model asks, what is the disparity observed when comparing patients that live in the same county. For Black Medicare beneficiaries, the same pattern holds as in the provider FE model: the disparity relative to White beneficiaries increased to -0.615, or about 35% of the unadjusted utilization rate (Figure 2, column 3). For women and dual-eligibles, accounting for county FE made no difference in the size of the disparity estimate and remained significantly different from male and non-dual beneficiaries, respectively. The estimate of disparity for Other race beneficiaries also decreased in this model, but was still not distinguishable from utilization rates for White beneficiaries.

Figure 1: Indicated Population and Procedure Populations for Cardiac Ablation by Demographic Variables, 2018-2019

Attribute		2018 Indicated Population N=214,825 (%)	2018 Procedure Population N=3,579 (%)	2019 Indicated Population N=217,212 (%)	2019 Procedure Population N=3,940 (%)
Race	White	88.0	89.5	87.9	90.5
	Black	6.5	4.7	6.5	4.1
	Other	5.5	5.8	5.6	5.3
Sex	Male	50.6	59.9	51.0	59.9
	Female	49.4	40.1	49.0	40.1
Age	Age 18 to 44	0.7	0.7	0.7	0.6
	Age 45 to 64	5.8	7.7	5.4	6.3
	Age 65 to 74	31.0	54.7	31.5	53.3
	Age 75 to 84	36.5	32.4	36.8	34.0
	Age 85 and above	26.0	4.5	25.6	5.8
Dual Status	Non dual-eligible	81.4	89.5	82.2	91.1
	Dual-eligible	18.6	10.5	17.8	8.9
Past Service Use	Any inpatient use in prior 12m (%)	27.5	28.2	26.8	27.4
	Number of inpatient admissions in prior 12m	0.5	0.5	0.5	0.4
	Any outpatient use in prior 12m (%)	80.6	81.9	80.3	81.5
	Number of outpatient visits in prior 12m	7.5	7.1	7.5	7.1

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Figure 2: Estimates of Race, Gender, and Dual-eligibility Disparity in Cardiac Ablation Utilization Rate, 2018-2019

Demographic Variable	Average (%)	(1) OLS	(2) Provider FE	(3) County FE
Overall	1.74			
Race				
White	1.78	--	--	--
Black	1.17	-0.448 ***	-0.627 ***	-0.615 ***
Other	1.74	0.099	0.039	-0.009
Gender				
Male	2.05	--	--	--
Female	1.42	-0.207 ***	-0.185 ***	-0.216 ***
Dual-eligible for Medicaid				
Non-dual	1.92	--	--	--
Dual	0.92	-0.941 ***	-0.752 ***	-0.904 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019. Cases limited to patients in the indicated population (i.e., diagnosis of atrial fibrillation or arrhythmia).

(1) presents OLS regression including demographic attributes, comorbid conditions, and history of service use.

(2) presents provider FE specification, including the same demographic, comorbidity, and utilization variables.

(3) presents the county FE specification, including the same demographic, comorbidity, and utilization variables.

Regression models included in Appendix C.1

B. Angioplasty

Over 80 percent of the indicated population for angioplasty was White, with approximately 10 percent among Black Medicare beneficiaries and just under 9 percent for Other race beneficiaries (Figure 3). Men were a slight majority of the indicated population, and over 85% were ages 65 and older across both years. About a quarter of the indicated population was dually-eligible for Medicaid.

The demographic characteristics of the patients receiving angioplasty differed from the indicated population. White beneficiaries accounted for 4 percentage points more in the procedure population than the indicated population, with a 2 percentage point decrease in the share of Black and Other Medicare beneficiaries. Approximately 6 out of every 10 angioplasties were performed on men, while men comprised about half of the indicated population. The age distribution among those receiving angioplasty skewed younger, with a higher share of beneficiaries in the 65 to 74 age group. The dual-eligible population was about 20 percent smaller in the procedure population compared to the indicated population.

The baseline regression estimates showed statistically significantly lower procedure rates for all groups. Relative to the White population, Black Medicare beneficiaries were 3.3 percentage points less likely to receive angioplasty, and Other race beneficiaries were 1.6 percentage points less likely (Figure 4). This translates to a 23% and 11% lower utilization rate for Black and Other race beneficiaries, respectively. Utilization rates for angioplasty were 2.4 percentage points lower for both women (relative to men) and dual-eligible beneficiaries (relative to non-dual); this represents a 17% lower utilization rate than the overall population.

The findings from the provider FE model, which controls for time-invariant provider factors, were comparable to the baseline model. Black beneficiaries' utilization rates were 3.1 percentage points lower than for White beneficiaries, while the Other race population was 1.7 percentage points lower. The measured disparity for female beneficiaries remained 2.5 percentage points lower than for males. For dual-eligibles, the estimated disparity was 1.5 percentage points lower than among non-duals (from 2.4). Across all patient demographic attributes though, the results suggest substantial disparities in access to the angioplasty procedure even after controlling for provider characteristics.

Column 3 presents the estimates from the county FE model, which controls for time-invariant variation across counties. The results were aligned with the baseline estimates. There was a 3.4 percentage point disparity for Black beneficiaries and a 1.7 percentage point disparity among Other race beneficiaries relative to the White population. The gender disparity, at 2.4 percentage points, was about the same size as the baseline model. The disparity by dual-eligibility status, although lower than in the baseline (1.9 percentage points versus 2.4), remained significant as well.

In summary, the inclusion of provider or county FE did not have a material impact on the size of the disparity estimates for these demographic characteristics. This suggests the disparities are persistent and hold for beneficiaries with the same provider or in the same geographic area.

Figure 3: Indicated and Procedure Population Characteristics for Angioplasty by Demographic Variables, 2018-2019

		2018		2019	
Attribute		Indicated Population N=38,779 (%)	Procedure Population N=5,393 (%)	Indicated Population N=37,272 (%)	Procedure Population N=5,343 (%)
Race	White	81.9	86.0	81.7	86.0
	Black	9.6	7.5	9.5	6.9
	Other	8.5	6.5	8.8	7.1
Sex	Male	51.8	61.8	52.3	63.1
	Female	48.2	38.2	47.7	36.9
Age	Age 18 to 44	1.0	0.6	0.9	0.8
	Age 45 to 64	12.1	13.1	11.3	12.2
	Age 65 to 74	40.5	45.5	40.7	44.0
	Age 75 to 84	31.5	29.0	32.2	31.3
	Age 85 and above	15.0	11.9	14.9	11.7
Dual Status	Non dual-eligible	74.6	80.0	76.0	80.3
	Dual-eligible	25.4	20.0	24.0	19.8
Past Service Use	Any inpatient use in prior 12m (%)	25.2	20.9	23.8	20.1
	Number of inpatient admissions in prior 12m	0.5	0.4	0.4	0.4
	Any outpatient use in prior 12m (%)	76.2	69.6	75.6	69.3
	Number of outpatient visits in prior 12m	6.5	5.4	6.4	5.5

Note: KNG Health calculations using 5% sample of the Medicare Standard Analytic Files for Inpatient, Outpatient and Carrier Claims, 2018-2019.

Figure 4: Estimates of Race, Gender, and Dual-eligibility Disparity in Angioplasty Utilization Rate, 2018-2019

Demographic Variable	Average (%)	(1) OLS	(2) Provider FE	(3) County FE
Overall	14.12	--	--	--
Race				
White	14.84	--	--	--
Black	10.64	-3.307 ***	-3.073 ***	-3.418 ***
Other	11.11	-1.552 ***	-1.673 **	-1.727 ***
Gender				
Male	16.93	--	--	--
Female	11.06	-2.367 ***	-2.466 ***	-2.454 ***
Dual-eligible for Medicaid				
Non-dual	15.02	--	--	--
Dual	11.36	-2.355 ***	-1.507 ***	-1.920 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019. Cases limited to patients in the indicated population (i.e., diagnosis of acute myocardial infarction or angina).

(1) presents OLS regression including demographic attributes, comorbid conditions, and history of service use.

(2) presents provider FE specification, including the same demographic, comorbidity, and utilization variables.

(3) presents the county FE specification, including the same demographic, comorbidity, and utilization variables.

Regression models included in Appendix C.2.

C. Transcatheter Aortic Valve Replacement (TAVR)

Approximately 90 percent of the TAVR indicated population was White, with the remainder almost evenly split between the Black and Other race categories (Figure 5). Equal shares of the indicated population were male or female. The age distribution skewed toward older Medicare beneficiaries: less than 5 percent of the indicated population was below age 65 and over 70 percent was age 75 or above. Just over 15 percent of the indicated population were dual-eligible beneficiaries.

The distribution of the procedure population was quite different, particularly by race and age. Whereas 89 percent of the indicated population was White Medicare beneficiaries, the procedure population was 93 percent White. The share of the procedure population that was Black or Other race was 2 percentage points lower than in the indicated population. Those aged 75 and above were more likely to be in the procedure population than younger ages, while the dual-eligible population was less likely to be part of the procedure population (about 10% versus 15% in the indicated population).

The baseline regression model showed statistically significant service disparities across three of the four dimensions (Figure 6). The regression coefficients indicated a 1.1 percentage point disparity in utilization rates for Black beneficiaries and a 0.6 disparity for Other race beneficiaries, relative to the White population. With respect to the dual-eligible population, we found a 1.3 percentage point disparity in utilization.

The provider FE model also shows an increased disparity by race. The disparity for Black Medicare beneficiaries (1.2 percentage points) and Other race Medicare beneficiaries (1.1 percentage points) were similar to the base model. The disparity by gender was smaller (0.3 percentage points) but still statistically significant. The estimate of disparity by dual-eligibility status was about 0.1 percentage points lower than in the baseline results.

The results of the county FE model (Figure 6, Column 3) did not show major differences from the baseline model. Utilization rates were 1.2 and 0.9 percentage points lower for Black and Other race beneficiaries relative to White Medicare beneficiaries, while the Other race population had a 0.9 percentage point disparity. The estimate of disparity by dual-eligibility status was the same as in the base model.

In summary, we saw a consistent pattern of disparity in TAVR utilization by race and dual-eligibility status. To demonstrate the magnitude of the disparity, we can compare the regression coefficients to the average procedure rate in the indicated population. For example, the size of the disparity as measured by the regression coefficient in both the provider and county FE models (-1.23) was about 40% of the size of the population utilization rate (3.10%). This suggests meaningful disparities in the use of TAVR.

Figure 5: Indicated and Procedure Population Characteristics for TAVR by Demographic Variables, 2018-2019

		2018		2019	
Attribute		Indicated Population N=53,570 (%)	Procedure Population N=1,553 (%)	Indicated Population N=55,735 (%)	Procedure Population N=1,836 (%)
Race	White	89.5	93.4	89.3	92.7
	Black	5.3	3.4	5.2	3.6
	Other	5.2	3.2	5.5	3.8
Sex	Male	50.2	54.3	50.6	53.2
	Female	49.8	45.7	49.4	46.8
Age	Age 18 to 44	0.3	0.0	0.2	0.1
	Age 45 to 64	3.5	1.6	3.3	2.2
	Age 65 to 74	25.4	15.8	25.6	22.3
	Age 75 to 84	38.1	45.2	38.6	44.3
	Age 85 and above	32.7	37.4	32.3	31.1
Dual Status	Non dual-eligible	84.3	89.3	84.7	89.2
	Dual-eligible	15.7	10.8	15.3	10.8
Past Service Use	Any inpatient use in prior 12m (%)	28.5	30.4	27.9	28.4
	Number of inpatient admissions in prior 12m	0.5	0.5	0.5	0.5
	Any outpatient use in prior 12m (%)	81.1	84.3	81.0	84.0
	Number of outpatient visits in prior 12m	7.3	7.8	7.3	7.5

Note: KNG Health calculations using 5% sample of the Medicare Standard Analytic Files for Inpatient, Outpatient and Carrier Claims, 2018-2019.

Figure 6: Estimates of Race, Gender, and Dual-eligibility Disparity in TAVR Utilization Rate, 2018-2019

Demographic Variable	Average (%)	(1) OLS	(2) Provider FE	(3) County FE
Overall	3.10	--	--	--
Race				
White	3.23	--	--	--
Black	2.07	-1.084 ***	-1.243 ***	-1.230 ***
Other	2.03	-0.601 **	-1.065 ***	-0.944 ***
Gender				
Male	3.30	--	--	--
Female	2.89	0.203	0.300 **	0.239
Dual-eligible for Medicaid				
Non-dual	3.27	--	--	--
Dual	2.16	-1.327 ***	-1.193 ***	-1.336 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019. Cases limited to patients in the indicated population (i.e., diagnosis of aortic stenosis).

(1) presents OLS regression including demographic attributes, comorbid conditions, and history of service use.

(2) presents provider FE specification, including the same demographic, comorbidity, and utilization variables.

(3) presents the county FE specification, including the same demographic, comorbidity, and utilization variables.

Regression models included in Appendix C.3.

D. Mechanical Thrombectomy

Figure 7 presents summary information about index cases used in the analysis. In 2018, White Medicare beneficiaries made up most of the indicated population of patients with ischemic stroke (78.2%), followed by Black (14.5%) and Other race (7.4%); a little more than half of the indicated population was female (53.2%). About 88 percent of the indicated population was 65 and older, and 30.5 percent of cases were dually-eligible for Medicaid. Slightly more than 30 percent of index cases had an inpatient admission in the year prior to the index event in 2018, and 76 percent had a hospital outpatient visit in the prior year. Index cases from 2019 followed the same demographic and utilization distribution.

The procedure population (i.e., those who received mechanical thrombectomy) were 3 percentage points more likely to be White race in each year, with most of that difference coming from the share of Black beneficiaries (decreased by 3.2 percentage points in 2018 and 2.4 percentage points in 2019). This population was equally likely to be male, and slightly more likely to be over age 65 years, and much more likely not to be dually-eligible for Medicaid (e.g., 75.2% of the procedure population in 2018 was non-dual compared to 69.5% for the indicated population).

From the baseline regression results (Figure 8, column 1), the largest disparity was among dual-eligibles relative to non-dual-eligibles, a difference of 0.5 percentage points. The initial disparity for Black race relative to White race was smaller, at 0.4 percentage points. This model also suggests there is no disparity in access for Other race beneficiaries and by gender.

In the provider FE model, the estimate of disparity for Black Medicare beneficiaries increased from -0.367 to 0.635 percentage points. In contrast, disparity for dual-eligibles was less than half of the estimate in the baseline, although still statistically significant. The estimates for Other race and women increased but were not statistically distinguishable from the reference group.

The county FE model results were similar to the baseline model. The Black v. White disparity in Mechanical Thrombectomy utilization was 0.4 percentage points, while for dual v. non-dual beneficiaries the difference was 0.6 percentage points. The estimates in this model also suggest there no disparity in access by gender or for the Other race beneficiaries.

Figure 7: Indicated and Procedure Population Characteristics for Mechanical Thrombectomy by Demographic Variables, 2018-2019

		2018		2019	
Attribute		Indicated Population N=45,587 (%)	Procedure Population N=723 (%)	Indicated Population N=46,356 (%)	Procedure Population N=927 (%)
Race	White	78.2	80.9	78.1	81.3
	Black	14.5	11.3	14.2	11.8
	Other	7.4	7.8	7.7	6.9
Sex	Male	46.9	49.9	46.6	50.5
	Female	53.2	50.1	53.4	49.5
Age	Age 18 to 44	1.2	1.5	1.0	1.5
	Age 45 to 64	11.0	8.3	10.6	6.8
	Age 65 to 74	32.4	33.1	32.5	35.1
	Age 75 to 84	32.3	33.2	32.7	34.2
	Age 85 and above	23.1	23.9	23.2	22.4
Dual Status	Non dual-eligible	69.5	75.2	69.7	75.6
	Dual-eligible	30.5	24.8	30.3	24.4
Past Service Use	Any inpatient use in prior 12m (%)	30.9	24.2	30.3	24.3
	Number of inpatient admissions in prior 12m	0.5	0.4	0.5	0.4
	Any outpatient use in prior 12m (%)	76.0	69.9	75.7	69.7
	Number of outpatient visits in prior 12m	6.5	5.1	6.6	5.3

Note: KNG Health calculations using 5% sample of the Medicare Standard Analytic Files for Inpatient, Outpatient and Carrier Claims, 2018-2019.

Figure 8: Estimates of Race, Gender, and Dual-eligibility Disparity in Mechanical Thrombectomy Utilization Rate, 2018-2019

Demographic Variable	Average (%)	(1) OLS	(2) Provider FE	(3) County FE
Overall	1.79	--	--	--
Race				
White	1.86	--	--	--
Black	1.45	-0.367 **	-0.635 ***	-0.391 **
Other	1.73	-0.189	-0.412	-0.168
Gender				
Male	1.93	--	--	--
Female	1.68	0.011	-0.036	0.013
Dual-eligible for Medicaid				
Non-dual	1.95	--	--	--
Dual	1.45	-0.542 ***	-0.258 *	-0.591 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019. Cases limited to patients in the indicated population (i.e., diagnosis of ischemic stroke).

(1) presents OLS regression including demographic attributes, comorbid conditions, and history of service use.

(2) presents provider FE specification, including the same demographic, comorbidity, and utilization variables.

(3) presents the county FE specification, including the same demographic, comorbidity, and utilization variables.

Regression models included in Appendix C.4.

E. Thrombolysis

Because both mechanical thrombectomy and thrombolysis share the same indicated population (ischemic stroke), there was no difference in the demographic and utilization profiles of the indicated population. The procedure population was 4-5 percentage points more likely to be White race, with most of that difference coming from the share of Black beneficiaries (4.7 percentage points lower in 2018 and 3.5 percentage points lower in 2019). The service-using population was still mostly female, although the difference from the indicated population was smaller. The procedure population was also slightly more likely to be over age 65 years, and much more likely not to be dually-eligible for Medicaid (e.g., 77.5% of the procedure population in 2018 was non-dual compared to 69.5% for the indicated population).

From the baseline regression results (Figure 10, column 1), as with mechanical thrombectomy, the largest disparity was among dual-eligibles relative to non-dual-eligibles, a difference of 1.4 percentage points. The initial disparity for Black race relative to White race was smaller but also significant (1.0 percentage points). The coefficients for gender and Other race category are statistically insignificant which suggests there is no measured disparity for these groups.

Column 2 shows the provider FE model. There was no change in the size of the disparity for Black Medicare beneficiaries relative to the White population. However, the disparity in the dual-eligible population declined to 0.8 percentage points. The coefficients of the gender and Other race category remained statistically insignificant, as in the baseline model.

The county FE model shows that when geographic characteristics were held constant, the disparities by dual-eligibility status and for Black beneficiaries persisted. Relative to the White population, Black beneficiaries had 0.8 percentage points lower utilization rates for thrombolysis while dual-eligible beneficiaries had 1.3 percentage points lower utilization rates relative to non-duals.

A comparison of the results from the three specifications suggests the disparities for each population might be more prominent along different dimensions. The base model found disparity in thrombolysis access for the Black and dual-eligible populations. The similar size of the coefficient for Black race in the provider FE model, and the decrease in disparity size for the dual population suggests that there was an appreciable disparity in utilization for Black beneficiaries seeing the same providers. The decline of the coefficient for Black race and stability of the coefficient for dual-eligibility in the county FE regression suggests that there is a substantial disparity in access by race and dual-eligibility status within the geographical area.

Figure 9: Indicated and Procedure Population Characteristics for Thrombolysis by Demographic Variables, 2018-2019

		2018		2019	
Attribute		Indicated Population N=45,587 (%)	Procedure Population N=1,344 (%)	Indicated Population N=46,356 (%)	Procedure Population N=1,465 (%)
Race	White	78.2	83.6	78.1	82.5
	Black	14.5	9.8	14.2	10.7
	Other	7.4	6.7	7.7	6.8
Sex	Male	46.9	49.3	46.6	47.8
	Female	53.2	50.7	53.4	52.2
Age	Age 18 to 44	1.2	0.6	1.0	0.5
	Age 45 to 64	11.0	8.0	10.6	8.9
	Age 65 to 74	32.4	34.5	32.5	31.7
	Age 75 to 84	32.3	32.0	32.7	33.8
	Age 85 and above	23.1	24.9	23.2	25.2
Dual Status	Non dual-eligible	69.5	77.5	69.7	78.0
	Dual-eligible	30.5	22.5	30.3	22.0
Past Service Use	Any inpatient use in prior 12m (%)	30.9	27.1	30.3	23.4
	Number of inpatient admissions in prior 12m	0.5	0.5	0.5	0.4
	Any outpatient use in prior 12m (%)	76.0	71.1	75.7	71.3
	Number of outpatient visits in prior 12m	6.6	5.5	6.6	5.5

Note: KNG Health calculations using 5% sample of the Medicare Standard Analytic Files for Inpatient, Outpatient and Carrier Claims, 2018-2019.

Figure 10: Estimates of Race, Gender, and Dual-eligibility Disparity in Thrombolysis Utilization Rate, 2018-2019

Demographic Variable	Average (%)	(1) OLS	(2) Provider FE	(3) County FE
Overall	3.06	--	--	--
Race				
White	3.25	--	--	--
Black	2.18	-0.968 **	-0.968 ***	-0.878 ***
Other	2.74	-0.311	-0.482	-0.263
Gender				
Male	3.17	--	--	--
Female	2.95	0.047	0.033	0.086
Dual-eligible for Medicaid				
Non-dual	3.41	--	--	--
Dual	2.24	-1.391 ***	-0.838 ***	-1.316 ***

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019. Cases limited to patients in the indicated population (i.e., ischemic stroke).

(1) presents OLS regression including demographic attributes, comorbid conditions, and history of service use.

(2) presents provider FE specification, including the same demographic, comorbidity, and utilization variables.

(3) presents the county FE specification, including the same demographic, comorbidity, and utilization variables.

Regression models included in Appendix C.5.

F. Summary

Figure 11 summarizes the disparities findings across each of the interventions for each demographic grouping. As described in the Methods section, we calculated a disparity metric that compared the size of the disparity for a given model (e.g., the effect of Black race on use of cardiac ablation in the provider fixed effect model) to the overall utilization rate of the intervention (e.g., the proportion of Medicare beneficiaries with atrial fibrillation or arrhythmia that received cardiac ablation). This percentage allows us to compare the disparity estimates across interventions in a way that accounts for how often the intervention is used.

The strongest pattern observed across models was of disparities by race (Black v. White Medicare beneficiaries) and dual-eligibility (dual v. non-dual Medicare beneficiaries). After adjusting for the impact of providers or geography on top of patient differences in clinical and utilization histories, disparities of 20 to 40 percent remained for Black Medicare beneficiaries and 10 to 50 percent for Other race Medicare beneficiaries.

Similarly, we observed some gender disparity in cardiac ablation and angioplasty, and disparity for Other race beneficiaries for angioplasty and TAVR. The size and significance levels for Other race are sensitive to the small number of Other race cases in the Medicare five percent sample and with one of the diagnoses of interest.

Accounting for provider FE resulted in either no material changes to the disparity estimate for Black Medicare beneficiaries (relative to the base model with only clinical and utilization history controls) or, in the case of cardiac ablation and mechanical thrombectomy, an increase in the estimated disparity (Figure 11). In the county FE models, the disparity for Black Medicare beneficiaries was either materially unchanged or, in the case of cardiac ablation, increased.

In contrast, for dual-eligibles, controlling for provider FE reduced estimated disparities relative to the baseline model for all interventions; adjusting for geography reduced the disparity for dual-eligibles only for angioplasty (Figure 14). Disparities by gender (Figure 13) and Other race (Figure 12) also generally remained the same after adding these additional controls.

Figure 11: Percent Change in Procedure Disparity by Race, Black Population Relative to White Population (2018-2019)

Intervention	Procedure Rate	Provider FE Model		County FE Model	
		Difference	Magnitude	Difference	Magnitude
Cardiac Ablation	1.7%	-0.63 ***	36%	-0.62 ***	36%
Angioplasty	14.1%	-3.07 ***	22%	-3.42 ***	24%
TAVR	3.1%	-1.24 ***	40%	-1.23 ***	40%
Mechanical Thrombectomy	1.8%	-0.64 ***	36%	-0.39 **	22%
Thrombolysis	3.1%	-0.97 ***	32%	-0.88 ***	29%

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Note: The percentage was calculated as: the adjusted estimate for each demographic attribute (in percentage points) from either the provider FE or county FE models, divided by the average utilization rate for the procedure in Medicare, then multiplied by 100. Values come from Figures 2, 4, 6, 8, and 10). The significance levels refer to the estimates for each patient attribute in the respective regressions in those Figures and Appendix C.

Figure 12: Percent Change in Procedure Disparity by Race, Other Population Relative to White Population (2018-2019)

Intervention	Procedure Rate	Provider FE Model		County FE Model	
		Difference	Magnitude	Difference	Magnitude
Cardiac Ablation	1.7%	0.04	2%	-0.01	1%
Angioplasty	14.1%	-1.67 ***	12%	-1.73 ***	12%
TAVR	3.1%	-1.07 ***	34%	-0.94 ***	31%
Mechanical Thrombectomy	1.8%	-0.41	23%	-0.17	9%
Thrombolysis	3.1%	-0.48	16%	-0.26	9%

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Note: The percentage was calculated as: the adjusted estimate for each demographic attribute (in percentage points) from either the provider FE or county FE models, divided by the average utilization rate for the procedure in Medicare, then multiplied by 100. Values come from Figures 2, 4, 6, 8, and 10). The significance levels refer to the estimates for each patient attribute in the respective regressions in those Figures and Appendix C.

Figure 13: Percent Change in Procedure Disparity by Gender, Female Population Relative to Male Population (2018-2019)

Intervention	Procedure Rate	Provider FE Model		County FE Model	
		Difference	Magnitude	Difference	Magnitude
Cardiac Ablation	1.7%	-0.19 ***	11%	-0.22 ***	12%
Angioplasty	14.1%	-2.47 ***	18%	-2.45 ***	17%
TAVR	3.1%	0.30 **	10%	0.24	7%
Mechanical Thrombectomy	1.8%	-0.04	2%	0.01	1%
Thrombolysis	3.1%	0.03	1%	0.09	3%

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Note: The percentage was calculated as: the adjusted estimate for each demographic attribute (in percentage points) from either the provider FE or county FE models, divided by the average utilization rate for the procedure in Medicare, then multiplied by 100. Values come from Figures 2, 4, 6, 8, and 10). The significance levels refer to the estimates for each patient attribute in the respective regressions in those Figures and Appendix C.

Figure 14: Percent Change in Procedure Disparity by Dual-Eligibility Status, Dual-Eligible Population Relative to Non-Dual-Eligible Population (2018-2019)

Intervention	Procedure Rate	Provider FE Model		County FE Model	
		Difference	Magnitude	Difference	Magnitude
Cardiac Ablation	1.7%	-0.75 ***	43%	-0.90 ***	52%
Angioplasty	14.1%	-1.51 ***	11%	-1.92 ***	14%
TAVR	3.1%	-1.19 ***	39%	-1.34 ***	43%
Mechanical Thrombectomy	1.8%	-0.26 *	14%	-0.59 ***	33%
Thrombolysis	3.1%	-0.89 ***	27%	-1.32 ***	43%

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Note: The percentage was calculated as: the adjusted estimate for each demographic attribute (in percentage points) from either the provider FE or county FE models, divided by the average utilization rate for the procedure in Medicare, then multiplied by 100. Values come from Figures 2, 4, 6, 8, and 10). The significance levels refer to the estimates for each patient attribute in the respective regressions in those Figures and Appendix C.

IV. Discussion

The analyses presented demonstrate disparities in the use of advanced medical technologies in the Medicare population across several dimensions. Black Medicare beneficiaries were significantly less likely to use all five procedures investigated, and, in the case of cardiac ablation, attempts to control for time-invariant provider and community factors increased the observed disparity relative to patient attributes alone. Dually-eligible beneficiaries were also less likely to receive all studied services than those without Medicaid coverage. This was also true for selected conditions among women (cardiac ablation and angioplasty) and Other race beneficiaries (angioplasty and TAVR).

A strength of the analytic approach here is that we could compare across procedures by standardizing the differences to the base utilization rate of the procedure. For example, the indicated population for valve replacement (severe symptomatic aortic stenosis) may be smaller than is estimated here and so the ideal utilization rate remains elusive; however, the model provides a disparity estimate for each attribute that may be fairly compared to the other conditions to assess the relative magnitude of disparity across these procedures.

To the extent that disparities remained at the same or higher levels even after accounting for provider effects suggests there are significant provider-level disparities to address. As noted in Phase II, there was evidence of challenges with respect to provider networks and referral patterns, particularly in access to cardiologists, for example, that could contribute to this pattern.[11] In the case of disparities by gender, the literature notes a consistent pattern of less aggressive treatment and discounting of symptoms among women with cardiovascular conditions, which may contribute to the larger deficit in utilization of ablation and angioplasty for women relative to men in the Medicare population.

In a few cases—TAVR for both Black and Other race Medicare beneficiaries and cardiac ablation for Black beneficiaries—accounting for county FE resulted in larger disparity estimates. In these situations, larger structural issues may impact access by minority patients more heavily.[12] A potential contributor to those issue for TAVR, for example, is the National Coverage Determination, which imposes restrictions on where and how TAVR care should be delivered.[13]

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[11] All FFS Medicare beneficiaries nominally share the same provider network (i.e., providers that accept Medicare for payment). There is still variation across beneficiaries in the providers actually seen and referral patterns between primary and specialty care.

[12] Existing evidence supports disparities in access to TAVR for disadvantaged populations. See for example: Reddy, K. P., Groeneveld, P. W., Giri, J., Fanaroff, A. C., & Nathan, A. S. (2022). Economic Considerations in Access to Transcatheter Aortic Valve Replacement. Circulation. Cardiovascular interventions, 15(2), e011489. https://doi.org/10.1161/CIRCINTERVENTIONS.121.011489.

[13] Nathan, A. S., Yang, L., Yang, N., Khatana, S. A. M., Dayoub, E. J., Eberly, L. A., Vemulapalli, S., Baron, S. J., Cohen, D. J., Desai, N. D., Bavaria, J. E., Herrmann, H. C., Groeneveld, P. W., Giri, J., & Fanaroff, A. C. (2021). Socioeconomic and Geographic Characteristics of Hospitals Establishing Transcatheter Aortic Valve Replacement Programs, 2012-2018. Circulation. Cardiovascular quality and outcomes, 14(11), e008260. https://doi.org/10.1161/CIRCOUTCOMES.121.008260

Some of the additional factors like comorbid conditions and past service use history are subject to disparity, so adding provider and community factors may simply redistribute the effect of race to other factors.[14] Also, to the extent that Black and Other race Medicare beneficiaries are present in the indicated population, delays in health service use over the course of the patient's lifetime (as discussed in Phase II) may result in a greater number of comorbidities (or other metrics of severity) that may preclude a provider recommending the service. As a result, interpreting the impact of disparities at the point of service requires consideration of the potential impact of disparities in access, identification, and outcome in prior treatments.

Procedures with similar patterns of disparity may share something in common and point to potential targets for disparity reduction. For example, cardiac ablation and mechanical thrombectomy models had similar patterns across the race, gender, and dual-eligibility categories: incorporating provider FE increased the disparity for Black Medicare beneficiaries, decreased them for dual-eligibles, and had no effect for Other race and women beneficiaries. The angioplasty and thrombolysis services also had a similar pattern of no change in effect for Black, Other race and women Medicare beneficiaries, but a decrease in disparity for dual-eligibles. Is there something about these respective treatments or their patterns of accessibility that may make them suitable targets for intervention?

Finding such a pattern may be challenging. For example, given that mechanical thrombectomy and thrombolysis serve the same indicated populations with similar time sensitivity issues (i.e., candidates for treatment with these interventions need to be treated very shortly after onset of stroke) yet have different patterns of effect by race and dual-eligibility suggests other issues with respect to treatment for patients with ischemic stroke.

Therefore, an important consideration when interpreting the disparity estimates is understanding the broader environment in which medical decision-making occurs. We noted above that patient complexity or severity may not be adequately measured by inclusion of comorbid conditions; greater specificity (e.g., "severe symptomatic aortic stenosis"; lab results or provider notes indicating severity), perhaps identified through other electronic databases (e.g., electronic medical records), could improve the analysis.

Patient preferences could also play a role. For example, racial minorities may suspect and want to avoid greater perceived risk for some interventions.[15] Unfortunately, we do not have data on patient

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[14] Cintina, I., Saunders, R.C., Piper, J., Hamlett, E., & Koenig,L. (2023). *Phase II: Literature Review: Racial Disparities in Use of Selected Medical Technologies*. North Bethesda, MD: KNG Health Consulting, LLC.

[15] Medical mistrust among Black Americans has a long history (Hostetter & Klein, 2021): Hostetter, M., & Klein, S. (2021, January 14). *Understanding and Ameliorating Medical Mistrust Among Black Americans*. The Commonwealth Fund. https://doi.org/10.26099/9grt-2b21. As noted in our Phase II report, there is evidence of non-Hispanic Black patients being more likely to decline tissue plasminogen (tPA) for acute ischemic stroke in the emergency department; see for example: Mendelson, S. J., Aggarwal, N. T., Richards, C., O'Neill, K., Holl, J. L., & Prabhakaran, S. (2018). Racial disparities in refusal of stroke thrombolysis in Chicago. Neurology, 90(5), e359–e364. https://doi.org/10.1212/WNL.0000000000004905; and, Zha, A., Rosero, A., Malazarte, R., Bozorgui, S., Ankrom, C., Zhu, L., Joseph, M., Trevino, A., Cossey, T. D., Savitz, S., Wu, T. C., & Jagolino-Cole, A. (2021). Thrombolytic Refusal Over Telestroke. Neurology: Clinical Practice, 11(3), e287–e293. https://doi.org/10.1212/CPJ.0000000000000975.

preferences or perceptions of risk for these services. However, expert knowledge and data about the role these and other factors play for various procedures should identify opportunities for policymakers, providers, and manufacturers to address disparities in use of these and other technologies.

While some of these interventions are new, some may be further into the technological adoption curve[16] (e.g., angioplasty may have a longer history of clinical use than TAVR), resulting in a different pattern of clinical decision making and subsequent treatment choices by race. The longer an intervention has been available the more likely it is that analysis of potential disparities has occurred, and corrective actions have been undertaken to address those disparities, affecting the size of the disparity observed in these results. Also, some of the conditions may have more potential alternative treatments, which may lead to more complicated clinical decision making (e.g., more options from which to assess expected net benefits of treatment).

The Phase III analysis has several limitations. First, the data are from 2018-2019, and so current patterns may differ from those observed here. However, the timing of this analysis helped avoid the potential confounding of the impact of COVID-19 on both service utilization and racial and other disparities. Second, we were limited to the 5 percent sample of Medicare beneficiaries and had small sample sizes for some analytic cohorts that may have influenced the magnitude of and change in the disparity estimates (e.g., Other race and mechanical thrombectomy). Third, we did not include any measures of service availability either for the procedures themselves (e.g., surgical centers that perform the procedure of interest) or the providers (e.g., number of cardiovascular or neurovascular specialists). However, the provider and county FE model limit the impact of this because all residents of the same county had the same nominal access on such measures.

The analysis also incorporated comorbid conditions and past service use, which themselves are known to have disparities. The analysis attempted to limit their impact by setting a common criterion for the index case to analyze (first service with a diagnosis signifying the case is part of the indicated population) and not overweighting for additional opportunities for patients that may present multiple times per year. Also, as noted above, the inclusion of these factors in some cases increased the observed disparity; therefore, including them may be appropriate but requires additional attention to understand how these factors play out for the intervention of interest, including services beyond those investigated here. Finally, there may be unmeasured individual factors (e.g., severity as distinct from number or type of comorbid condition; patient preferences or risk tolerances). This represents an important future opportunity for analysis.

[16] Rogers, Everett (16 August 2003) [1962]. Diffusion of Innovations, 5th Edition. Simon and Schuster. ISBN 978-0-7432-5823-4. Sociological theory suggests that innovations spread through society by adoption among five groups over time, in this order: innovators, early adopters, early majority, late majority, and laggards. The five technologies addressed in this analysis may be at different stages of adoption. Adoption in this context might include whether an intervention can only be performed on an inpatient basis or other restrictions on service setting or type of approved provider.

V. Conclusion

The three phases of analyses documented disparities in access to several important minimally invasive interventions across a range of conditions by race and ethnicity, gender, and dual-eligibility for Medicaid. The Phase III analyses demonstrated for a subset of those interventions—cardiac ablation, angioplasty, TAVR, mechanical thrombectomy, and thrombolysis—that the disparities were not simply the result of case mix differences but were detectable even in the presence of robust controls for patient, provider, and community factors. The literature review in Phase II coupled with the Phase III results suggest a variety of potential directions for further action.

This series of reports and the variability of evidence observed in the literature reminds us that a definitive estimate of disparity for these or any other procedures is probably not possible. However, the consistency of the evidence of disparities—that it exists and the commonalities of factors across conditions—provides a foundation for developing an action plan to address disparities and fulfill the goals of manufacturers in ensuring access to the most advanced technologies for improving patient health and well-being.

Appendix A: Methods

A. Data Sources

Data for this analysis came from the Medicare Standard Analytic File and the Medicare Beneficiary Summary Files for calendar years 2018-2019:

- 5% Medicare Beneficiary Summary File
- 5% Medicare Inpatient Standard Analytic Files
    - Claims file – identifies clinical diagnoses, procedure codes, and DRGs.
    - Revenue code file – identifies hospital revenue codes and HCPCS and CPT codes.
    - Condition code file – identifies claim-related conditions (an additional CMS coding system relevant for some of the procedures/services of interest).
- 5% Medicare Outpatient Standard Analytic Files
    - Claims file – identifies clinical diagnoses and procedure codes.
    - Revenue code file – identifies hospital revenue codes and HCPCS and CPT codes for relevant procedures/services.
    - Condition code file – identifies claim-related conditions (an additional CMS coding system relevant for some of the procedures/services of interest).
- 5% Medicare Carrier Standard Analytic Files

B. Study Variables

Dependent Variables for each service type, (e.g., cardiac ablation, angioplasty), we identified whether a beneficiary received that service on the claim. Each service was identified using codes from one or more of these systems, varying by service (see Table A.1):

- ICD-10-PCS procedure codes.
- HCPCS/CPT codes.
- MS-DRGs.
- Hospital revenue codes.
- Claim-related condition codes.
- Ambulatory payment classification code.

We then identified whether the beneficiary data indicated receipt of each intervention in any of the file types and coding systems. For example, cardiac ablation used codes from the ICD-10 and CPT coding systems. We identified whether the beneficiary had any indication of cardiac ablation from any of the inpatient, outpatient, or carrier files using either coding system. If there was an occurrence (e.g., a cardiac ablation ICD-10 procedure code in the inpatient file), then the beneficiary received a “1” indicating that she received the service.

Next, we identified whether the beneficiary had any indication of a relevant diagnosis to define them as part of the "indicated population" for the service. For example, cardiac ablation is indicated for patients diagnosed with atrial fibrillation or arrhythmia; so, we identified whether each beneficiary had a diagnosis of atrial fibrillation or arrhythmia in the year. In the case of TAVR, the "true" indicated population is beneficiaries diagnosed with severe symptomatic aortic stenosis. However, diagnoses in the claims data do not include severity information for this condition. Therefore, the indicated population for TAVR in this analysis is more broadly defined to include patients with any aortic stenosis diagnosis. Future work may develop a claims-based definition based on common comorbid conditions (e.g., heart failure, angina, syncope, dsypnea).

Independent Variables We defined the following independent variables:

- **Age**: We used the age variable on the MBSF for the beneficiary in that year. The age variable on the file is the beneficiary's age on January 1. We added one year to the age category based on age at the end the year; this allows patients who start the year at age 64, for example, to count in the 65-74 age group so as not to distort the utilization patterns for those under age 65, who are more likely to be eligible through disability coverage. We created the following age categories: 18-44, 45-64, 65-74, 75-84, and 85 and older.
- **Gender**: We used the gender code (male or female) on the MBSF for the beneficiary.
- **Race/ethnicity**: We used the race/ethnicity variable from the Medicare enrollment database and classified beneficiaries into three categories: White, Black, and Other.
- **Dual-eligible beneficiaries**: Dual-eligible beneficiaries were identified based on the dual status variable available in the Medicare Beneficiary Summary File. A beneficiary's dual-eligibility status may change over time. For simplicity, if a beneficiary was identified as dual-eligible (full or partial) at any point during the year, the person was classified as dual-eligible.
- **Inpatient utilization**. We identified whether a beneficiary had a hospital inpatient visit in the 12 months prior to the index claim and how many prior hospital inpatient visits in that time period.
- **Outpatient utilization**. We identified whether a beneficiary had a hospital outpatient visit in the 12 months prior to the index claim and how many prior hospital outpatient visits in that time period.
- **Year**. We controlled for whether the case was from 2018 (reference year) or 2019.
- **Hierarchical condition categories**. We cross-walked ICD-10-CM diagnosis codes to the condition categories of the HCC applicable in 365 day period prior to and including the index service.
- **County of residence**. The beneficiary's county of residence at the time of the index service.

Figure A.1: Diagnosis and Procedure Codes Used to Identify Patient Populations and Service Recipients for Selected Cardiovascular and Neurovascular Interventions.

Procedure or Service	Conditions Appropriate (ICD-10-CM)	Procedure code lists (ICD-10-PCS, HCPCS, etc.)	Coding Notes
Cardiovascular			
Cardiac Ablation	**Arrhythmias**: I49x, I49xx **Atrial Fibrillation**: I48x, I48xx	**CPT**: 93653, 93654, 93656 **ICD-10-PCS Codes**: 02553ZZ, 02563ZZ, 02573ZZ, 02583ZZ, 025K3ZZ, 025L3ZZ, 025M3ZZ, 025S3ZZ, 025T3ZZ	**Diagnosis**: Primary diagnosis only
Angioplasty with and without Drug Eluting Stent	**Acute Myocardial Infarction**: I21x, I21xx **Angina**: I20.x	**CPT/HCPCS:** 92928, 92929, 92933, 92937, 92943; C1874, C9600, C9602, C9604, C9607 **Ambulatory Payment Classifications (APC)**: 5193, 5194 **MS-DRG**: 246-249	**Diagnosis**: Primary diagnosis only **Procedure:** Inpatient must have MS-DRG 246-249
Transcatheter Aortic Valve Replacement	**Aortic stenosis**: I060, I062, I350, I352	**ICD-10-PCS Codes**: 02RF37H, 02RF37Z,02RF38H,02RF38Z, 02RF3JH, 02RF3JZ, 02RF3KH, 02RF3KZ	**Diagnosis**: Any diagnosis
Neurovascular			
Mechanical Thrombectomy	**Acute Ischemic stroke**: I63.xx	**HCPCS**: C1757, C2628, C1894, C1887 **CPT**: 36215, 36216, 36217, 36218, 36221, 36222, 36223, 36224, 36225, 36226, 61623, 61624, 61626, 61630, 61635, 61645, 61650, 61651 **ICD-10-PCS**: 03CG3Z7, 03CH3Z7, 03CJ3Z7,03CK3Z7, 03CL3Z7, 03CM3Z7, 03CN3Z7, 03CP3Z7, 03CQ3Z7, 03CG3ZZ, 03CH3ZZ, 03CJ3ZZ, 03CK3ZZ, 03CL3ZZ, 03CM3ZZ, 03CN3ZZ, 03CP3ZZ, 03CQ3ZZ **MS-DRG**: 023, 024	**Diagnosis**: Primary diagnosis only
Thrombolysis	**Acute Ischemic stroke**: I63.xx	**HCPCS**: J0350, J2993 **CPT**: 37195, 37211 – 37214 , 37201, 92975 **ICD-10-PCS**: 3E04317, 3E03317 **ICD-10-CM:** Z92.82 **MS-DRG**: 023,024, 061, 062, 063	**Diagnosis**: Primary diagnosis only

Appendix B: Supplemental Descriptive Statistics: Region and Comorbidities

Figure B.1: Indicated Population and Procedure Populations for Cardiac Ablation by Census Division and Most Common Condition Categories, 2018-2019

	2018		2019	
Attribute	Indicated Population N=214,825 (%)	Procedure Population N=3,579 (%)	Indicated Population N=217,212 (%)	Procedure Population N=3,940 (%)
Census Division				
New England	6.3	3.8	6.2	3.6
Middle Atlantic	13.8	10.6	13.4	12.1
E. North Central	15.9	15.4	15.9	14.8
W. North Central	7.4	5.8	7.88	5.9
South Atlantic	22.0	24.0	22.2	23.9
E. South Central	6.8	7.9	6.7	7.5
W. South Central	10.0	13.1	9.9	12.3
Mountain	6.0	7.1	6.0	7.3
Pacific	11.9	12.4	11.9	12.6
HCC Category				
17 Diabetes with acute complications	0.1	0.3	0.1	0.2
18 Diabetes with chronic complications	5.1	12.5	5.3	13.7
19 Diabetes without complications	9.5	24.4	9.2	23.5
80 Coma, Brain Compression/Anoxic Damage	0.1	0.1	0.1	0.1
84 Cardio-Respiratory Failure and Shock	2.9	6.0	2.9	6.8
85 Congestive Heart Failure	19.8	43.7	20.3	44.1
86 Acute Myocardial Infarction	1.5	3.1	1.5	3.6
87 Unstable Angina and Other Acute Ischemic Heart Disease	0.7	3.0	0.8	3.0
88 Angina Pectoris	1.8	5.1	1.9	5.0
96 Specified Heart Arrythmias	82.9	98.2	81.4	97.9
99 Cerebral Hemorrhage	0.3	0.2	0.3	0.3
100 Ischemic or unspecified Stroke	2.3	3.0	2.2	2.3
108 Vascular Disease	6.3	17.2	6.6	18.0
111 Chronic Obstructive Pulmonary Disease	6.5	15.4	6.4	15.4
135 Acute Renal Failure	2.3	6.2	2.4	7.5

Figure B.2: Indicated Population and Procedure Populations for Angioplasty by Census Division and Most Common Condition Categories, 2018-2019

Attribute	2018 Indicated Population N=38,779 (%)	2018 Procedure Population N=5,393 (%)	2019 Indicated Population N=37,272 (%)	2019 Procedure Population N=5,343 (%)
Census Division				
New England	4.5	5.3	4.4	4.7
Middle Atlantic	12.0	11.9	11.4	11.5
E. North Central	14.3	15.3	14.2	16.0
W. North Central	5.4	7.5	5.6	7.7
South Atlantic	25.7	21.2	25.2	21.1
E. South Central	7.6	8.6	7.3	8.2
W. South Central	13.3	12.3	13.7	12.4
Mountain	5.1	6.8	5.7	7.2
Pacific	12.2	11.2	12.4	11.2
HCC Category				
17 Diabetes with acute complications	0.4	0.5	0.4	0.7
18 Diabetes with chronic complications	11.9	23.2	12.3	23.2
19 Diabetes without complications	14.7	26.1	14.8	25.6
80 Coma, Brain Compression/Anoxic Damage	0.6	0.9	0.6	0.8
84 Cardio-Respiratory Failure and Shock	7.6	13.4	7.9	14.0
85 Congestive Heart Failure	20.7	30.6	21.5	32.3
86 Acute Myocardial Infarction	36.0	87.0	37.4	87.8
87 Unstable Angina and Other Acute Ischemic Heart Disease	25.6	30.9	24.4	28.8
88 Angina Pectoris	56.1	23.6	55.2	23.1
96 Specified Heart Arrythmias	17.2	23.9	17.4	25.0
99 Cerebral Hemorrhage	0.1	0.2	0.1	0.2
100 Ischemic or unspecified Stroke	0.9	1.1	0.9	1.1
108 Vascular Disease	9.2	14.2	9.9	14.8
111 Chronic Obstructive Pulmonary Disease	10.0	16.1	9.8	16.6
135 Acute Renal Failure	8.0	13.7	8.2	14.5

Figure B.3: Indicated Population and Procedure Populations for TAVR by Census Division and Most Common Condition Categories, 2018-2019

	2018		2019	
Attribute	Indicated Population N=53,570 (%)	Procedure Population N=1,553 (%)	Indicated Population N=55,735 (%)	Procedure Population N=1,836 (%)
Census Division				
New England	6.3	4.9	6.1	6.1
Middle Atlantic	17.0	16.7	16.4	18.5
E. North Central	15.2	15.7	15.2	12.8
W. North Central	6.9	7.5	7.3	6.6
South Atlantic	21.6	23.4	22.0	23.1
E. South Central	5.8	5.1	5.7	4.7
W. South Central	9.9	9.3	10.0	9.0
Mountain	5.4	5.8	5.3	6.7
Pacific	12.1	11.6	12.1	12.6
HCC Category				
17 Diabetes with acute complications	0.2	0.3	0.2	0.2
18 Diabetes with chronic complications	12.0	30.8	12.7	30.3
19 Diabetes without complications	15.7	37.2	15.6	35.8
80 Coma, Brain Compression/Anoxic Damage	0.4	0.9	0.3	0.8
84 Cardio-Respiratory Failure and Shock	7.6	21.4	7.4	19.7
85 Congestive Heart Failure	32.9	87.0	33.7	84.2
86 Acute Myocardial Infarction	4.0	10.4	4.0	10.8
87 Unstable Angina and Other Acute Ischemic Heart Disease	3.1	10.1	3.1	10.0
88 Angina Pectoris	5.9	22.3	6.0	21.4
96 Specified Heart Arrythmias	32.9	59.8	32.3	55.3
99 Cerebral Hemorrhage	0.4	1.2	0.4	0.8
100 Ischemic or unspecified Stroke	2.8	7.3	2.7	7.9
108 Vascular Disease	17.2	54.5	17.6	51.2
111 Chronic Obstructive Pulmonary Disease	11.2	31.8	11.1	29.9
135 Acute Renal Failure	7.3	19.4	7.1	16.5

Figure B.4: Indicated Population and Procedure Populations for Mechanical Thrombectomy by Census Division and Most Common Condition Categories, 2018-2019

	2018		2019	
Attribute	Indicated Population N=45,587 (%)	Procedure Population N=723 (%)	Indicated Population N=46,356 (%)	Procedure Population N=927 (%)
Census Division				
New England	4.9	4.6	4.9	3.8
Middle Atlantic	14.5	13.8	14.8	14.4
E. North Central	15.4	16.3	15.1	16.2
W. North Central	5.9	7.2	6.0	6.6
South Atlantic	23.2	22.7	23.3	21.8
E. South Central	7.3	5.5	7.1	6.8
W. South Central	11.8	11.8	11.7	12.6
Mountain	5.5	4.3	5.4	4.6
Pacific	11.6	13.8	11.7	13.2
HCC Category				
17 Diabetes with acute complications	0.2	0.4	0.3	0.9
18 Diabetes with chronic complications	9.7	20.3	10.0	19.7
19 Diabetes without complications	13.4	25.9	13.5	29.9
80 Coma, Brain Compression/Anoxic Damage	2.9	32.1	3.1	31.3
84 Cardio-Respiratory Failure and Shock	3.5	32.2	3.5	29.7
85 Congestive Heart Failure	8.8	33.2	9.5	31.2
86 Acute Myocardial Infarction	1.5	5.3	1.6	5.2
87 Unstable Angina and Other Acute Ischemic Heart Disease	0.6	3.2	0.6	2.3
88 Angina Pectoris	0.6	0.8	0.6	0.5
96 Specified Heart Arrythmias	15.5	55.6	15.1	54.9
99 Cerebral Hemorrhage	2.9	27.3	2.9	25.1
100 Ischemic or unspecified Stroke	99.0	100.0	95.0	99.9
108 Vascular Disease	7.0	20.3	7.2	19.1
111 Chronic Obstructive Pulmonary Disease	6.2	17.0	6.2	15.2
135 Acute Renal Failure	4.7	16.0	5.0	17.3

Figure B.5: Indicated Population and Procedure Populations for Thrombolysis by Census Division and Most Common Condition Categories, 2018-2019

	2018		2019	
Attribute	Indicated Population N=45,587 (%)	Procedure Population N=1,344 (%)	Indicated Population N=46,356 (%)	Procedure Population N=1,465 (%)
Census Division				
New England	4.9	3.3	4.9	4.4
Middle Atlantic	14.5	12.7	14.8	11.0
E. North Central	15.4	15.4	15.1	16.2
W. North Central	5.9	8.0	6.0	8.1
South Atlantic	23.2	22.2	23.3	22.8
E. South Central	7.3	6.0	7.1	7.2
W. South Central	11.8	13.7	11.7	12.9
Mountain	5.5	6.8	5.4	5.2
Pacific	11.6	12.0	11.7	12.2
HCC Category				
17 Diabetes with acute complications	0.2	0.3	0.3	0.8
18 Diabetes with chronic complications	9.7	24.7	10.0	24.2
19 Diabetes without complications	13.4	30.5	13.5	30.5
80 Coma, Brain Compression/Anoxic Damage	2.9	15.1	3.1	17.4
84 Cardio-Respiratory Failure and Shock	3.5	17.1	3.5	14.5
85 Congestive Heart Failure	8.8	28.0	9.5	28.1
86 Acute Myocardial Infarction	1.5	3.9	1.6	4.3
87 Unstable Angina and Other Acute Ischemic Heart Disease	0.6	2.5	0.6	1.8
88 Angina Pectoris	0.6	1.6	0.6	1.2
96 Specified Heart Arrythmias	15.5	42.1	15.1	40.1
99 Cerebral Hemorrhage	2.9	14.4	2.9	14.1
100 Ischemic or unspecified Stroke	99.0	100.0	95.0	99.6
108 Vascular Disease	7.0	17.2	7.2	15.0
111 Chronic Obstructive Pulmonary Disease	6.2	17.4	6.2	15.8
135 Acute Renal Failure	4.7	15.6	5.0	15.0

Appendix C: Phase III Regression Results by Procedure

Figures C.1-C.5 present the regression models for each clinical intervention we examined.

- **(1) Demographic & Clinical/Use**. The Base model plus the individual HCC condition categories and the utilization variables described in Appendix A.[17]
- **(2) Demographic & Clinical/Use with Provider FE**. Model (2) but accounting for provider level characteristics by including provider FE.
- **(3) Demographic & Clinical/Use with County FE**. Model (3) with the addition of the beneficiaries' county-level social deprivation index score.

[17] We omitted the output for the 79 condition categories that represent the comorbidities; results are available upon request.

Figure C.1: Coefficients from Phase III Regression Models for Cardiac Ablation, 2018-2019

	(1) OLS	(2) Provider FE	(3) County FE
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Race (ref. White)			
Black	-0.448 ***	-0.627 ***	-0.615 ***
	(0.070)	(0.085)	(0.075)
Other	0.099	0.039	-0.009
	(0.090)	(0.107)	(0.102)
Female	-0.207 ***	-0.185 ***	-0.216 ***
	(0.040)	(0.043)	(0.038)
Dual-eligible for Medicaid	-0.941 ***	-0.752 ***	-0.904 ***
	(0.045)	(0.054)	(0.048)
Age (ref. Age 65-74)			
Age 18-44	0.534 *	0.405	0.529 *
	(0.241)	(0.259)	(0.239)
Age 45-64	-0.139	-0.133	-0.104
	(0.106)	(0.114)	(0.113)
Age 75-84	-1.619 ***	-1.544 ***	-1.631 ***
	(0.057)	(0.064)	(0.059)
Age 85 and older	-2.891 ***	-2.737 ***	-2.897 ***
	(0.054)	(0.070)	(0.067)
At least one Inpatient Visit	0.290 ***	0.258* ***	0.245 ***
	(0.067)	(0.071)	(0.072)
At least one outpatient Visit	0.281 ***	0.294* ***	0.319 ***
	(0.053)	(0.058)	(0.057)
Number of Inpatient Visits	-0.121 ***	-0.122 ***	-0.133 ***
	(0.027)	(0.028)	(0.028)
Number of outpatient visits	-0.018 ***	-0.014 ***	-0.010 ***
	(0.002)	(0.002)	(0.002)
Year (ref. Year=2018)	0.146 ***	0.140* ***	0.141 ***
	(0.039)	(0.044)	(0.041)
Constant	1.090 ***	1.007 ***	1.056 ***
	(0.061)	(0.071)	(0.068)
Observations	432,037	432,037	431,267

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Figure C.2: Coefficients from Phase III Regression Models for Angioplasty, 2018-2019

	(1) OLS	(2) Provider FE	(3) County FE
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Race (ref. White)			
Black	-3.307 ***	-3.073 ***	-3.418 ***
	(0.374)	(0.491)	(0.420)
Other	-1.552 ***	-1.673 **	-1.727 ***
	(0.393)	(0.520)	(0.438)
Female	-2.367 ***	-2.466 ***	-2.454 ***
	(0.229)	(0.260)	(0.243)
Dual-eligible for Medicaid	-2.355 ***	-1.507 ***	-1.920 ***
	(0.288)	(0.352)	(0.308)
Age (ref. Age 65-74)			
Age 18-44	0.107	-0.048	-0.016
	(1.036)	(1.198)	(1.109)
Age 45-64	1.088 **	0.680	0.909 *
	(0.408)	(0.464)	(0.423)
Age 75-84	-1.351 ***	-1.228 ***	-1.276 ***
	(0.269)	(0.301)	(0.271)
Age 85 and older	-5.643 ***	-5.302 ***	-5.408 ***
	(0.002)	(0.420)	(0.372)
At least one inpatient admission	-3.374 ***	-3.429 ***	-3.477
	(0.357)	(0.407)	(0.381)
At least one outpatient visit	-1.498 ***	-1.263	-1.465
	(0.301)	(0.337)	(0.306)
Number of inpatient admissions	0.218	0.299 *	0.159
	(0.137)	(0.156)	(0.136)
Number of outpatient visits	-0.124 ***	-0.085 ***	-0.098
	(0.014)	(0.018)	(0.016)
Year (ref. Year=2018)	0.003	-0.065	-0.031
	(0.225)	(0.253)	(0.218)
Constant	5.845 ***	6.587 ***	5.532 ***
	(0.492)	(0.559)	(0.512)
Observations	76,051	76,051	75,903

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Figure C.3: Coefficients from Phase III Regression Models for TAVR, 2018-2019

	(1) OLS	(2) Provider FE	(3) County FE
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Race (ref. White)			
Black	-1.084 ***	-1.243 ***	-1.230 ***
	(0.203)	(0.243)	(0.200)
Other	-0.601 **	-1.065 ***	-0.944 ***
	(0.194)	(0.239)	(0.190)
Female	0.203	0.300 **	0.239 *
	(0.106)	(0.116)	(0.104)
Dual-eligible for Medicaid	-1.327 ***	-1.193 ***	-1.336 ***
	(0.141)	(0.165)	(0.141)
Age (ref. Age 65-74)			
Age 18-44	0.113	0.516	-0.104
	(0.590)	(0.672)	(0.491)
Age 45-64	-0.708 **	-0.657 *	-0.586 *
	(0.250)	(0.279)	(0.246)
Age 75-84	0.923 ***	0.937 ***	0.855 ***
	(0.126)	(0.142)	(0.135)
Age 85 and older	0.499 ***	0.545 ***	0.411 **
	(0.134)	(0.153)	(0.142)
At least one Inpatient Visit	-0.549 **	-0.619 **	-0.660 ***
	(0.177)	(0.191)	(0.173)
At least one outpatient Visit	0.121	0.223	0.203
	(0.132)	(0.151)	(0.140)
Number of Inpatient Visits	-0.363 ***	-0.401 ***	-0.343 ***
	(0.077)	(0.083)	(0.077)
Number of outpatient visits	-0.062 ***	-0.066 ***	-0.061 ***
	(0.006)	(0.007)	(0.006)
Year (ref. Year=2018)	0.334 **	0.325 **	0.322 **
	(0.102)	(0.111)	(0.106)
Constant	-1.221 ***	-1.406 ***	-1.266 ***
	(0.144)	(0.180)	(0.179)
Observations	109,305	109,305	109,089

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Figure C.4: Coefficients from Phase III Regression Models for Mechanical Thrombectomy, 2018-2019

	(1) OLS	(2) Provider FE	(3) County FE
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Race (ref. White)			
Black	-0.367 **	-0.635 ***	-0.391 **
	(0.121)	(0.158)	(0.128)
Other	-0.189	-0.412	-0.168
	(0.162)	(0.219)	(0.194)
Female	0.011	-0.036	0.013
	(0.087)	(0.104)	(0.088)
Dual-eligible for Medicaid	-0.542 ***	-0.258 *	-0.591 ***
	(0.098)	(0.129)	(0.099)
Age (ref. Age 65-74)			
Age 18-44	1.384 **	1.342 **	1.395* **
	(0.494)	(0.502)	(0.512)
Age 45-64	-0.159	-0.173	-0.201
	(0.138)	(0.129)	(0.141)
Age 75-84	-0.132	-0.111	-0.125
	(0.109)	(0.094)	(0.109)
Age 85 and older	-0.483 ***	-0.454 ***	-0.486 ***
	(0.120)	(0.125)	(0.132)
At least one Inpatient Visit	-0.482 ***	-0.294 ***	-0.491 ***
	(0.124)	(0.159)	(0.128)
At least one outpatient Visit	-0.244 *	-0.159	-0.234
	(0.119)	(0.140)	(0.116)
Number of Inpatient Visits	-0.067	-0.110	-0.070
	(0.051)	(0.072)	(0.051)
Number of outpatient visits	-0.016 ***	-0.018 **	-0.015 **
	(0.005)	(0.006)	(0.005)
Year (ref. Year=2018)	0.444 ***	0.417 ***	0.432 ***
	(0.086)	(0.102)	(0.092)
Constant	-0.418 **	-0.436 *	-0.339 *
	(0.005)	(0.236)	(0.169)
Observations	91,942	91,942	91,729

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.

Figure C.5: Coefficients from Phase III Regression Models for Thrombolysis, 2018-2019

	(1) OLS	(2) Provider FE	(3) County FE
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Race (ref. White)			
Black	-0.968 ***	-0.968 ***	-0.878 ***
	(0.151)	(0.200)	(0.178)
Other	-0.311	-0.482	-0.263
	(0.208)	(0.269)	(0.234)
Female	0.047	0.033	0.086
	(0.113)	(0.134)	(0.111)
Dual-eligible for Medicaid	-1.391 ***	-0.838 ***	-1.316 ***
	(0.126)	(0.172)	(0.138)
Age (ref. Age 65-74)			
Age 18-44	-0.392	-0.328	-0.448
	(0.408)	(0.493)	(0.447)
Age 45-64	-0.141	-0.144	-0.142
	(0.187)	(0.228)	(0.185)
Age 75-84	-0.090	0.106	-0.111
	(0.141)	(0.167)	(0.147)
Age 85 and older	-0.084	0.167	-0.135
	(0.160)	(0.195)	(0.178)
At least one Inpatient Visit	-0.763 ***	-0.629 **	-0.776 ***
	(0.167)	(0.199)	(0.167)
At least one outpatient Visit	-0.427 **	-0.207	-0.437 **
	(0.153)	(0.182)	(0.157)
Number of Inpatient Visits	-0.038	-0.032	-0.038
	(0.069)	(0.083)	(0.067)
Number of outpatient visits	-0.020 **	-0.028 ***	-0.021 **
	(0.006)	(0.008)	(0.007)
Year (ref. Year=2018)	0.262 *	0.201	0.268 *
	(0.112)	(0.132)	(0.110)
Constant	0.136 **	-0.077	0.041 *
	(0.209)	(0.292)	(0.247)
Observations	91,942	91,942	91,729

***: Significant at 0.001 level; **: Significant at 0.01 level; *: Significant at 0.05 level.

Source: KNG Health Consulting calculation using the 5% Standard Analytic File, 2018-2019.