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A Fresh Perspective on a Familiar Problem

Examining Disparities in Knee Osteoarthritis Using a Markov Model

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Background: Disparities in the presentation of knee osteoarthritis (OA) and in the utilization of treatment across sex, racial, and ethnic groups in the United States are well documented.

Objectives: We used a Markov model to calculate lifetime costs of knee OA treatment. We then used the model results to compute costs of disparities in treatment by race, ethnicity, sex, and socioeconomic status.

Research Design: We used the literature to construct a Markov Model of knee OA and publicly available data to create the model parameters and patient populations of interest. An expert panel of physicians, who treated a large number of patients with knee OA, constructed treatment pathways. Direct costs were based on the literature and indirect costs were derived from the Medical Expenditure Panel Survey.

Results: We found that failing to obtain effective treatment increased costs and limited benefits for all groups. Delaying treatment imposed a greater cost across all groups and decreased benefits. Lost income because of lower labor market productivity comprised a substantial proportion of the lifetime costs of knee OA. Population simulations demonstrated that as the diversity of the US population increases, the societal costs of racial and ethnic disparities in treatment utilization for knee OA will increase.

Conclusions: Our results show that disparities in treatment of knee OA are costly. All stakeholders involved in treatment decisions for knee OA patients should consider costs associated with delaying and forgoing treatment, especially for disadvantaged populations. Such decisions may lead to higher costs and worse health outcomes.

Key Words: health disparities, health care costs, decision analysis, Markov model, cost simulations, osteoarthritis

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Understanding costs and outcomes of treatment options for a given disease can promote value-based care. The prevalence of chronic conditions is increasing nationally and contributing to rapidly rising health care costs. Patients' disease experience depends on certain characteristics—leading to disparities at all disease stages. We aimed to understand the influence of these different parameters on costs, benefits, and disparities.

The Global Burden of Disease 2010 Study found hip and knee osteoarthritis (OA) were ranked as the 11th highest contributor to global disability.[1] As the US population continues to age and experience obesity at alarmingly high rates, the physical and financial impact of knee OA is likely to increase. Recent estimates show that knee OA affects almost 9.3 million adults in the United States and accounts for about $27 billion[2] in annual health care expenses. Incremental costs of health care because of pain have been estimated to range between $261 and $300 billion.[3] Including lost productivity increases societal costs and ranges from $560 to $635 billion. Racial health disparities lead to about $35 billion in excess health care expenditures, $10 billion in illness-related lost productivity, and nearly $200 billion in premature deaths.[4]

Racial/ethnic disparities have been extensively studied and exist regarding the onset of knee OA,[5] perception of pain and functionality,[6] treatment utilization,[7,8] and outcomes.[9] While a majority of this literature focuses on the utilization of total knee replacement[9] (TKR), there exists a significant gap in the understanding of the utilization of nonsurgical treatment.

According to the Census Bureau, the proportion of the US population comprised of African Americans and Hispanics is projected to rise from 38% in 2014 to 56% of the total population by 2060. Understanding the implications of sustained or increasing health disparities[10] in the face of demographic shifts could facilitate targeted interventions to reduce the clinical and economic burden of disparities at a societal level. We aimed to construct a model that incorporates the nuances of disease progression in various patient populations to understand costs and benefits of different treatment options. In an innovative application of the model, our analysis quantifies disparities from three perspectives—patient, employer, and society.

MODEL FRAMEWORK

Using the framework for decision modeling described in the handbook by Briggs et al,[11] we used Microsoft Excel to build a Markov model to simulate patient transitions through the stages of knee OA. This was a cohort model with a cycle length of 1 year and spanned 40 years.

Although Markov models are often used for cost-effectiveness analyses, our ultimate goal was to use the model to perform the societal analysis to quantify the costs of disparities in treatment utilization across patient populations.

Our analysis focuses on minority women given the significance of the impact of these disparities on this particular population.

The Model

We constructed disease states to follow the Kellgren-Lawrence[2,12] radiographic scale of knee OA (Fig. 1) as the data on disease progression in the literature is based on this scale. Although the literature is mixed,[13] we consulted with expert physicians and assumed that each subsequent disease state, defined by a K-L grade, correlated with increasing pain and functional limitations from the validated Western Ontario and McMaster Universities Arthritis Index (WOMAC).

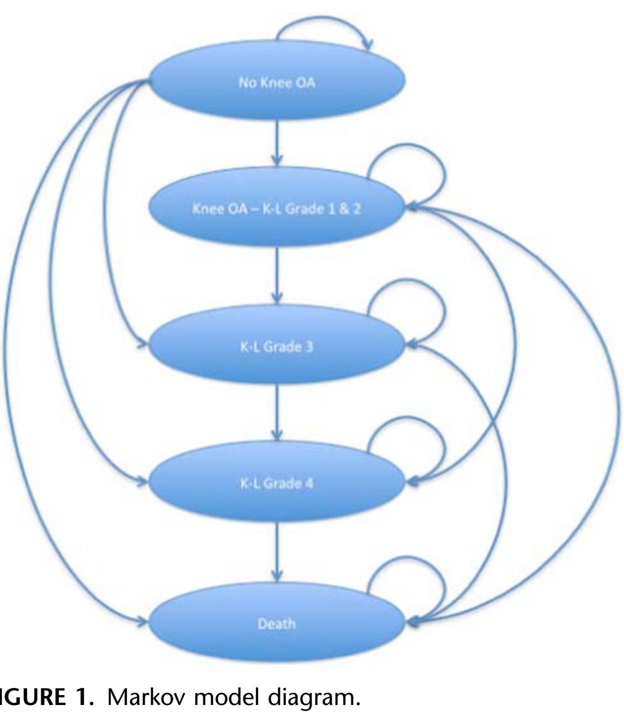

FIGURE 1. Markov model diagram.

We assumed patients in the cohort simulations began in stage 0 and either remained in a state or moved to a more severe state. We used a 40-year time horizon as knee OA develops between the ages of 45 and 60 and progresses over a lifetime.[14]

Input Parameters

Patient Characteristics

Model parameters included age (45–54, 55–64, 65–74, 75–84, 85+), sex, race/ethnicity (white non-Hispanic, black non-Hispanic, Hispanic) and presence of 3 comorbid conditions (obesity, hypertension, and diabetes). We also included education level and insurance coverage (Table 1). We ran simulations on select patient populations—African American women, Hispanic women, and white men—in different treatment pathways to facilitate comparisons. White men and African American women track very similarly in utilization in the HCUP data.[15] We focused on disparities by race/ethnicity and chose populations that had similar utilization rates to highlight the impact of race/ethnicity.

Incidence and Transition Probabilities

We constructed 240 unique sets of disease progression rates defined by demographic characteristics and presence of comorbid conditions. We determined how many people from the survey samples belonged to each category to calculate the incidence of each stage that matched the transition states in Figure 1.

The incidence rates of knee OA were calculated using 2 nationally representative surveys used in previous economic evaluations of knee OA: National Health Interview Survey (NHIS) and the Behavioral Risk Factor Surveillance System (BRFSS). On the basis of the questions asked in these surveys, the stages were defined as follows. Stage 0: patient has no knee pain, no diagnosis, no activity limitations or use of special equipment; stage 1: knee pain, no diagnosis of arthritis, no activity limitations or use of special equipment. stage 2: knee pain, diagnosis of knee OA, no activity limitations or use of special equipment. stage 3: knee pain, diagnosis of knee OA and have activity limitations or use special equipment (Appendix I, Supplemental Digital Content 1, http://links.lww.com/MLR/B478).

It has been shown that among patients with knee OA, there is a higher prevalence of obesity,[16,17] hypertension,[17,18] and diabetes.[17] Some studies have also shown their association with the onset and progression of knee OA.[17,19] We can assume that patients who have these conditions experience worsening of knee OA quicker than otherwise healthier individuals.

The probability of death, from any cause, was derived from the National Vital Statistics Report stratified by sex and age.[20] The CDC website section on knee OA statistics provided the probability of death from knee OA.[14]

TABLE 1. Input Parameters

Treatment Effects			**Health State Utilities**	
Type of treatment	Effect on progression (reference)		Model stage	Health state utility
Nonsteroidal anti-inflammatory drugs	0.6 (12)		Stage 0	1 (12, 26)
Nutritional supplements	0.79 (30)		Stage 1	0.943 (12, 26)
Physical therapy	0.65 (27, 31)		Stage 2	0.69 (12, 26)
Prescription painkillers	0.63 (25)		Stage 3	0.69 (12, 26)
Lifestyle management	0.502 (29)		Stage 4	0 (12, 26)
Corticosteroid injections	0.323 (22)			
Bracing	0.65 (24)			
Viscosupplementation	0.3 (23)			
Total knee replacement	0.2 (21, 26)			
Arthroscopy	1 (28)			
Posttreatment utilities*				
Model stage	Path 1	Path 2	Path 3	Path 4
Stage 0	1	1	1	1
Stages 1, 2, 3	0.9	0.8	0.7	0.6
Stage 4	0	0	0	0
Direct medical costs				
Treatment type	Medicare	Medicaid (Assumption-0.66*Medicare)	Uninsured	Private (Assumption-1.3*Medicare)
Nonsteroidal antiinflammatory drugs	$1248 (52)	$1248 (52)	$1248 (52)	$1659 (Assumption)
Nutritional supplements	$53 (32)	$53 (32)	$53 (32)	$70 (Assumption)
Physical therapy	$806 (32, 33, 37)	$806 (Assumption)	$806 (Assumption)	$1072 (Assumption)
Prescription painkillers	$48 (12, 35)	$48 (12, 35)	$48 (12, 35)	$63 (Assumption)
Lifestyle management	$575 (32, 33, 37)	$460 (Assumption)	$1692 (Assumption)	$764 (Assumption)
Bracing	$400 (34)	$400 (34)	$300 (34)	$337 (Assumption)
Corticosteroids	$253 (32, 33, 37)	$208 (Assumption)	$300 (Assumption)	$337 (Assumption)
Viscosupplementation	$1268 (32, 33, 37)	$1014 (Assumption)	$1400 (Assumption)	$1687 (Assumption)
Total knee replacement	$6400 (32, 33, 37)	$5120 (Assumption)	$17,662 (32, 33, 37)	$8512 (Assumption)
Arthroscopy	$2748 (32, 33, 37)	$2200 (Assumption)	$4500 (Assumption)	$3654 (Assumption)
Indirect costs during treatment (39)				
Model Stage	High School	Some College	College Degree	Advanced Degree
Stage 0	$0	$0	$0	$0
Stage 1	$152.72	$154.89	$157.30	$162.89
Stage 2	$1395.21	$1425.09	$1437.12	$1488.19
Stage 3	$1972.23	$2000.32	$2031.46	$2103.66
Stage 4	$31,285.01	$31,530.62	$37,745.69	$53,586.28
Indirect costs posttreatment (39)				
Model Stage	High School	Some College	College Degree	Advanced Degree
Stage 0	$0	$0	$0	$0
Stage 1	$30.54	$30.97	$31.46	$32.57
Stage 2	$279.04	$283.01	$287.42	$297.63
Stage 3	$394.44	$400.06	$406.29	$420.73
Stage 4	$6257.00	$6306.12	$7549.13	$10,717.25

In order to model the indirect costs from the Medical Expenditure Panel Survey, we had to define the stages slightly differently based on the questions asked in the survey. Using the MEPS, the stages were defined as follows. Stage 0: no knee OA so 0 indirect costs; stage 1: confirmed diagnosis of knee OA; stage 2: moderate pain; stage 3: extensive pain. The indirect costs were stratified based on education level (high school, some college, college degree, advanced degree) and pain level (confirmed diagnosis of knee osteoarthritis, moderate pain, extensive pain). We employed a Heckman 2-part model to determine the probable level of lost income for an individual with a specific level of education and experiencing a specific level of pain. Utilities are a quality of life metric that patients experience in each health state.

The posttreatment health state utilities are based on assumptions about how quality of life changes for patients who surgery (vs. those who did not) and for those with comorbid conditions (vs. those who are relatively healthier). Patients follow the utility trajectories using the following: path 1: Patients who had TKR during their treatment sequence and have no comorbidities, path 2: Patients who did not have TKR during their treatment sequence and have no comorbidities, path 3: Patients who had TKR during their treatment sequence but have comorbidities, and path 4: Patients who did not have TKR during their treatment sequence and have comorbidities.

Treatment Pathways

We identified 10 common knee OA treatment options that the American Academy of Orthopedic Surgeons (AAOS) designated as appropriate in their clinical guidelines.[21] We consulted an expert panel of 6 physicians who treat a large patient population with knee OA to construct a set of 20 clinically realistic treatment pathways (Appendix II, Supplemental Digital Content 1, http://links.lww.com/MLR/B478), which range from no treatment to, for example, surgical intervention by year 3 and can span up to 20 years. We reviewed treatment pathways with an expert panel of 15 clinicians involved in the treatment of knee OA, then subsequently presented the data to a cross-functional panel of approximately 20 health care professionals across various medical disciplines. The table (Appendix II, Supplemental Digital Content 1, http://links.lww.com/MLR/B478) provides more detail about the types of patients in 20 treatment pathways.

Effect of Treatment

The effect of the treatments in Table 1 were extracted from systematic literature reviews, meta-analyses of randomized controlled trials, published randomized controlled trials and cohort studies that assessed the effectiveness of these 10 types of treatments.[12,22–32] The treatment effect is assumed to influence a patient's progression of the disease by changing the transition probability of a patient moving from one state in the model to a more severe state. We made the assumption that the treatment effect on each of the transition probabilities is the same for all patient subgroups and at all stages over the course of the disease (Appendix III, Supplemental Digital Content 1, http://links.lww.com/MLR/B478).

Direct and Indirect Costs

Direct medical costs for each treatment were measured as Medicare reimbursement rates.[33,34] If not reimbursed by Medicare, we collected costs from resources in the literature[35–37] or made assumptions. We assumed that private insurers paid about 133%[38] of Medicare reimburses for treatment; Medicaid pays[39] on average 66% of what Medicare pays. We also computed out-of-pocket payments for uninsured patients.

Indirect costs, lower labor market productivity in the form of lost wages, were derived from the Medical Expenditure Panel Survey (MEPS) Household Component using survey weights in the analysis.[40] Using the MEPS, the stages were defined as follows: stage 0: no knee OA so 0 indirect costs; stage 1: confirmed diagnosis of knee OA; stage 2: moderate pain; stage 3: extensive pain. We employed a Heckman 2-part model to determine, on average, the cost of days missed work, stratified by levels of education (high school, some college, college degree, advanced degree) and pain (confirmed diagnosis of knee OA, moderate pain, extensive pain). Annual earnings lost were included as the indirect cost associated with the final stage of death. Patients in stage 0, with no knee OA, incurred no indirect or direct costs. All costs (Table 1) were discounted at 3%—the standard rate for economic evaluations conducted in the US setting.[41]

Patients incurred a loss of productivity in the cycles before and during treatment. We assumed that after treatment was completed, patients were able to recoup 80% of their lost earnings.[42] We also assumed that patients participated in the workforce between the ages of 45 and 65 and retired above age 65.

Health State Utilities

Benefits of treatment were operationalized as quality-adjusted life-years (QALYs) equivalent to the product of the utility of a particular health state and the probability of being in that health state. Health state utilities were taken from the literature (Table 1).[12,43] We assumed that health state utilities improved upon treatment completion, but differed based on the treatment pathway and comorbid conditions.[44,45] The magnitude of improvement differed and were categorized as follows from the most improvement to the least (Table 1): (1) treatment pathway concluded with TKR; (2) treatment pathway concluded with TKR and patient had any of the comorbidities; (3) treatment pathway did not conclude with TKR and had no comorbidities; or (4) treatment pathway did not conclude with TKR and the patient had any of the comorbidities. QALYs were discounted at the same rate as costs, as recommended by the Panel on Cost-Effectiveness in Health & Medicine.[41]

Analysis

Given the established disparities discussed in a previous report,[46] we focused on comparing the costs and benefits of treatment between African American women, Hispanic women, and non-Hispanic white men for the patient and employer perspective. The simulated populations of patients were college-educated ages 45 to 54 and in the workforce for both of these perspectives. We focused on 5 treatment pathways representative of the multiple treatment modalities in the original 20 pathways (Appendix II, Supplemental Digital Content 1, http://links.lww.com/MLR/B478): no medical treatment (Pathway 1), 2 nonsurgical pathways with varying degrees of weight loss or recommended lifestyle management therapy (pathways 10 and 19) and 2 surgical pathways including TKR at year 6 or year 12 (pathways 3 and 7). Results were analyzed from 3 perspectives: the patient, employer, and societal perspective (Appendix IV, Supplemental Digital Content 1, http://links.lww.com/MLR/B478).

We examined: (1) differences in lifetime costs and benefits of treatment; (2) the impact of delaying treatment; and (3) the impact of comorbidities from the patient perspective. We quantified the levels of lost productivity across groups from the employer perspective by separating direct and indirect costs in the model. Lifetime costs included medical and nonmedical, or labor market, costs. Costs are all measured in US dollars and benefits are measured in quality-adjusted life-years.

We also explored the impact of delayed therapy and comorbidities on costs and benefits (Appendix IX, Supplemental Digital Content 1, http://links.lww.com/MLR/B478).

Societal Analysis

Finally, we quantified the cost of disparities in current treatment utilization rates by race/ethnicity and sex at the societal level by creating different national populations. We constructed a national population that reflected the distribution of each of the 240 subgroups with knee OA similar to that in the BRFSS. We then multiplied the prevalence of knee OA in each subgroup by the total number of simulated patients in the subgroup to obtain the number of patients with knee OA in each subgroup.

We obtained current, disparate treatment utilization rates for each of the 5 selected pathways, by racial/ethnic group, from Medicare MEDPAR[47] and Healthcare Cost & Utilization Project (HCUP)[48] data. The distribution of education level was obtained from data from the Current Population Survey. The total cost for each subgroup was the product of the treatment utilization rate, lifetime cost of the pathway, and simulated sample of knee OA patients within that subgroup for all 5 pathways. Summing across all subgroups, we estimated a total population cost with current disparate treatment utilization rates.

We repeated the above analysis with all subgroup treatment utilization rates equal to those for the non-Hispanic white male population. The societal cost of disparate rates of treatment was calculated as the difference between these summations.

Finally, using the 2 populations constructed above, we calculated potential future costs of disparities by simulating societal costs as diversity increases over time.

Scenario Analysis

We conducted 2 scenario analyses around the cost assumptions because patients may be affected by treatment in different ways. First, we tested the assumptions about the different prices that payers may reimburse for similar treatments. Specifically, we conducted all cost analyses from the Medicare perspective to conduct comparisons with costs closest to the actual resource cost of the treatment. Second, we tested the assumption around what level of functionality knee OA patients can achieve after treatment completion. Specifically, we estimated the levels of lost income if patients only recovered 60% of their lost income upon treatment completion.

RESULTS

Patient Perspective

No treatment results in significantly higher lifetime costs for all patient groups studied (Fig. 2). Specifically, the lifetime cost of going without care for those without any comorbidities is $92,974 for African American women and $72,712 for Hispanic women. This compares to $85,093 for white non-Hispanic men. Figure 2 demonstrates this comparison graphically and the Appendix (Supplemental Digital Content 1, http://links.lww.com/MLR/B478) provides the results in tabular form for a quantitative comparison.

In Figure 2, we plot QALYs gained and use the no treatment option as the control pathway. The upper left quadrant (Fig. 2) shows patients going without any treatment do not gain any benefit and will continue to progress to more severe disease states. A table of numeric comparisons is provided in Appendix V (Supplemental Digital Content 1, http://links.lww.com/MLR/B478). Healthy African American women see the greatest reduction in cost when they utilize the health care system ranging from a $65,429 drop from a surgical pathway to a $41,199 reduction for a nonsurgical pathway (Appendix V, Supplemental Digital Content 1, http://links.lww.com/MLR/B478). Hispanic women gain the most QALYs over foregoing therapy ranging from a 6.2 QALY gain from a surgical pathway to a 1.3 QALY gain for a nonsurgical pathway (Appendix V, Supplemental Digital

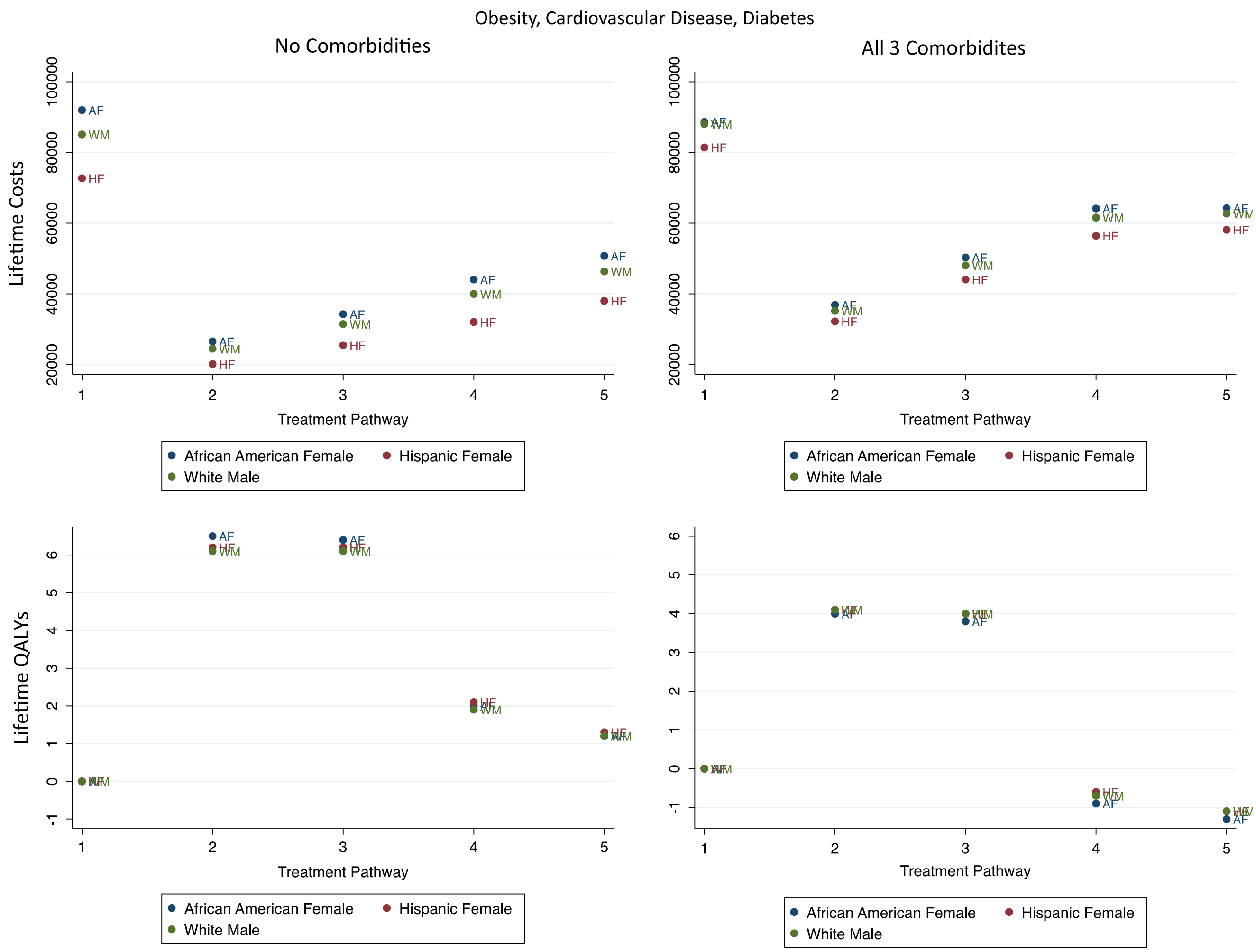

FIGURE 2. Lifetime costs and QALYs of treatment for healthy and comorbid patients. QALYs indicates quality-adjusted life-years.

Content 1, http://links.lww.com/MLR/B478). The primary takeaway here is that across all patient populations, foregoing therapy costs the most and yields the least amount of QALYs gained.

Employer Perspective

Those forgoing treatment incur the highest loss of productivity in each time interval. We demonstrate income lost in years 1, 5, and 10 (Appendix VI, Supplemental Digital Content 1, http://links.lww.com/MLR/B478) for each of the patient groups either with or without comorbid conditions. The greatest levels of lost income are incurred for patients experiencing multiple comorbidities and those who forego treatment entirely. In comparison to choosing no medical treatment, the nonsurgical pathway reduces levels of lost productivity for both healthy and comorbid patients. The figure in the Appendix (Supplemental Digital Content 1, http://links.lww.com/MLR/B478) highlights these comparisons for the "no treatment" pathway (pathway 1) and one of the nonsurgical pathways (pathway 10).

Societal Perspective

Table 2 illustrates societal costs of disparities in treatment. In our example, we begin with the 2015 racial/ethnic distribution of the population: 77% white non-Hispanic, 11% African American, and 12% Hispanic. In the top panel, we assumed that treatment rates for African Americans are 60% of those for non-Hispanic whites and treatment rates for Hispanic patients are 50% of those for non-Hispanic whites.[47,48] We found that the societal costs of disparities in knee OA over 40 years were $13.28 billion.

Table 3 illustrates the effect of demographic shifts on societal costs. The cost of disparities increases to $15.6 billion given the predicted demographic in 2025. As the population demographic continues to change in the United States, this analysis highlights that the costs of treatment disparities will rise if not addressed.

Scenario Analysis

For both scenario analyses outlined above, while the absolute magnitudes of the cost and benefit values changed, the relative comparisons and conclusions remained unchanged (Appendix VII to VIII, Supplemental Digital Content 1, http://links.lww.com/MLR/B478).

TABLE 3. Calculating Future Costs of Disparities

		2015		2025	
Costs at Current Disparate Treatment Rates (in billions)					
White	77%	$94.27	73%	$89.38	
African American	11%	$33.81	12%	$42.26	
Hispanic/Latino	12%	$33.81	15%	$42.26	
Total		$167.20		$174.30	$7.1 Billion
Costs without disparities (in billions)					
White	77%	$94.28	73%	$89.38	
African American	11%	$32.83	12%	$35.82	
Hispanic/Latino	12%	$26.82	15%	$33.53	
Total		$153.90		$158.70	$4.7 Billion
Costs of disparities		$13.30		$15.60	$2.3 Billion

The calculations are for a simulated population of individuals constructed based on data from the US Census Bureau and the Behavioral Risk Factor Surveillance System. Specific treatment utilization rates for each of the 5 pathways incorporated in the calculation are from the Medicare MEDPAR and HCUP data. Overall treatment rates across racial/ethnic groups are assumptions relative to the non-Hispanic white population. The population cost estimates model considers education level, insurance type (private vs. public), age, sex, race, and level of comorbidity. Changes in the population demographic are taken from the US Census Bureau population projections, mid-variant.

Strengths and Limitations

Inherent in any Markov model are limitations surrounding structural and parameter assumptions. While we used the Kellgren-Lawrence scale as previous studies have done,[2,12,26] the multifactorial treatment pathways that allow for different modes of therapy over time sets us apart from the current literature. We did not include cost of a replacement TKR for individuals who received their initial TKR at a relatively young age. However, we do assume that, even after surgery, patients do not achieve "perfect" health.

Although direct costs were based on some percentage of Medicare reimbursement rates, we do not believe this will change the conclusions. It is generally accepted that private insurance reimbursement is routinely more generous than Medicare reimbursement, thus changing percent differences will only create absolute changes in magnitude.[38] We only included costs of knee OA to focus the analysis. Treating knee OA may have positive spillover effects by improving other comorbid conditions and decreasing costs.

Indirect costs only included loss of income. Other costs such as caregiver costs, childcare costs, loss of leisurely activities or retirement costs were not included. We recognize that the exclusion of these costs from our model may lead to

TABLE 2. Societal Costs of Disparities Today

	Treatment Rate (%)	Treatment Costs With Current Disparity Levels (Billions)	Treatment Rate (%)	Treatment Costs without Disparities (Billions)
White	100	$94.27	100	$94.73
African American	60	$39.14	100	$32.83
Hispanic/Latino	50	$33.81	100	$26.83
Total costs		$167.20		$153.90
Cost savings over 40 y				$13.28
Average annual cost savings				$332 million

The calculations are for a simulated population of individuals constructed based on data from the US Census Bureau and the Behavioral Risk Factor Surveillance System. Specific treatment utilization rates for each of the 5 pathways incorporated in the calculation are from the Medicare MEDPAR and HCUP data. Overall treatment rates across racial/ethnic groups are assumptions relative to the non-Hispanic white population. The population cost estimates model considers education level, insurance type (private vs. public), age, sex, race and level of comorbidity. Changes in the population demographic are taken from the US Census Bureau population projections, mid-variant.

an underestimation of lifetime costs and widen differences across the populations; however, we believe that the resulting comparisons between populations would lead to similar conclusions. Further, the human capital approach to measuring lost productivity is commonly used.[49] We assumed individuals were in the workforce until they reached 65, but some do continue to work beyond this age, which would increase their indirect costs. To facilitate societal level comparisons, we assumed that knee OA follows the same trajectory of need if African American and Hispanic women used health care services similar to white men. While the strengths of the datasets from which we pulled model inputs are established, deriving inputs from multiple datasets may produce correlations in these variables.

Finally, our estimates are conservative, since we did not factor in dynamic influences on disease progression.

DISCUSSION

Through an innovative application of a Markov model for knee OA we demonstrated the effect of no treatment on lifetime cost, productivity, and quality of life. We quantified the impact of disparities in care from three perspectives: the patient, the employer, and society. We also forecasted future increasing health care costs because of changing demographics of the nation. The known disparities of delaying or foregoing treatment cost significantly more than equitable care at a societal level.

Clinical experts support the notion that if comorbid conditions are well controlled, patients with knee OA can achieve a greater benefit from treatment. Knee OA patients with comorbid conditions analyzed in this study had increased cost and gained fewer QALYs over the lifetime. Although small, the reductions in cost from controlling one's weight can influence knee pain and effectiveness of treatment.

The disparities in treatment utilization for knee OA are especially problematic given the differences in disease presentation across racial/ethnic groups. Given the projected rise in the minority population,[50] if treatment disparities are not addressed, the nation will face significant increases in health care costs and lost worker productivity.

While we found differences in costs and benefits across simulated patient groups, Hispanic women consistently experienced the lowest lifetime costs. However, their accumulated benefits were not significantly lower than experienced by other patient groups. Plausibly, knee OA progression may be slower in this Hispanic population than in African American women or white non-Hispanic men. With slower progression, Hispanic women may spend less time in the more clinically severe, economically burdensome states of the disease yielding lower lifetime costs.

The objectives of this paper could have also been achieved using a generalized linear regression model of costs and QALYs. However, few studies have forecasted disparities[51] and quantified potential cost savings from reducing gaps in care[52] using Markov models in different clinical contexts, especially in knee OA.[51,52] Although the Markov model itself is not a new approach, its use in forecasting the societal cost of disparities is unique. Most studies[12] have used Markov models to determine the cost-effectiveness of single treatment modalities.[53] Our study builds on this literature by examining more clinically realistic treatment pathways and quantifying disparities in a clinical context in which disparities are well established.

This study provides insight to multiple stakeholders regarding disparities. Patients should make a conscious effort to avoid delaying treatment and providers should advise and engage their patients accordingly. Employers should encourage appropriate treatment of this condition given the cost of diminished productivity and replacing workers. Finally, health plans and systems can use the societal analysis to manage growing, diverse populations and reduce costly disparities in treatment. The model highlights population health and economic cases for addressing disparities at the policy level as well.

This work contributes to a growing discussion on the use of decision support tools that engage the patient in the decision-making process.[54] These are especially important in clinical areas such as knee OA in which the utilization of treatment, specifically TKR, varies substantially by race.[55] More outcomes research is needed to assure that benefits accrue to minority patients at a similar level to their white counterparts.

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