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High-Risk Surgery Among Medicare Beneficiaries Living in Health Professional Shortage Areas

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Key words: health professional shortage area; surgical outcomes; rural surgery; travel burden; surgical access

Abstract

Purpose: Americans who reside in Health Professional Shortage Areas currently have less than half of the needed physician workforce. While the shortage designation has been associated with poor outcomes for chronic medical conditions, far less is known about outcomes after high-risk surgical procedures.

Methods: We performed a retrospective review of Medicare beneficiaries living in Health Professional Shortage Areas and non-shortage areas who underwent abdominal aortic aneurysm repair, coronary artery bypass graft, esophagectomy, liver resection, pancreatectomy, or rectal resection between 2014 and 2018. Risk-adjusted multivariable logistic regression was used to determine whether rates of postoperative complications and 30-day mortality differed between patient cohorts. Beneficiary and hospital ZIP codes were used to quantify travel time to obtain care.

Findings: Compared with patients living in non-shortage areas, patients living in Health Professional Shortage Areas traveled longer (median 60.0 minutes vs. 28.0 minutes, p<0.001). There were no differences in risk-adjusted rates of complications (28.5% vs. 28.6%, OR=1.00, 95% CI 1.00–1.00, p=0.59) and small differences in rates of 30-day mortality (4.2% vs. 4.4%, OR=0.95, 95% CI 0.95–0.95, p<0.001) between beneficiaries living in shortage areas versus those not in shortage areas, respectively.

Conclusions: Patients living in Health Professional Shortage Area undergoing high-risk surgery traveled more than two times longer for their care to obtain similar outcomes. While reassuring for clinical outcomes, additional efforts may be needed to mitigate the travel burden experienced by shortage area patients.

Key words: health professional shortage area; surgical outcomes; rural surgery; travel burden; surgical access

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Background

Americans living in Health Professional Shortage Areas have less than half of the necessary physician workforce to adequately service their population.[1] These shortage areas, predominately rural, are designated based on three key criteria: provider-to-patient ratio, percent of population below the federal poverty level, and travel time to the nearest source of care outside of the shortage designation area.[2] Health Professional Shortage Area designations have been used to guide federal resource allocation to these medically underserved areas and have also been used to inform policy aimed at improving access to surgical care.[3,4] Current evidence suggests that Health Professional Shortage Area hospitals have been responsive to federal incentives with appreciable increases in surgical volume.[5]

While living in a Health Professional Shortage Area has been associated with worse medical conditions, far less is known about surgery.[6-9] For example, patients in Health Professional Shortage Areas have higher rates of common medical comorbidities and have worse overall health status.[6-8] However, recent findings suggest that patients living Health Professional Shortage Area can obtain safe surgical care for common operations, but with a higher travel burden[10]. However, less is known about high-risk surgery, which commonly requires the care of surgical subspecialists. In fact, many such high-risk operations have been restricted to higher volume centers given their known volume-outcome relationships.[11] As such, patients residing in Health Professional Shortage Area may be at risk for having worse quality and longer travel times.

In this context, this study sought to compare surgical quality and travel burden among Medicare beneficiaries residing in Health Professional Shortage Areas to those living in non-shortage areas who underwent high-risk surgery. We hypothesized that compared to their non-shortage area counterparts, beneficiaries living in Health Professional Shortage Areas undergoing high-risk surgery would be observed to have worse outcomes from high-risk operations and endure longer travel times to obtain this care.

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Methods

Data Source

Patient-level data was obtained for fee-for-service eligible Medicare beneficiaries ages 65-99 from the Medicare Provider Analysis and Review (MEDPAR) file between the years of 2014 and 2018. The MEDPAR database captures claims on an annual basis, which are submitted to the Centers for Medicare and Medicaid Services (CMS) by hospitals where Medicare beneficiaries obtained care. Patient ZIP codes from MEDPAR were linked to the CMS list of ZIP codes that met criteria for primary care Health Professional Shortage Area designation in order identify beneficiaries living in Health Professional Shortage Areas. This list of Health Professional Shortage Area ZIP codes is released on an annual basis by CMS. Patients were considered to be living in an shortage area if their ZIP code in MEDPAR was designated as a Health Professional Shortage Area at the time they underwent their high-risk surgery.[12] No current Health Professional Shortage Area designation for surgical providers exists. The primary care Health Professional Shortage Area designation was used to identify these patients because it was also the basis for creation of the Health Professional Shortage Area Surgical Incentive Payment (HSIP) Program.[3]

Hospital-level characteristics where beneficiaries obtained care were assessed using the American Hospital Association (AHA) Annual Survey. AHA data were linked to individual Medicare beneficiaries based on each hospital's individual facility identification code.[13] This study was approved by the University of Michigan Investigational Review Board and deemed exempt due to use of secondary data.

Identification of Procedures and Analytic Cohort

We identified beneficiaries aged 65-99 years who underwent one of six high-risk procedures. These procedures included abdominal aortic aneurysm repair (AAAR), coronary artery bypass graft (CABG), esophagectomy, liver resection, pancreatectomy, and rectal resection. These procedures were identified using International Classification of Diseases, Ninth (*ICD-9-CM*) and Tenth (*ICD-10-CM*) Revision, Clinical Modification codes (*Supplemental Table 1*). These six procedures were

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selected based on their described volume-outcome relationships, which have prompted suggestions of subspecialist care and centralization for performing these procedures at higher volume centers. [14-19]

Outcome Variables

The primary outcome in this study was 30-day mortality, which was defined as patients who died within 30 days of discharge from their index admission. This was determined using the Medicare beneficiary denominator file. Separately, patient vital signs at discharge were used to ascertain in-hospital mortality.

Secondary 30-day outcomes included postoperative complications, serious complications, reoperations, and readmissions. Complications were identified using *ICD-9-CM* and *ICD-10-CM* codes as previously validated using Medicare claims data.[20-22] These complications included pulmonary failure, pneumonia, myocardial infarction, deep venous thrombosis, acute kidney failure, postoperative hemorrhage, surgical site infection, and gastrointestinal bleed. Serious complications were defined as the development of a complication in a patient whose length of stay was higher than the 75th percentile for the index procedure, which is recognized to increase the outcome variable's specificity.[23] Reoperations were defined using *ICD-9-CM* and *ICD-10-CM* codes indicating secondary procedures during the index hospitalization as previously described in studies using the MEDPAR file.[24] Readmissions were defined as any inpatient admission within 30 days to any hospital after discharge from their index hospitalization.[24]

Statistical Analysis

The purpose of this study was to compare major outcomes after high-risk surgery between Medicare beneficiaries living in Health Professional Shortage Areas and non-shortage areas. Patient characteristics of interest included age, sex, race, comorbidities, Elixhauser comorbidity index[25], discharge disposition, admission type, proportion of patients going to a hospital located in a shortage area, operation type, and travel time to obtain care. These were compared using chi square tests for categorical variables and t-tests for continuous variables.

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Number of minutes for travel time was determined using Google Maps and was based on the centroid of each patient's ZIP code and the corresponding hospital's ZIP code centroid where they underwent surgery. If a patient lived in the same ZIP code as the hospital where they obtained care, travel time was calculated as zero.

Next, hospital characteristics were assessed to uncover any differences between the facilities where Health Professional Shortage Area patients obtained care, compared to their non-shortage area counterparts. Bed capacity, hospital geographic region, teaching hospital status, patient to nurse ratio, and Medicare hospital procedure volumes were all compared using chi square and t-tests where appropriate.

Multivariable logistic regression was used to compare major outcomes between patient cohorts. Models were risk-adjusted for patient age, sex, comorbidities, procedure type and admission type at the patient level. At the hospital level, models were risk-adjusted for teaching hospital status and patient to nurse ratio. Finally, models were adjusted for the year patients underwent their operations to account for potential secular trends in the data. Statistical analyses were performed using STATA, version 16 (STATA Corp). All statistical tests were two-tailed, and a p value of < 0.05 was used as the threshold for significance.

Results

A total of 788,380 beneficiaries underwent one of six high-risk surgical procedures (Table 1). Among these patients, 60,494 (7.7%) lived in a Health Professional Shortage Area. The average overall patient age was 75.1 years (standard deviation = 7.0), and 283,480 (36.0%) of patients in the overall cohort were female. Comorbidity burdens, discharge disposition, admission type, proportion of patients who went to a hospital located in a shortage area for their care, and operative procedure distribution comparing the Health Professional Shortage Area beneficiaries and the non-shortage area cohort are summarized in Table 1.

Compared to patients living in non-shortage areas, patients living in Health Professional Shortage Areas traveled farther (median 50.0 miles vs. 18.2 miles, $p < 0.001$) and longer (median

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60.0 minutes vs. 28.0 minutes, p < 0.001) (Table 1). The comparative distributions of travel times among beneficiaries residing in shortage areas versus those not living in shortage areas are demonstrated in Figure 1.

Hospital characteristics where Health Professional Shortage Area beneficiaries and non-shortage area beneficiaries received care for high-risk surgery are summarized in Table 2. Health Professional Shortage Area beneficiaries were less likely to obtain care at a facility with a capacity of ≥ 500 beds (24,405 [40.5%] versus 316,758 [43.5%], p < 0.001). Similarly, shortage area beneficiaries were less likely to obtain care at a teaching hospital compared to the non-shortage area cohort (50,244 [83.1%] versus 626,830 [86.1%], p < 0.001).

Risk-adjusted clinical outcomes are summarized in Table 3. For clinical outcomes comparing Health Professional Shortage Area and non-shortage area beneficiaries combining all six high-risk operations, 30-day mortality was 4.2% and 4.4%, respectively (OR = 0.95, CI 0.95-0.95, p < 0.001). Rates of serious complications were 13.6% for shortage area beneficiaries and 13.8% for non-shortage area beneficiaries (OR=0.98, CI 0.98 – 0.98, p <0.001). Rates of reoperation were 2.7% and 2.8% for shortage and non-shortage area beneficiaries, respectively (OR=0.95, CI 0.95-0.95, p < 0.001). Finally, readmission rates were 15.4% for shortage area beneficiaries and 15.7% for their non-shortage area counterparts (OR=0.98, CI 0.97-0.98, p < 0.001). Readmissions to index versus non-index hospitals are demonstrated in supplemental Table 1. Risk-adjusted outcomes for each of the six individual high-risk operations are also summarized in Table 3. Supplemental table 2 includes a sensitivity analysis for patients with disproportionately long travel time burdens. Supplemental Table 3 demonstrates an additional sensitivity comparing travel time in minutes across Rural-Urban Commuting Area (RUCA) codes among shortage are and non-shortage area beneficiaries in this analysis.

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Discussion

This study evaluating surgical outcomes and travel times for high-risk surgery among Health Professional Shortage Area Medicare beneficiaries and non-shortage area beneficiaries had two principal findings. First, the findings here revealed no evidence of worse clinical outcomes from high-risk surgery among Health Professional Shortage Area beneficiaries compared to their non-shortage area counterparts. However, Health Professional Shortage Area beneficiaries were found to sustain an average travel time more than twice as far as non-shortage area beneficiaries. Taken together, these findings underscore that Health Professional Shortage Area patients take on a disproportionate travel burden to obtain similar quality of care for high-risk operations.

Prior work has raised concerns about the quality of medical and surgical care for patients living in Health Professional Shortage Areas. Multiple studies have identified the population's poor health status, disproportionate rates of medical comorbidities, and delays in diagnosis of medical conditions.[6,8,26,27] In contrast, Health Professional Shortage Area patients have been found to receive similar quality of care for common general surgery operations such as cholecystectomy and appendectomy.[10] This study extends the existing literature by assessing clinical outcomes in this population for high-risk surgery, which often is subject to centralization of care at higher volume centers.

While our study could not identify the mechanism by which patients in Health Professional Shortage Areas obtain safe surgical care for complex operations, our data suggest two possibilities. First, it is clear that patients in Health Professional Shortage Areas traveled farther for care. In doing so, they likely obtained their procedures at relatively similar centers as those not living in shortage areas. Second, the travel burden associated with these high-risk procedures may be self-selecting for patients with more means or social support to obtain and undergo specialized care, both have which have been associated with better outcomes.[28,29] In other words, more socially vulnerable patients, who are potentially sicker and have less means to travel to obtain high-risk surgery, may have been selected out and not included in this study.

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Our findings also add important information to the ongoing debates of centralizing high-risk surgical procedures. As volume-outcome relationships have become better understood for high quality high-risk surgery, centralization for surgical care has become increasingly studied and adopted in the past two decades.[17,30,31] However, whether or not the relatively small improvement in clinical outcomes are worth the associated increased travel burden has been called into question.[30] Our present study underscores the significant travel burden for these high-risk procedures, and at a minimum, raises interest in how that burden can be mitigated.

This study should be interpreted within the context of its limitations. First, a known limitation of Medicare claims data is the limited reliability in identifying complications. To address this, codes from the Complication Screening Project, that have been shown to have a high level of specificity in Medicare claims data, were used.[20-22] Second, using Medicare beneficiaries as the population of interest may limit the generalizability of our findings. However, our cohort is representative of older patients more likely to undergo high-risk surgery and reflects the population most relevant to policymakers who created the Health Professional Shortage Area designation in question. Further, we were unable to assess underlying disease prevalence related to these operations in these shortage areas to assess whether or not it is proportional to the general population. Lastly, the reported time traveled between patient and hospital utilized ZIP code centroids and were estimated using Google Maps and may not reflect the true travel time or mode of transportation used by the patient. However, any measurement error was likely equally present in both patient cohorts and thus should not threaten the validity of our results.

The findings in this study have several implications for both policymakers and providers on how access to high-risk surgical care can be optimized in these communities. First, policymakers could consider subsidy policies for Health Professional Shortage Area patients who are faced with significant travel burdens to obtain high-risk surgical care. Additionally, policymakers could consider infrastructural investment to provide travel to obtain surgical care for more vulnerable patient populations to promote equity in obtaining high-risk surgical care. Policymakers must keep in mind

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the possible regional variability that appears to exist within shortage areas and will ultimately need to tailor policy interventions accordingly. At the provider level, hospital systems and surgeons, especially those who serve a large proportion of Health Professional Shortage area residents, could pursue development of outreach clinics in rural communities to increase catchment of vulnerable populations in need of high-risk surgical care who otherwise may not possess the means to present to clinic for evaluation of their condition.[32] Additionally, or alternatively, the COVID-19 pandemic has required surgeons to become even more flexible and innovative in providing outpatient clinic care to their surgical patients in the form of telehealth visits in the perioperative setting. Careful and measured considerations will have to be made with respect to emerging technologies such as telehealth and the reality that a considerable proportion of rural patients lack access to broadband. Providers could potentially better serve Health Professional Shortage Area-residing patients by continuing to lean into and perhaps expand virtual visits in both the preoperative and postoperative settings to alleviate the travel burden this population experiences with respect to the outpatient management of their high-risk surgical care.

Conclusion

This study found similar quality of high-risk surgical care for Health Professional Shortage Area and non-shortage area Medicare beneficiaries but identified a significant travel burden that is experienced by shortage area patients. While outcomes may be similar between these cohorts, additional policy and provider efforts should be undertaken to mitigate the travel burden patients experience to obtain this care.

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Table 1: Patient characteristics.

	Total	Lives in HPSA	Does not live in HPSA	P Value
No. of Patients	788,380	60,494	727,886	
Demographic characteristics				
Age, mean (SD)	75.1 (7.0)	74.4 (6.6)	75.2 (7.0)	<0.001
Men	504,900 (64.0%)	39,425 (65.2%)	465,475 (63.9%)	<0.001
Race				
White	699,652 (88.7%)	53,931 (89.2%)	645,721 (88.7%)	0.001
Black	47,971 (6.1%)	4,246 (7.0%)	43,725 (6.0%)	<0.001
Asian	11,977 (1.5%)	165 (0.3%)	11,812 (1.6%)	<0.001
Hispanic	11,176 (1.4%)	976 (1.6%)	10,200 (1.4%)	<0.001
Native American	3,370 (0.4%)	617 (1.0%)	2,753 (0.4%)	<0.001
Other	14,234 (1.8%)	559 (0.9%)	13,675 (1.9%)	<0.001
Comorbidities				
Hypertension	535,224 (67.9%)	41,834 (69.2%)	493,390 (67.8%)	<0.001
Diabetes	300,782 (38.2%)	24,219 (40.0%)	276,563 (38.0%)	<0.001
Fluid and electrolyte disorders	240,231 (30.5%)	18,027 (29.8%)	222,204 (30.5%)	<0.001
Chronic pulmonary disease	191,609 (24.3%)	15,945 (26.4%)	175,664 (24.1%)	<0.001
Renal failure	165,207 (21.0%)	12,126 (20.0%)	153,081 (21.0%)	<0.001
Peripheral vascular disease	157,513 (20.0%)	12,358 (20.4%)	145,155 (19.9%)	0.004
Obesity	151,148 (19.2%)	12,480 (20.6%)	138,668 (19.1%)	<0.001
Deficiency Anemias	135,726 (17.2%)	10,037 (16.6%)	125,689 (17.3%)	<0.001
Coagulopthy	132,253 (16.8%)	9,513 (15.7%)	122,740 (16.9%)	<0.001
Hypothyroidism	117,573 (14.9%)	8,488 (14.0%)	109,085 (15.0%)	<0.001
Depression	63,396 (8.0%)	4,609 (7.6%)	58,787 (8.1%)	<0.001
Weight loss	50,982 (6.5%)	3,814 (6.3%)	47,168 (6.5%)	0.092
Other neurological disorders	47,950 (6.1%)	3,639 (6.0%)	44,311 (6.1%)	0.48
Metastatic cancer	31,239 (4.0%)	1,954 (3.2%)	29,285 (4.0%)	<0.001
Rheumatoid arthritis	24,094 (3.1%)	1,734 (2.9%)	22,360 (3.1%)	0.005
Liver disease	20,972 (2.7%)	1,378 (2.3%)	19,594 (2.7%)	<0.001
Solid tumor	20,713 (2.6%)	1,409 (2.3%)	19,304 (2.7%)	<0.001
Congestive heart failure	18,994 (2.4%)	1,403 (2.3%)	17,591 (2.4%)	0.13
Valvular disease	11,586 (1.5%)	674 (1.1%)	10,912 (1.5%)	<0.001
Psychoses	10,167 (1.3%)	642 (1.1%)	9,525 (1.3%)	<0.001
Elixhauser comorbidities				
0	32,515 (4.1%)	2,376 (3.9%)	30,139 (4.1%)	0.011
1	107,493 (13.6%)	8,101 (13.4%)	99,392 (13.7%)	0.070
≥2	648,372 (82.2%)	50,017 (82.7%)	598,355 (82.2%)	0.003
Discharge location				
Home	570,631 (72.4%)	44,361 (73.3%)	526,270 (72.3%)	<0.001
Skilled Nursing Facility, rehabilitation	185,533 (23.5%)	12,967 (21.4%)	172,566 (23.7%)	<0.001
Transferred	4,063 (0.5%)	339 (0.6%)	3,724 (0.5%)	0.11
Hospice	2,678 (0.3%)	182 (0.3%)	2,496 (0.3%)	0.088
Other	25,475 (3.2%)	2,645 (4.4%)	22,830 (3.1%)	<0.001
Admission Type				
Elective	514,254 (65.2%)	39,681 (65.6%)	474,573 (65.2%)	0.049
Unplanned	274,126 (34.8%)	20,813 (34.4%)	253,313 (34.8%)	0.049
Went to a Hospital in a HPSA	5,822 (0.7%)	2,435 (4.0%)	3,387 (0.5%)	< 0.001
Type of operation				
AAAR	222,804 (28.3%)	15,780 (26.1%)	207,024 (28.4%)	<0.001
CABG	401,623 (50.9%)	33,773 (55.8%)	367,850 (50.5%)	<0.001
Esophagectomy	14,922 (1.9%)	986 (1.6%)	13,936 (1.9%)	<0.001
Liver resection	25,266 (3.2%)	1,511 (2.5%)	23,755 (3.3%)	<0.001
Pancreatectomy	33,542 (4.3%)	2,011 (3.3%)	31,531 (4.3%)	<0.001
Rectal resection	90,223 (11.4%)	6,433 (10.6%)	83,790 (11.5%)	<0.001
Travel time in minutes, mean (SD)	70.2 (180.6)	96.1 (173.9)	68.1 (181.0)	<0.001
Travel time in minutes, median (IQR)	29.0 (17.0-56.0)	60.0 (40.0-95.0)	28.0 (17.0-51.0)	<0.001
Travel time in minutes				
<30	394,867 (50.1%)	7,945 (13.1%)	386,922 (53.2%)	<0.001
30-60	216,335 (27.4%)	22,731 (37.6%)	193,604 (26.6%)	<0.001
>60	177,178 (22.5%)	29,818 (49.3%)	147,360 (20.2%)	<0.001

HPSA – Health Professional Shortage Area, SD – standard deviation, AAAR – abdominal aortic aneurysm repair, CABG – coronary artery bypass graft

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Table 2: Hospital characteristics.

	Total	Lives in HPSA	Does not live in HPSA	P Value
No. of Patients	788,380	60,494	727,886	
Hospital Size				
Has fewer than 250 beds	143,503 (18.2%)	12,904 (21.3%)	130,599 (17.9%)	<0.001
Has between 250 and 499 beds	303,714 (38.5%)	23,185 (38.3%)	280,529 (38.5%)	0.30
Has 500 or more beds	341,163 (43.3%)	24,405 (40.3%)	316,758 (43.5%)	<0.001
Hospital Region				
Northeast	141,644 (18.0%)	2,366 (3.9%)	139,278 (19.1%)	<0.001
Midwest	187,406 (23.8%)	14,968 (24.7%)	172,438 (23.7%)	<0.001
South	321,434 (40.8%)	32,314 (53.4%)	289,120 (39.7%)	<0.001
West	137,896 (17.5%)	10,846 (17.9%)	127,050 (17.5%)	0.003
Teaching Hospital	677,074 (85.9%)	50,244 (83.1%)	626,830 (86.1%)	<0.001
Patient to Nurse Ratio	9.0 (2.8)	8.9 (2.9)	9.0 (2.8)	<0.001
Hospital Medicare Procedure Volume				
AAAR	80.9 (91.1)	66.4 (75.3)	82.1 (92.2)	<0.001
CABG	114.6 (82.8)	107.1 (74.3)	115.2 (83.5)	<0.001
Esophagectomy	4.8 (7.9)	3.9 (7.2)	4.9 (8.0)	<0.001
Liver resection	9.1 (15.3)	6.9 (12.9)	9.3 (15.5)	<0.001
Pancreatectomy	12.3 (20.2)	9.3 (16.8)	12.5 (20.5)	<0.001
Rectal resection	21.7 (22.4)	18.0 (19.2)	22.0 (22.6)	<0.001

HPSA – Health Professional Shortage Area, IQR – interquartile range, AAAR – abdominal aortic aneurysm repair, CABG – coronary artery bypass graft

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Table 3: Comparison of clinical outcomes after undergoing high-risk surgery procedures at Health Professional Shortage Area hospitals and non-shortage hospitals.

	Risk-Adjusted Rates (95% CI), %			
	Beneficiaries living in a HPSA	**Beneficiaries not living in a HPSA**	**Odds Ratio**	**P Value**
All Cohorts				
Mortality, 30-d	4.20 (4.16 to 4.24)	4.36 (4.32 to 4.41)	0.95 (0.95 to 0.95)	<0.001
Mortality, in-hospital	2.62 (2.59 to 2.66)	2.72 (2.69 to 2.76)	0.95 (0.95 to 0.95)	<0.001
Any complications	28.53 (28.44 to 28.62)	28.61 (28.52 to 28.70)	1.00 (1.00 to 1.00)	0.59
Serious complications	13.58 (13.51 to 13.65)	13.78 (13.71 to 13.85)	0.98 (0.98 to 0.98)	<0.001
Reoperations	2.70 (2.67 to 2.74)	2.83 (2.80 to 2.87)	0.95 (0.95 to 0.95)	<0.001
Readmissions	15.39 (15.31 to 15.47)	15.70 (15.62 to 15.78)	0.98 (0.97 to 0.98)	<0.001
AAAR				
Mortality, 30-d	4.61 (4.52 to 4.69)	4.59 (4.50 to 4.67)	1.00 (0.99 to 1.00)	0.10
Mortality, in-hospital	2.98 (2.91 to 3.05)	2.92 (2.86 to 2.99)	1.02 (1.01 to 1.02)	<0.001
Any complications	21.59 (21.44 to 21.74)	21.66 (21.51 to 21.8)	1.00 (0.99 to 1.00)	<0.001
Serious complications	12.77 (12.65 to 12.89)	12.68 (12.56 to 12.8)	1.00 (1.00 to 1.00)	0.31
Reoperations	1.93 (1.87 to 1.99)	1.78 (1.73 to 1.83)	1.09 (1.08 to 1.10)	<0.001
Readmissions	13.98 (13.83 to 14.12)	14.24 (14.1 to 14.39)	0.98 (0.97 to 0.98)	<0.001
CABG				
Mortality, 30-d	3.69 (3.63 to 3.74)	3.86 (3.80 to 3.92)	0.96 (0.96 to 0.96)	<0.001
Mortality, in-hospital	2.32 (2.28 to 2.37)	2.45 (2.40 to 2.49)	0.96 (0.95 to 0.96)	<0.001
Any complications	32.84 (32.71 to 32.97)	33.78 (33.65 to 33.91)	0.95 (0.95 to 0.95)	<0.001
Serious complications	13.77 (13.67 to 13.86)	14.29 (14.19 to 14.38)	0.95 (0.95 to 0.95)	<0.001
Reoperations	1.61 (1.57 to 1.65)	1.69 (1.65 to 1.73)	0.96 (0.95 to 0.96)	<0.001
Readmissions	14.84 (14.73 to 14.95)	15.00 (14.89 to 15.11)	0.99 (0.99 to 0.99)	<0.001
Esophagectomy				
Mortality, 30-d	9.86 (9.39 to 10.34)	9.26 (8.83 to 9.70)	1.04 (1.03 to 1.06)	<0.001
Mortality, in-hospital	6.45 (6.05 to 6.85)	6.10 (5.74 to 6.47)	1.03 (1.02 to 1.05)	<0.001
Any complications	38.67 (37.97 to 39.37)	37.43 (36.75 to 38.11)	1.07 (1.06 to 1.08)	<0.001
Serious complications	19.71 (19.11 to 20.31)	18.10 (17.55 to 18.66)	1.10 (1.08 to 1.11)	<0.001
Reoperations	5.75 (5.36 to 6.14)	5.48 (5.12 to 5.84)	1.04 (1.02 to 1.05)	<0.001
Readmissions	22.00 (21.30 to 22.70)	21.83 (21.16 to 22.51)	1.01 (1.00 to 1.02)	0.09
Liver resection				
Mortality, 30-d	4.26 (4.03 to 4.49)	4.73 (4.49 to 4.98)	0.91 (0.90 to 0.92)	<0.001
Mortality, in-hospital	2.61 (2.43 to 2.80)	2.92 (2.73 to 3.12)	0.92 (0.90 to 0.93)	<0.001
Any complications	22.94 (22.48 to 23.39)	23.73 (23.27 to 24.18)	0.95 (0.95 to 0.96)	<0.001
Serious complications	13.19 (12.82 to 13.55)	13.87 (13.51 to 14.24)	0.94 (0.94 to 0.95)	<0.001
Reoperations	5.82 (5.53 to 6.11)	5.90 (5.62 to 6.19)	1.00 (0.99 to 1.01)	0.90
Readmissions	15.65 (15.20 to 16.10)	15.90 (15.45 to 16.35)	0.98 (0.98 to 0.99)	<0.001
Pancreatectomy				
Mortality, 30-d	6.30 (6.04 to 6.57)	6.12 (5.88 to 6.37)	1.05 (1.04 to 1.06)	<0.001
Mortality, in-hospital	3.93 (3.72 to 4.14)	3.85 (3.65 to 4.04)	1.05 (1.04 to 1.06)	<0.001
Any complications	31.10 (30.64 to 31.56)	29.90 (29.47 to 30.34)	1.07 (1.06 to 1.07)	<0.001
Serious complications	16.00 (15.63 to 16.37)	15.08 (14.74 to 15.42)	1.08 (1.07 to 1.09)	<0.001
Reoperations	6.63 (6.36 to 6.91)	6.36 (6.10 to 6.61)	1.04 (1.03 to 1.05)	<0.001
Readmissions	24.71 (24.23 to 25.19)	24.24 (23.77 to 24.70)	1.03 (1.02 to 1.03)	<0.001
Rectal resection				
Mortality, 30-d	4.44 (4.32 to 4.57)	4.44 (4.32 to 4.57)	0.99 (0.98 to 1.00)	0.001
Mortality, in-hospital	2.43 (2.33 to 2.52)	2.40 (2.30 to 2.49)	1.00 (0.99 to 1.01)	0.51
Any complications	23.01 (22.76 to 23.25)	22.41 (22.18 to 22.65)	1.04 (1.03 to 1.04)	<0.001
Serious complications	13.47 (13.27 to 13.67)	13.00 (12.81 to 13.19)	1.03 (1.02 to 1.03)	<0.001
Reoperations	7.97 (7.79 to 8.14)	7.80 (7.63 to 7.97)	1.02 (1.02 to 1.03)	<0.001
Readmissions	18.28 (18.02 to 18.54)	18.12 (17.87 to 18.37)	1.01 (1.01 to 1.01)	<0.001

CI – confidence interval, HPSA – Health Professional Shortage Area, d – day, AAAR – abdominal aortic aneurysm repair, CABG – coronary artery bypass graft

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Figure legend:

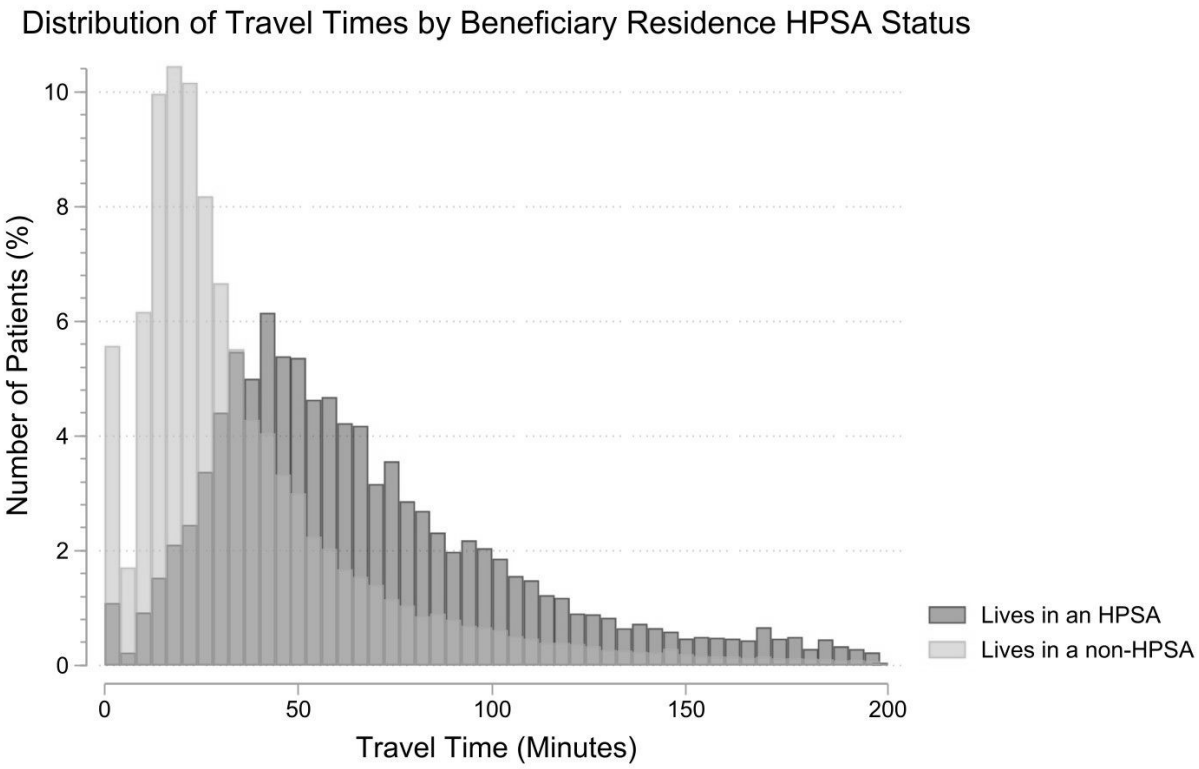


Figure 1: Distribution of travel times by beneficiary based on Health Professional Shortage Area residency status. HPSA – Health Professional Shortage Area

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