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Original Research

Influence of Demographic and Socioeconomic Factors on Hospital Distance for Total Knee Arthroplasty

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ABSTRACT

Background: Disparities exist in access to and outcomes following total knee arthroplasty. However, there is a paucity of data examining the relationship between travel distance and these disparities.
Methods: We used the Healthcare Cost and Utilization Project, American Hospital Association, and UnitedStatesZipCodes.org Enterprise databases to gather patient demographic and postoperative outcomes data. We calculated the distance traveled between patient population-weighted zip code centroid points and the hospitals at which they received total knee arthroplasty. We then examined the association between travel distance and patient demographic characteristics as well as postoperative adverse outcomes.
Results: Among of cohort of 384,038 patients, white patients (16.58 miles) traveled farther on average than Black (10.05) or Hispanic patients (10.54) ($P < .0001$). Medicare and commercial insurance coverage were associated with greater travel distance ($P < .0001$). Fewer medical comorbidities ($P < .001$) and residence in the highest-income areas ($P < .0001$) were associated with increased travel distance. Differences in postoperative complication rates related to travel distance were not clinically significant.
Conclusions: Increased travel distance for total knee arthroplasty was associated with white race, commercial and Medicare insurance coverage, fewer medical comorbidities, and increased socioeconomic status. Future work is needed to determine the underlying causal mechanisms leading to these differences in access to specialized care.

Introduction

Total knee arthroplasty (TKA) is frequently employed and highly effective in the treatment of osteoarthritis [1]. There is evidence that disparities exist in patient access to total knee arthroplasty. One review found that black and Hispanic patients are less likely as compared to white patients to receive total joint replacement surgery. Additionally, Reyes et al. [2] found that higher socioeconomic status was associated with increased utilization of total joint replacement operations and that these patients had more favorable outcomes postoperatively. Additional studies have found that disparities in postoperative outcomes exist for these operations [3,4]. For example, there is evidence that white race, increased financial resources, and commercial insurance coverage are associated with shorter length of stay following total joint replacement [4].

However, while there are robust data describing the associations between patient demographics and postoperative outcomes following total joint replacement, there are limited data that assess the role that travel distance plays in creating these disparities. One single-site study found that patients with more severe disease presentations traveled farther to receive TKA [5]. There is additionally a small body of orthopaedic research that has found no association between postoperative outcomes following orthopaedic operations and travel distance [6–8]. Notably, there is evidence that among patients receiving surgical care for breast cancer treatment, those who were white, younger, had private insurance coverage, and fewer comorbidities were more likely to travel farther for their operations [9].

The purpose of this study is to examine the relationship between travel distance to undergo primary TKA and patient

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demographic characteristics as well as adverse postoperative outcomes. We hypothesized that increased travel distance would be associated with increased medical comorbidities and the need for more intensive perioperative care which may only be available at distant, tertiary care facilities. In addition, we hypothesized that patients with greater financial means would travel farther to receive care due to an increased ability to take time off of work and travel to receive care at specialized centers. Finally, we hypothesized that patients who traveled farther to receive care would be more likely to experience adverse outcomes following surgery. We believed that these patients may have more severe knee pathologies and increased medical comorbidities, forcing them to receive care at distant facilities capable of providing comprehensive care in the postoperative period.

Material and methods

Databases

The Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases were used to gather patient demographic data including age, Charlson comorbidity index (CCI) score (see Appendix A), race, insurance provider, zip code median income quartile, and name of the hospital at which each patient underwent TKA [10]. The HCUP database was further used to quantify patient adverse postoperative outcomes (see Appendix B). We queried the HCUP State Inpatient databases in Florida and New York from 2006 to 2014 to identify all patients who received TKA. Florida and New York were selected for analysis given their large patient populations and geographic and sociodemographic diversity. In addition, the HCUP database contained high-quality data for our analysis from these 2 states.

We used the American Hospital Association database in order to gather the coordinate points of the hospitals at which patients sought care. The UnitedStatesZipCodes.org Enterprise database was then used to collect patient population-weighted zip code centroid points. Population-weighted zip code centroid points have increased accuracy compared with simple zip code centroid points [11]. This observational study was exempt from institutional review board review.

Exclusion criteria and analysis

Patients with missing hospital or home zip code information were excluded from analysis. Patients were excluded if they were younger than 18 years of age at the time of TKA. Additionally, those patients who underwent simultaneous bilateral knee replacement and those who had emergent surgery were excluded.

We used the Stata “geodist” command in order to calculate the distance between patient population-weighted zip code centroid points and the hospital at which they received TKA. This command uses the Great Circle Equation which is a highly accurate measure of distance along the surface of a sphere [12]. Stata MP 16 analytical software (StataCorp, LLC, College Station, Texas) was used to perform statistical analyses. We first evaluated the relationship between distance traveled for TKA and patient demographic variables. We used linear regression to analyze the association between age and CCI with travel distance. We assessed the relationship between travel distance and categorical variables such as patient race, insurance provider, and zip code income quartile using 1-way analysis of variance. Finally, logistic regression was utilized to determine the relationship between travel distance and various adverse postoperative outcome measures. Statistical significance was set at $P < .05$.

Results

Our patient cohort included 384,038 patients who underwent primary TKA in Florida and New York between 2006 and 2014. Patients were an average age of 67.75 years (standard deviation: 10.08) and 63.2% were female. The average CCI score was 3.06 (standard deviation: 1.55). White patients made up 81.1% of the cohort with Black (7.8%) and Hispanic (7.0%) patients being the next most represented. Medicare insurance coverage was the most common in our patient population (64.1%). Patients residing in zip codes with the highest income quartile were the least represented (17.7%), while those in the second lowest quartile were the most represented (31.3%). Table 1 summarizes these data.

Age was not significantly associated with travel distance ($P = .990$). Increased travel distance was associated with lower Charlson Comorbidity Index score ($P < .001$). However, the R^2 value was 0.0001. Table 2 summarizes these findings.

Patient race, insurance provider, and zip code income quartile were each associated with travel distance ($P < .0001$). White patients traveled farther on average (16.58 miles) than Black (10.05), Hispanic (10.54), Asian (10.13), or Native American patients (13.66). Patients with Medicare (15.85) and commercial (15.20) insurance coverage traveled farther for TKA as compared to those with Medicaid coverage (11.90). A small subset of patients used self-pay for TKA and this group traveled 16.49 miles on average to receive care. Patients residing in zip codes with the highest median income levels traveled the farthest for TKA (17.97). Conversely, those in the lowest income zip codes traveled 14.59 miles on average. These data are detailed in Table 3.

We assessed the relationship between a number of adverse postoperative outcomes and travel distance. Only 3 of the 13 analyzed outcomes were significantly associated with travel distance. Increased travel distance was slightly associated with decreased risk of genitourinary complication within 30 days (odds ratio: 0.999, $P = .004$). Similarly, lower rates of mechanical malfunction within 365 days and respiratory complication within 30 days of TKA were associated with increased travel distance ($P = .018$, $P = .041$). However, the effect sizes of these analyses were similarly small. Table 4 summarizes these data.

Table 1
Demographic data.

Age: mean ± standard deviation	67.75 (10.08)
CCI: mean ± standard deviation	3.06 (1.55)
Gender: n (%)	
Male	141,360 (36.8)
Female	242,678 (63.2)
Race: n (%)	
Asian	2725 (0.7)
Black	30,113 (7.8)
Hispanic	26,731 (7.0)
Native American	759 (0.2)
White	311,380 (81.1)
Missing or other	12,332 (3.2)
Insurance provider: n (%)	
Commercial	111,746 (29.1)
Medicaid	9017 (2.4)
Medicare	246,300 (64.1)
Other	16,977 (4.4)
Hospital state: n (%)	
Florida	271,743 (70.8)
New York	112,297 (29.2)
Zip code income quartile: n (%)	
1 (lowest)	92,139 (24.0)
2	120,351 (31.3)
3	98,276 (25.6)
4 (highest)	67,821 (17.7)
Null	5453 (1.4)

CCI, Charlson comorbidity index.

Table 2
Travel Distance vs continuous demographic variables.

Variable	Coefficient	Confidence interval	R^2	*P* value
Age	0.0001	−0.018 to 0.018	0.0000	*P* = .990
Charlson comorbidity index	−0.362	−0.478 to −0.247	0.0001	*P* < .001

Discussion

Among our cohort of 384,083 individuals who underwent TKA, patient CCI score, race, insurance provider, and zip code median income quartile were significantly associated with travel distance. Notably, we did not find an association between patient age and travel distance. In addition, we found that genitourinary complication within 30 days, mechanical malfunction within 365 days, and respiratory complication within 30 days of TKA were each significantly associated with distance traveled. The majority of outcome measures that we evaluated (10 of 13) were not significantly associated with travel distance.

We found that lower CCI score was significantly associated with increased travel distance for TKA (*P* < .001). This is consistent with findings from Kirkpatrick et al. [9] who found that patients with fewer comorbid conditions were more likely to travel great distances for breast cancer operations. Conversely, Maradit Kremers et al. [5] found that increased travel distance for TKA was associated with more severe disease processes. While medical comorbidities are not necessarily directly related to severity of disease presentation, each of these factors is likely related to a need for more intensive perioperative care need. Our results conflict with our hypothesis that patients with increased medical comorbidities would travel greater distances for TKA. It is possible that patients with very high CCI scores are determined not to be candidates for TKA and are thus underrepresented in our sample of patients. The present data suggest that patients with fewer medical comorbidities may be better able to travel safely to undergo TKA. Future work is necessary to better characterize (1) the degree to which patients with high CCI scores are being treated nonoperatively due to increased perioperative risk and (2) the degree to which lower CCI scores among operative patients may predict one's ability to travel to distant care facilities of his or her choice. Additionally, the correlation coefficient for this finding was low at 0.0001, which may further imply that this relationship is not clinically significant. We also found that patient age was not significantly associated with travel distance (*P* = .990).

Table 3
Travel distance vs categorical demographic variables.

Race[a]	Observations	Mean (miles)	95% CI
White	303,249	16.58	16.37-16.79
Black	29,261	10.05	9.71-10.39
Hispanic	26,294	10.54	10.10-10.97
Asian	2684	10.13	9.01-11.25
Native American	734	13.66	10.57-16.75
Insurance provider[a]			
Commercial	108,755	15.20	14.93-15.47
Medicaid	8832	11.90	11.50-12.29
Medicare	240,518	15.85	15.61-16.10
Self-Pay	1368	16.49	13.01-19.96
Zip code income quartile[a]			
1 (lowest income)	91,110	14.59	14.34-14.83
2	118,526	15.28	14.98-15.58
3	95,997	15.01	14.64-15.38
4 (highest income)	67,257	17.97	17.40-18.53

CI, confidence interval.
[a] ANOVA: *P* < .0001 race, insurance provider, and zip code.

Table 4
Travel distance vs postoperative adverse outcomes.

Outcome	Odds ratio	Confidence interval	Correlation coefficient (R^2)	*P* value
Stroke	1.000	0.997-1.000	0.0001	.149
Death within 30 d	1.000	0.996-1.001	0.0002	.349
Death within 90 d	1.000	0.997-1.000	0.0001	.324
Death within 365 d	0.999	0.997-1.000	0.0002	.082
Cardiac Complication within 30 d	1.000	0.999-1.000	0.0000	.237
DVT within 60 d	1.000	0.999-1.000	0.0000	.115
Genitourinary complication within 30 d	0.999	0.999-1.000	0.0001	.004
Hematoma within 30 d	0.999	0.998-1.000	0.0002	.059
Mechanical malfunction within 365 d	1.000	0.999-1.000	0.0000	.018
Pulmonary embolism within 60 d	0.999	0.997-1.000	0.0002	.055
Prosthetic joint infection within 365 d	0.999	0.998-1.000	0.0001	.058
Respiratory complication within 30 d	0.999	0.998-1.000	0.0001	.041
Readmission within 30 d	1.000	1.000-1.000	0.0000	.634

We found that patient race was significantly associated with travel distance with white patients traveling farther than Black, Hispanic, Asian, and Native American patients (*P* < .0001). This is consistent with Kirkpatrick et al. [9] who found that white patients traveled farther on average for breast cancer surgery. While there is well-established literature describing disparities in utilization of joint replacement surgery based on race, the present data indicate a unique dimension to this relationship [2,4]. There are a number of reasons why white patients may be more likely to travel greater distances for TKA. First, it is possible that hospital density, particularly in rural and suburban areas, contributes to these findings. White patients are more likely to live in rural areas [13]. As such, it is possible that these patients live in areas with lesser hospital density and thus need to travel greater distance for surgery. If this is in fact a driving factor related to increased travel distance for white patients, this may indicate a need for increased medical resource allocation to rural hospital systems.

Additionally, it is possible that the data regarding race and distance traveled reflect trends in income levels. White individuals earn more money on average than Black and Hispanic individuals in the United States [14]. Therefore, it is possible that this is a driving force in creating the differences in average travel distance. We notably found that patients who lived in more affluent zip codes traveled farther on average for TKA (*P* < .0001). As such, there may be a relationship between these variables. It is possible that white patients and those with greater financial means are traveling greater distances due to patient preference for specific, distant care facilities. We hypothesized that patients with higher socioeconomic status would travel farther to receive care due to an increased ability to pay higher prices for specific orthopaedic centers, take the requisite time off from work, pay for travel, and potentially pay for lodging for family members. These data support our hypothesis; however, the causal mechanisms underlying these findings are not able to be deduced based on our study design.

Future data are necessary to determine the driving forces behind these data. This may help to address any barriers to care that may exist such as referral patterns. In addition, solutions to this potential disparity in access to TKA may be addressed, such as through voucher programs.

We similarly found that patients with commercial or Medicare insurance coverage traveled farther on average for TKA than did patients with Medicaid insurance ($P < .0001$). This further supports the possibility that socioeconomic status plays a central role in creating the differences in travel distance observed in this study.

We assessed the relationship between distance traveled and 13 postoperative adverse outcome measures. Of these, only 3 statistically significant associations were observed. However, the odds ratio and correlation coefficient for each of these associations were very small. As such, these statistically significant relationships are likely not clinically significant. This is consistent with prior research indicating that travel distance does not play a role in postoperative outcomes following orthopaedic operations [6–8]. These results may be statistically significant due to the large sample size of the present study. A case-control study which retrospectively assesses differences in risk factors, such as travel distance, among a cohort that includes patients with and without specific outcomes may be better able to evaluate these relationships given the relative infrequency with which these adverse events occur.

Limitations

There are certain limitations related to the present study design. First, we used population-weighted zip code centroid points, not patient home addresses in order to approximate distance traveled to the hospital. Population-weighted zip code centroid points are likely more accurate than simple zip code centroid points [11]. However, zip code centroids in general may be less accurate in rural areas [15]. In addition, we used patient zip code median income quartile as a proxy measure for patient socioeconomic status. This allows us to create inferences based on trends in the data but does not allow for concrete conclusions regarding socioeconomic status and patient travel distance to be made. Furthermore, there are limitations to using large databases such as those employed in this study. For example, the most recently available HCUP data at the time of our analysis included the years 2006-2014. Therefore, it is possible that trends in patient travel distance may have evolved over time. In addition, the HCUP database only captured inpatients and thus future research may seek to evaluate travel distance and patient demographic characteristics in the context of outpatient total joint replacement operations as well. Another limitation of the large databases used in this study is the potential for errors in coding accuracy. Additionally, the databases included in this study only contain information of operative patients. It is possible that certain patients in need of TKA, such as those with very high CCI scores, are being treated nonoperatively due to increased perioperative risk. If these patients were to receive TKA, it might require care at specialized care facility with increased perioperative capabilities and thus this could impact the relationship between travel distance and CCI scores.

Our study included a patient population that was 81.1% white. This is moderately greater than the proportion of white individuals in Florida (76.9%), New York (69.1%), or the United States (75.8%) and may reflect disparities in utilization of total joint replacement operations by racial minority patients [2,16–18]. As a result, this may diminish the generalizability of the present data. Finally, our study design does not allow us to determine the causal mechanisms underlying the relationships observed in this study. Future work will be needed to better determine whether differences in travel distance are related more to patient necessity or choice and whether factors such as race, insurance provider, and socioeconomic status are working synergistically to create these disparities.

Conclusions

In sum, we found that white patients, those with fewer medical comorbidities, patients with commercial or Medicare insurance plans, and those residing in more affluent zip codes were more likely to travel greater distances for TKA. This constellation of findings suggests that increased travel distance for primary TKA may be related to patient choice and ability to travel as opposed to (or in addition to) patient necessity. This presents a unique disparity in access to specialized medical care. Future work is needed to determine the causal mechanisms creating these differences in access to care in order to better understand how to devote resources to close these gaps. This may include voucher programs for patients for desire or require care at distant care facilities. In sum, the present data indicate specific sociodemographic differences in travel distance for TKA and may serve as a foundation for future research which may help to eliminate any barriers in access to TKA that may exist today.

Conflicts of interest

Dr. Derek Ward is a consultant for DePuy Synthes. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101131.

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Appendix A
Charlson comorbidity tndex.

CCI (Charlson comorbidity index)	MI = 1 point CHF = 1 point Peripheral vascular disease = 1 point Cerebrovascular disease = 1 point Hemiplegia/Paraplegia = 2 points Chronic pulmonary disease = 1 point Diabetes, uncomplicated = 1 point Diabetes, with complications = 2 points Renal disease = 2 points Mild liver disease = 1 point Mod-severe liver disease = 3 points Peptic ulcer disease = 1 point Metastatic solid tumor = 6 points Other cancer = 2 points Dementia = 1 point Rheumatic disease = 1 point AIDS/HIV = 6 points Depression = 1 point Age 50-59 = 1 point Age 60-69 = 2 points Age 70-79 = 3 points Age $\geq$ 80 = 4 points

Appendix B
Post-operative outcomes.

Outcome	Definition	ICD-9 codes
Death ($\leq$30 d)		N/A; Coded from discharge disposition
Death ($\leq$90 d)		N/A; Coded from discharge disposition
Death ($\leq$1 y)		N/A; Coded from discharge disposition
Myocardial infarction ($\leq$30 d)		‘410.01’, ‘410.11’, ‘410.21’, ‘410.31’, ‘410.41’, ‘410.51’, ‘410.61’, ‘410.71’, ‘410.81’, ‘410.91’
Ischemic stroke ($\leq$30 d)		‘997.02’, ‘433.01’, ‘433.11’, ‘433.21’, ‘433.31’, ‘433.81’, ‘433.91’, ‘434.01’, ‘434.11’, ‘434.91’
Cardiac complications ($\leq$30 d)		‘997.1’, ‘428.21’, ‘428.23’, ‘428.31’, ‘428.33’, ‘428.41’, ‘428.43’, ‘427.5’, ‘785.51’
Respiratory complications ($\leq$30 d)		‘997.3’, ‘466.0’, ‘466.1’, ‘480’, ‘481’, ‘482’, ‘483’, ‘484’, ‘485’, ‘486’, ‘487’, ‘488’
Digestive complications ($\leq$30 d)		‘997.4’, ‘560.1’
Genitourinary complications ($\leq$30 d)		‘997.3’, ‘584.5’, ‘584.6’, ‘584.7’, ‘584.8’, ‘584.9’, ‘590.10’, ‘590.11’, ‘595.0’
Hematoma ($\leq$30 d)		‘998.12’, ‘719.15’, ‘719.16’
Deep vein thrombosis ($\leq$60 d)		‘415.11’, ‘415.19’, ‘451.81’, ‘451.83’, ‘451.89’, ‘453.40’, ‘453.41’, ‘453.42’, ‘453.8’, ‘453.9’ ‘444.22’, ‘444.81’, ‘996.77’
Pulmonary embolism ($\leq$60 d)		‘415.11’, ‘415.12’, ‘415.13’, ‘415.19’
Knee infection ($\leq$1 y)	A periprosthetic joint infection requiring revision hip arthroplasty, liner removal, arthrotomy, debridement, synovectomy, or other excision	Any of (‘996.66’, ‘996.67’, ‘998.59’) AND any of (‘00.80’, ‘00.82’, ‘00.83’, ‘00.84’, ‘80.06’, ‘80.16’, ‘86.22’, ‘80.76’, ‘80.86’, ‘81.55’)
Hip infection ($\leq$1 y)	A periprosthetic joint infection requiring revision hip arthroplasty, liner removal, arthrotomy, debridement, synovectomy, or other excision	Any of (‘996.66’, ‘996.67’, ‘998.59’) AND any of (‘00.70’, ‘00.71’, ‘00.72’, ‘00.73’, ‘80.05’, ‘80.15’, ‘80.75’, ‘80.85’, ‘80.95’, ‘81.53’, ’86.05’, ‘86.22’)
Mechanical malfunction, knee ($\leq$1 y)	A mechanical malfunction of the prosthetic joint such as loosening, dislocation, fracture, surface wear, osteolysis, or ankyloses/arthrofibrosis, that required revision hip arthroplasty, internal fixation of bone, ostectomy, joint capsule division	‘81.55’, ‘78.67’, ‘78.55’, 77.86, 79.06, 80.46, 93.26, 93.16, 718.56, 718.36, 884.1, 996.40, 996.41, 996.42, 996.43, 996.44, 996.45, 996.46, 996.47, 996.49, 996.77, 996.78
Mechanical malfunction, hip ($\leq$1 y)	A mechanical malfunction of the prosthetic joint such as loosening, dislocation, fracture, surface wear, osteolysis, or ankyloses/arthrofibrosis, that required revision hip arthroplasty, internal fixation of bone, ostectomy, joint capsule division	Any of (‘996.40’, ‘996.41’, ‘996.42’, ‘996.43’, ‘996.44’, ‘996.45’, ‘996.46’, ‘996.47’, ‘996.49’, ‘718.55’, ‘718.35’, ‘996.77’, ‘996.78’) OR any of (‘81.53’, ‘78.65’, ‘78.55’, ‘79.05’, ‘80.45’)