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Cost-Effectiveness of Arthroscopic Partial Meniscectomy and Physical Therapy for Degenerative Meniscal Tear

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Objective. We examined the cost-effectiveness of treatment strategies for concomitant meniscal tear and knee osteoarthritis (OA) involving arthroscopic partial meniscectomy surgery and physical therapy (PT).

Methods. We used the Osteoarthritis Policy Model, a validated Monte Carlo microsimulation, to compare three strategies, 1) PT-only, 2) immediate surgery, and 3) PT + optional surgery, for participants whose pain persists following initial PT. We modeled a cohort with baseline meniscal tear, OA, and demographics from the Meniscal Tear in Osteoarthritis Research (MeTeOR) trial of arthroscopic partial meniscectomy versus PT. We estimated risks and costs of arthroscopic partial meniscectomy complications and accounted for heightened OA progression post surgery using published data. We estimated surgery use rates and treatment efficacies using MeTeOR data. We considered a 5-year time horizon, discounted costs, and quality-adjusted life-years (QALYs) 3% per year and conducted sensitivity analyses. We report incremental cost-effectiveness ratios.

Results. Relative to PT-only, PT + optional surgery added 0.0651 QALY and $2,010 over 5 years (incremental cost-effectiveness ratio = $30,900 per QALY). Relative to PT + optional surgery, immediate surgery added 0.0065 QALY and $3080 (incremental cost-effectiveness ratio = $473,800 per QALY). Incremental cost-effectiveness ratios were sensitive to optional surgery efficacy in the PT + optional surgery strategy. In the probabilistic sensitivity analysis, PT + optional surgery was cost-effective in 51% of simulations at willingness-to-pay thresholds of both $50,000 per QALY and $100,000 per QALY.

Conclusion. First-line arthroscopic partial meniscectomy has a prohibitively high incremental cost-effectiveness ratio. Under base case assumptions, second-line arthroscopic partial meniscectomy offered to participants with persistent pain following initial PT is cost-effective at willingness-to-pay thresholds between $31,000 and $473,000 per QALY. Our analyses suggest that arthroscopic partial meniscectomy can be a high-value treatment option for patients with meniscal tear and OA when performed following an initial PT course and should remain a covered treatment option.

INTRODUCTION

Knee osteoarthritis (OA) and degenerative meniscal tear are highly prevalent and often concomitant conditions. Symptomatic radiographic OA affects more than 14 million adults in the United States (1), most of whom also have meniscal tear on imaging studies (2). Treatments for meniscal tear in the presence of OA include nonsurgical (physical therapy [PT]) and surgical (arthroscopic partial meniscectomy) options. About 450,000 arthroscopic partial meniscectomies are performed annually in the United States for this indication on adults 45 to 64 years old (3,4). A growing body of research, including results from eight

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randomized controlled trials (RCTs) (5–12) and seven meta-analyses (13–19), indicates that participants with meniscal tear who are randomized to receive arthroscopic partial meniscectomy experience similar or only slightly better outcomes than those randomized to receive PT or sham surgery. Nonetheless, the applicability of these findings to clinical practice is limited by the high rates of crossover to surgery observed among participants randomized to PT. Nearly a third of participants randomized to PT crossed over in many of these RCTs (5,6,9–12), suggesting that some of the beneficial effects seen in the nonoperative arms may in fact be due to the effects of crossover arthroscopic partial meniscectomy. With such high rates of crossover, these trials effectively compare arthroscopic partial meniscectomy with "surgery if PT fails" rather than with PT as the sole treatment. Furthermore, some trials have demonstrated that arthroscopic partial meniscectomy is associated with increased progression of structural changes in cartilage and bone as well as with synovitis (20–22).

Given the difficulty in assessing true PT-only versus arthroscopic partial meniscectomy treatment outcomes using existing RCT data and the potential risks of surgery-associated structural changes, the American Academy of Orthopaedic Surgeons guidance on arthroscopic partial meniscectomy for treatment of meniscal tear in the presence of OA remains "inconclusive" (23). An economic evaluation weighing the relative benefits and harms of available alternatives might help inform policy and medical decision-making (24). To our knowledge, three cost-effectiveness analyses of arthroscopic partial meniscectomy as treatment for meniscal tear in the setting of knee OA have been published (25–27). Similar to the arthroscopic partial meniscectomy RCTs, two of these analyses are limited by the lack of a true PT-only treatment comparator (25,27). The study by Rongen et al (25) is further limited by its reliance on observational data, which introduce the possibility of confounding by indication, and the study by van de Graaf et al (27) is limited by a short time horizon that may not fully capture structural effects of surgery. In the final cost-effectiveness analysis, Losina et al (26) use 2-year follow-up data from the Meniscal Tear in Osteoarthritis Research (MeTeOR) RCT of arthroscopic partial meniscectomy versus PT (6) to model a true PT-only cohort and assess the cost-effectiveness of true PT-only, surgery if PT fails, and immediate arthroscopic partial meniscectomy strategies. Nonetheless, the analysis remains limited by its extrapolation of 2-year data, which may not fully capture the structural effects of surgery, to a 10-year time horizon. Because arthroscopic partial meniscectomy may worsen patients' knee OA progression and have health impacts beyond 2 years, a long-term evaluation is necessary to comprehensively evaluate its cost-effectiveness.

We aimed to address the gaps, uncertainty, and limitations in the literature with a cost-effectiveness analysis of three treatment strategies for concomitant meniscal tear and OA using 5-year follow-up data from the MeTeOR trial, a large prospective RCT of arthroscopic partial meniscectomy with postoperative PT versus PT alone in participants with magnetic resonance imaging–confirmed meniscal tear (6,20,28–30). Our analysis expands on existing RCT data and cost-effectiveness analyses by including a modeled PT-only cohort, allowing more direct comparison with surgery if PT fails and immediate arthroscopic partial meniscectomy strategies and incorporating longer-term follow-up data that may better capture the long-term impacts of surgery.

MATERIALS AND METHODS

Analytic overview. We used the Osteoarthritis Policy (OAPol) Model, a validated probabilistic state-transition computer microsimulation of knee OA (31–36), to evaluate the cost-effectiveness of three treatment strategies for adults with meniscal tear and OA over a 5-year time horizon, 1) PT-only, 2) immediate surgery, and 3) PT + optional surgery, for participants whose pain remains uncontrolled after an initial course of PT. All treatment strategies included a final option of total knee replacement for those with persistent pain and advanced OA. The primary outcome of interest was the incremental cost-effectiveness ratio, measured in dollars per quality-adjusted life-year (QALY) gained. QALYs capture both the quantity and quality of survival in a single measure, weighting each year of life with a utility value ranging from 0 (death) to 1 (perfect health) (37). We considered a range of willingness-to-pay thresholds typically used by US payers (38): $50,000 to $200,000 per QALY, as recommended by the Second Panel on Cost-Effectiveness in Health and Medicine (24). To be cost-effective, a strategy must be cost-saving (ie, improve quality of life at a lower cost) or have the highest incremental cost-effectiveness ratio that still falls below the willingness-to-pay threshold (ie, provide the greatest improvement in quality of life at an acceptable cost). Costs (2019 US dollars [USD]) and QALYs were discounted at 3% per year (39). Only direct medical costs were considered in the base case analysis. We included indirect costs (due to lost workplace productivity) in a sensitivity analysis.

The MeTeOR trial. We used data from 5-year follow-up of the MeTeOR trial to model the cohort's demographic and clinical characteristics, including pain relief and costs associated with PT and arthroscopic partial meniscectomy. The MeTeOR trial was the largest of the arthroscopic partial meniscectomy RCTs, randomizing 351 patients aged 45 or older with meniscal tear and mild-to-moderate OA to receive arthroscopic partial meniscectomy with postoperative PT or PT alone. As with all arthroscopic partial meniscectomy RCTs, participants were allowed to crossover from PT to surgery, and 30% did so by 6-months' follow-up and 35% by 1 year (6). The primary outcome of the trial was between-group difference in change in the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (40) physical function score from baseline to 6-months' follow-up.

WOMAC pain scores, magnetic resonance imaging and radiograph imaging, and self-reported costs were also collected at regular intervals through 5-years' follow-up (6,28–30,41).

The OAPol Model. The OAPol Model generates a hypothetical cohort of participants with user-defined demographic and clinical characteristics and tracks each participant through various health states over a prespecified time frame, applying costs and quality of life (QOL) utility weights associated with each health state.

Subjects were initialized with meniscal tear and baseline characteristics derived from the MeTeOR cohort (6). Consistent with actual clinical trajectories, participants' body mass index (BMI) and Kellgren–Lawrence (KL) grade—a measure of radiographic OA severity (42)—progressed in a probabilistic manner. Pain groups were set prior to analysis using 0 to 100 pain scores (no pain: 0-1; mild pain: 2-15; moderate pain: 16-40; severe pain: 41-70; and extreme pain: 71-100). Because thresholds for defining mild, moderate, and severe OA pain have not yet been well established, several validated indices informed our categorizations. First, Kapstad et al (43) used the Body Pain Index (BPI) to define thresholds of mild-to-moderate and moderate-to-severe pain as 4 and 7 of 10, respectively. Our analysis used the Knee Injury and Osteoarthritis Outcome Score (KOOS) and WOMAC pain scales (closely related scales that both range from 0 to 100, with 100 being the worst), so the upper limits of our "moderate" and "severe" pain groups were set at 40 and 70, respectively, to match the BPI thresholds. Second, to distinguish between mild and moderate pain, we used the study by Bourne et al (44) on total knee replacement efficacy, which found that a WOMAC pain score of less than15 was indicative of mild pain. Finally, studies using categorical scales of the WOMAC pain level similar to ours have shown that downgrading by one group corresponds to a clinically meaningful pain decrement (45,46).

The model accounted for major prevalent and incident comorbidities, including diabetes, cardiovascular disease, chronic obstructive pulmonary disease, cancer, and other musculoskeletal conditions. Each cycle, participants accrued a QOL utility (37) and a cost based on their background medical and treatment costs, both of which were stratified by age, number of comorbid conditions, BMI, and pain level. Derivations of knee OA natural history, comorbidity, and mortality parameters in the OAPol Model have been described previously (31–36). In this analysis, we used a 3-month cycle (the intervention period in the MeTeOR trial) to update characteristics relating to participants' knee OA and treatment. Each participant in the model was observed for 5 years or until death, whichever occurred first.

Specific treatments (PT, arthroscopic partial meniscectomy, or total knee replacement) could influence a participant's costs, pain, and QOL. Arthroscopic partial meniscectomy and total knee replacement were associated with risks of complications that increase costs, reduce QOL, or cause death.

Strategies. We considered three treatment strategies. PT-only consisted of a 3-month standard PT course (28). Immediate surgery consisted of arthroscopic partial meniscectomy surgery with a 3-month postoperative PT course. PT + optional surgery consisted of an initial 3-month PT course followed by the option to undergo subsequent arthroscopic partial meniscectomy for participants who did not have successful pain relief following PT. Across all strategies, participants with persistent pain and advanced OA became eligible for total knee replacement.

The immediate surgery treatment strategy most closely resembles the experience of MeTeOR participants randomized to arthroscopic partial meniscectomy, whereas the PT + optional surgery strategy resembles the experience of MeTeOR participants randomized to PT (a subset of whom ultimately crossed over to surgery). PT-only is not replicated in the MeTeOR trial because subjects had the opportunity to cross over. PT-only reflects a hypothetical cohort randomized to PT and not permitted to cross over to surgery. This cohort mimics the real-world scenario of eliminating arthroscopic partial meniscectomy as a treatment option for patients with meniscal tear.

Model inputs: cohort characteristics. Participant demographics, including distributions of sex, race and ethnicity, BMI, and KL grade, matched those of the MeTeOR cohort (Table 1a) (6). The mean (SD) age of the cohort was 57.9 (7.4) years, and the mean (SD) baseline pain KOOS (47) was 46.6 (16.0) (6).

Model inputs: treatment parameters. Background medical costs included occasional analgesic use and costs associated with management of non-OA comorbidities. Participants experiencing pain incurred an additional $149 annually to represent the costs of intermittent pharmacologic pain management. We calculated this cost as a use-weighted average of opioid and acetaminophen costs from the 2009 Medicare Current Beneficiary Survey knee OA cohort, inflating to 2019 USD (48). Cost, efficacy, and complications of total knee replacement have been described in previously published work (31,34,49) (See Supplementary Materials for additional details).

Efficacy. Treatment success was defined as a clinically meaningful pain decrement that 1) moved a participant into a lower pain group and 2) was maintained for an entire year following treatment start.

Because longitudinal pain data gathered in the MeTeOR trial used the WOMAC (40) pain scale, we assessed treatment efficacies (both initial pain decrements and probabilities of pain failure) using WOMAC values. The OAPol Model uses the closely related KOOS pain scale to anchor starting pain and model natural history progression of pain. Both pain scales are commonly used in OA studies and have similar validity and responsiveness (50).

Both PT and arthroscopic partial meniscectomy reduced participants' pain initially. We used MeTeOR data to calculate the mean (SD) decrement in pain, stratified by pretreatment pain,

Table 1a. Baseline characteristics of adult patients with meniscal tear and knee osteoarthritis

Parameter	Estimate	Source
Mean (SD) age, years	57.9 (7.4)	MeTeOR (6)
Sex		MeTeOR (6)
Female	57%	
Male	43%	
Mean (SD) BMI, kg/m^2	30 (6.1)	MeTeOR (6)
KL[a] grade		MeTeOR (6)
0	0%[b]	
1	45%	
2	26%	
3	29%	
4	0%[c]	
Mean (SD) pain, KOOS[f]	46.6 (16.0)	MeTeOR (6)

Abbreviations: BMI, body mass index; KL, Kellgren-Lawrence; SD, standard deviation.
[a]Due to constraints in the OAPol Model, MeTeOR subjects with KL 0 at baseline were included as KL 1 subjects in the modeled cohort.
[b]Having KL 4 osteoarthritis was an exclusion criterion for participation in the MeTeOR trial.
[c]KOOS: Knee Injury and Osteoarthritis Outcome Score (0-100 with 0 being the best and 100 being the worst) (47). The KOOS scale is used to anchor starting pain and model natural history progression of pain consistently across treatment strategies.

from baseline to 3 months for those assigned to PT or arthroscopic partial meniscectomy. Pain decrements following arthroscopic partial meniscectomy were derived directly from the MeTeOR intention-to-treat (ITT) arthroscopic partial meniscectomy cohort. Because of the high PT-to-surgery crossover (>30%) observed in the MeTeOR trial, true PT pain decrements could not be directly derived from the ITT or as-treated PT cohorts. To overcome this limitation, we derived initial (3-month) PT pain decrements from the MeTeOR ITT PT cohort, excluding participants who crossed over prior to 3 months. If a participant's initial decrement was not clinically meaningful (ie, did not move them into or a lower pain group and/or was not maintained for an entire year), the model deemed the treatment a failure.

For participants who experienced clinically meaningful pain relief initially, a probability of failure was assessed with each subsequent cycle (3 months/cycle) up to 1 year, as derived from MeTeOR data and stratified by pretreatment pain (Table 1b). Participants who experienced failure returned to their baseline pain. Arthroscopic partial meniscectomy failure rates were derived directly from the MeTeOR ITT arthroscopic partial meniscectomy cohort, whereas PT failure rates were derived using the ITT PT cohort and a set of failure criteria that included crossover.

Cost. Participants incurred treatment costs only during the first 3 months of PT or arthroscopic partial meniscectomy; those who underwent optional surgery in the PT + optional surgery treatment strategy incurred treatment costs from both. We calculated the cost of PT using 2019 Medicare PT data (51) and MeTeOR participant-reported health care costs (26) (total cost: $804 per 3-month treatment). We calculated the cost of arthroscopic partial meniscectomy ($4301) using 2019 Medicare data on arthroscopic partial meniscectomy procedural costs (51) and MeTeOR participant-reported health care costs (26). Arthroscopic partial meniscectomy treatment cost includes the cost of postoperative PT.

Complications. During the 3 months following arthroscopic partial meniscectomy, participants had a 1.5% probability of

Table 1b. Meniscal tear treatment parameters

Parameter	PT	APM	Source
Total treatment cost, 2019 USD	$804	$4,301	
Surgical costs[a]	n/a	$3,363	Medicare Physician Fee Schedule 2019 (51)
Utilization-weighted PT costs[b]	$578	$448	Medicare Physician Fee Schedule 2019 (51) MeTeOR (6)
Other care costs[c]	$226	$491	MeTeOR (26)
Mean (SD) pain decrement, WOMAC[d]			MeTeOR (6)
Low starting pain (WOMAC 1-40)	8 (13)	15 (16)	
High starting pain (WOMAC >40)	17 (19)	30 (18)	
Probability of pain failure[e] within one year of treatment			MeTeOR (6)
Low starting pain (WOMAC 1-40)	11%	7%	
High starting pain (WOMAC >40)	26%	18%	
Probability of experiencing *any* complication during the three-month treatment period	0%	1.5%	Hame et al (52)
Relative risk of OA progression	1.00	1.62	Sonesson et al (21)

Abbreviations: APM, arthroscopic partial meniscectomy; incorporates surgery and a post-operative PT course; PT, physical therapy; USD, US dollars.
[a]Surgical costs include the cost of the APM surgery and related anesthesia. Please see the Appendix for further details. PT is a non-surgical treatment and therefore surgical costs are not applicable (n/a) for this treatment.
[b]PT costs include the cost of a single PT evaluation visit and the cost of follow-up PT visits. The number of PT visits included in the cost were derived from the MeTeOR PT and APM cohorts. Please see the Appendix for further details.
[c]Other care costs were gathered from the MeTeOR cohort and describe the average amount subjects in each treatment spent on other medical care during the three-month treatment period.
[d]WOMAC: Western Ontario and McMaster Universities Osteoarthritis Score (0-100 with 0 being the best and 100 being the worst) (40). The WOMAC scale is used to model treatment effects on pain consistently across treatment strategies.
[e]Pain failure is defined as a return to baseline pain.

Table 1c. APM treatment complication parameters

Parameter	PE	SA	DVT	Source
Probability of occurrence, given complication	0.200	0.267	0.533	Hame et al (52)
Probability of death, given occurrence	0.015	0.012	0.008	HCUP (53)
Multiplier to QOL utility[a]	0.739	0.778	0.802	PE and DVT: Melnikow et al (54) SA: Fisman et al (55)
Cost, 2019 USD	$11,470	$15,609	$9,566	HCUP (53)

Abbreviations: DVT, deep venous thrombosis; PE, pulmonary embolism; SA, septic arthritis.
[a]The QOL multiplier is only applied over the three-month treatment period.

experiencing one of the following: pulmonary embolism, septic arthritis, or deep venous thrombosis (52). Costs associated with each complication were derived from the 2014 US Healthcare Cost and Utilization Project (53) and inflated to 2019 USD. Each complication reduced a participant's annual QOL utility via a multiplier derived from the literature (Table 1c and d) (54,55).

Additionally, participants who underwent arthroscopic partial meniscectomy, through either the immediate surgery or PT + optional surgery strategy, experienced heightened OA progression throughout the 5-year time horizon, with an annual relative risk of 1.62 (21). We assumed PT carried no risk of serious complications.

Model calibration. We calibrated acceptance rates for optional surgery and total knee replacement use to MeTeOR data. Acceptance of optional surgery in the PT + optional surgery strategy was calibrated to yield an overall use rate of 35% crossover from PT to arthroscopic partial meniscectomy, per MeTeOR data (6). Total knee replacement acceptance rates were calibrated to match the overall use rate of 2% over 5 years for participants treated only with PT and 10% for participants treated at any point with arthroscopic partial meniscectomy, per MeTeOR (29).

We also calibrated cohort pain progressions to match those of MeTeOR participants (see Supplementary Material).

Sensitivity analyses. We performed deterministic and probabilistic sensitivity analyses to address uncertainty in the data from which base case values were derived. In deterministic sensitivity analyses, we evaluated whether including indirect costs from productivity losses affected incremental cost-effectiveness ratios and also varied the following: optional surgery and total knee replacement acceptance rates, baseline pain, relative risk of OA progression following arthroscopic partial meniscectomy, the period during which participants who failed PT could be considered for optional surgery, and the initial pain decrement and probability of failure associated with optional surgery. The sensitivity analysis of optional surgery efficacy was designed to address clinician suspicion that arthroscopic partial meniscectomy may be less efficacious if delayed. Decreased efficacy of delayed arthroscopic partial meniscectomy could conceivably reduce the cost-effectiveness of a PT + optional surgery strategy (see Supplementary Materials).

Table 1d. Surgery utilization rates (calibrated)

Procedure	Utilization Rate	Source
Optional APM	35% within 1 year	MeTeOR (6)
Post-PT TKR	2% over 5 years	MeTeOR (29)
Post-APM TKR	10% over 5 years	MeTeOR (29)

Abbreviation: TKR, total knee replacement.

In a probabilistic sensitivity analysis consisting of 1000 model runs, we drew independent realizations from distributions of key parameters to account for their uncertainty. We varied the following parameters that had the most uncertainty: PT and arthroscopic partial meniscectomy treatment initial pain decrements, PT and arthroscopic partial meniscectomy treatment probabilities of failure, probability of accepting optional surgery, and probability of accepting total knee replacement following surgical or nonsurgical meniscal tear treatment (see Supplementary Materials).

RESULTS

Base case. OAPol Model pain progressions calibrated to match those of MeTeOR participants are displayed in Figure 1. The mean difference in pain observed between the MeTeOR ITT PT and arthroscopic partial meniscectomy cohorts and summed over 5 years (ie, the area between the pain progression curves) was 86.5 KOOS points (29). In comparison, the mean difference in pain between the modeled PT + optional surgery and immediate surgery strategies over 5 years was 90.2, within 5% of the desired MeTeOR value.

Relative to PT-only, PT + optional surgery improved QOL by 0.0651 QALY and increased medical costs by $2010 per person over 5 years (incremental cost-effectiveness ratio: $30,876 per QALY). Relative to PT + optional surgery, immediate surgery added 0.0065 QALY and $3080 (incremental cost-effectiveness ratio: $473,846 per QALY) (Table 2).

Deterministic sensitivity analyses. PT + optional surgery incremental cost-effectiveness ratios were not sensitive (ie, remained within a similar range of willingness-to-pay thresholds) to including indirect costs from productivity losses or to changes in surgery use rates, baseline pain, relative risk of OA progression following arthroscopic partial meniscectomy, or duration of the

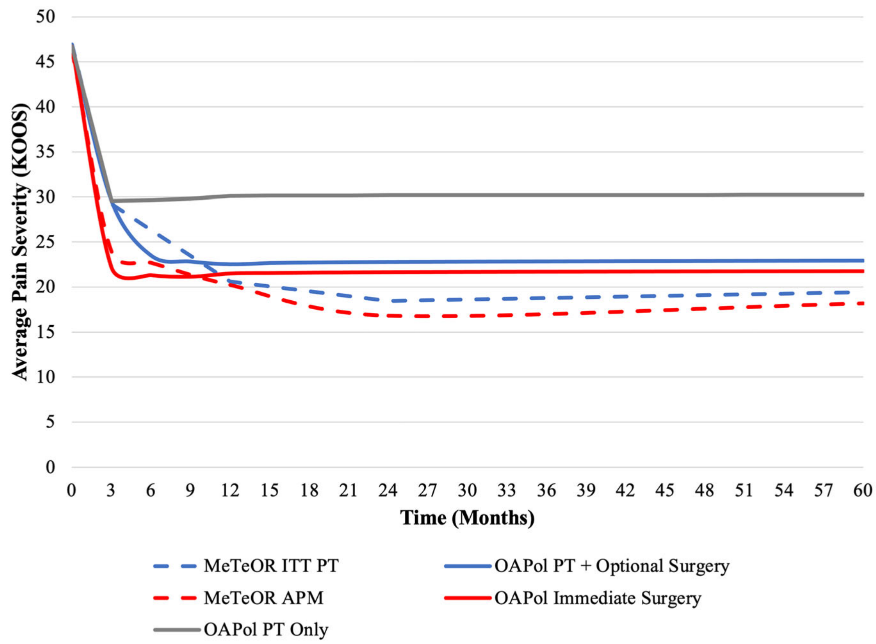

Figure 1. Five-year pain progressions of modeled cohorts calibrated to Meniscal Tear in Osteoarthritis Research (MeTeOR) data. Each curve represents the average cohort pain from baseline to 5 years (MeTeOR intention-to-treat [ITT] physical therapy [PT]: dashed blue; Osteoarthritis Policy [OAPol] PT + optional surgery: solid blue; MeTeOR arthroscopic partial meniscectomy [APM]: dashed red; OAPol immediate surgery: solid red; OAPol PT-only: solid gray). The area between the blue and red dashed curves (86.5) represents the cumulative sum difference in average pain observed between the MeTeOR ITT PT and APM cohorts. The area between the blue and red solid curves (90.2) represents the cumulative sum difference in average pain modeled between the OAPol PT + optional surgery and immediate surgery strategies.

crossover period during which participants who failed PT were eligible for optional surgery.

PT + optional surgery and immediate surgery incremental cost-effectiveness ratios were sensitive to reduced arthroscopic partial meniscectomy efficacy in the PT + optional surgery strategy relative to that in the immediate surgery strategy (Figure 2A and B). In extreme, highly improbable scenarios, in which the efficacy of optional surgery after failed PT was significantly lower than that of immediate surgery, the incremental cost-effectiveness ratio for PT + optional surgery surpassed $100,000 per QALY. Under less extreme scenarios with marginally reduced efficacy of optional surgery, the immediate surgery incremental cost-effectiveness ratio fell below $100,000, $150,000, or $200,000 per QALY but never below $50,000 per QALY.

Immediate surgery incremental cost-effectiveness ratios were also sensitive to changes in optional surgery acceptance rates. By lowering the acceptance rate of optional surgery, the PT + optional surgery strategy was made to more closely resemble the PT-only strategy, in that fewer participants who would be eligible for optional surgery actually underwent the surgery. When optional surgery acceptance was equal to or less than 40% of the base case value, the incremental cost-effectiveness ratio for immediate surgery fell below $100,000 per QALY. PT + optional surgery maintained an incremental cost-effectiveness ratio of less than $50,000 per QALY in all tested scenarios (see Supplementary Materials for incremental cost-effectiveness ratios from all deterministic sensitivity analyses).

Probabilistic sensitivity analysis. Figure 3 presents the percentage of scenarios in the probabilistic sensitivity analysis in which each treatment strategy was cost-effective compared with

Table 2. Base case results

Strategy	Cost	QALY	ΔCost	ΔQALY	ICER
PT-only	$31,270	3.4044	—	—	—
PT + optional surgery	$33,280	3.4695	$2010	0.0651	$30,900/QALY
Immediate surgery	$36,360	3.4760	$3080	0.0065	$473,800/QALY

Note: "Cost" denotes cumulative medical costs over a 5-year period in 2019 US dollars. "QALY" denotes quality-adjusted life-years over a 5-year period. "ICER" denotes incremental cost-effectiveness ratio in units of dollars per quality-adjusted life-year ($/QALY). ICERs are rounded to $100s in this table.
Abbreviations: ICER, incremental cost-effectiveness ratio; PT, physical therapy; QALY, quality-adjusted life-year.

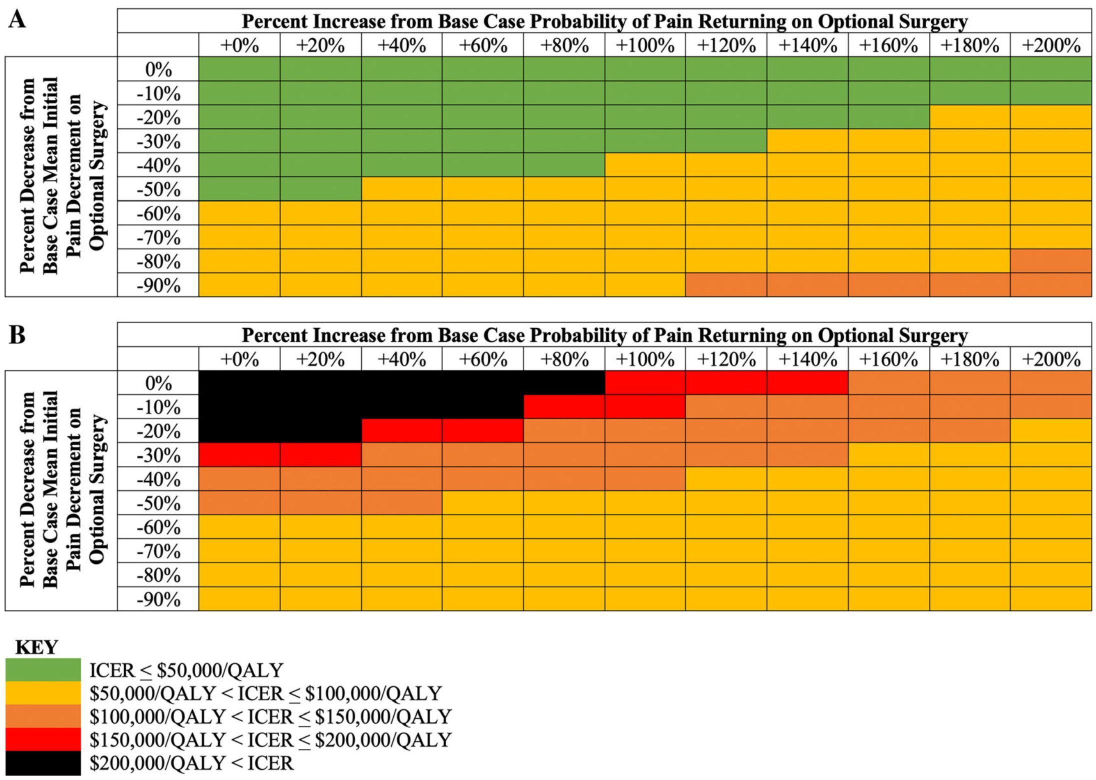

Figure 2. Heat maps of physical therapy (PT) + optional surgery cost-effectiveness, relative to PT-only (**A**), and immediate surgery cost-effectiveness, relative to PT + optional surgery (**B**), when the efficacy of optional surgery is reduced relative to the efficacy of immediate surgery. Incremental cost-effectiveness ratios (ICERs) are measured in dollars per quality-adjusted life-year (QALY).

available alternatives at a given willingness-to-pay threshold. PT + optional surgery was cost-effective compared with the available alternatives at willingness-to-pay thresholds of $50,000 per QALY, $100,000 per QALY, $150,000 per QALY, and $200,000 per QALY in 51%, 51%, 49%, and 47% of scenarios, respectively. At the same thresholds, immediate surgery was cost-effective in 19%, 32%, 37%, and 40% of scenarios, respectively.

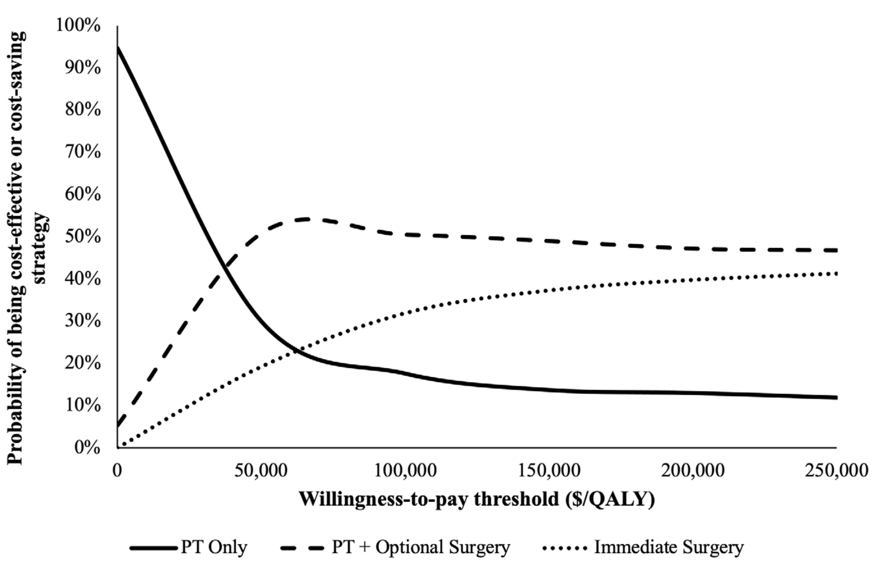

Figure 3. Cost-effectiveness acceptability curves. Each curve represents the percentage of scenarios in the probabilistic sensitivity analysis for which each treatment strategy (physical therapy [PT] only: solid; PT + optional surgery: dashed; immediate surgery: dotted) was cost-effective compared with the available alternatives at a given willingness-to-pay threshold (in dollars per quality-adjusted life-year [QALY]).

DISCUSSION

Using the OAPol Model, we evaluated the cost-effectiveness of arthroscopic partial meniscectomy–related treatment strategies for knee OA concomitant with meniscal tear: 1) PT-only, 2) immediate surgery, and 3) PT + optional surgery. As is typical of cost-effectiveness analyses of interventions that affect QOL, as opposed to life-saving interventions, the differences in QALYs achieved by each treatment strategy were relatively small (56). The cost-effectiveness analysis uses the incremental cost-effectiveness ratio to place these seemingly modest benefits within the context of cost. Under base case assumptions and relative to PT-only, PT + optional surgery had an incremental cost-effectiveness ratio of $30,900 per QALY, indicating cost-effectiveness at a willingness-to-pay threshold of $50,000 per QALY. Despite yielding the highest QALYs of the three strategies, immediate surgery was not cost-effective at any commonly used willingness-to-pay thresholds below $200,000 per QALY.

Though PT-only is unlikely to be the preferred strategy at willingness-to-pay thresholds of $50,000 per QALY or more, the distinction between PT + optional surgery and immediate surgery is less clear, and more research is needed to distinguish an unequivocally preferred strategy. Nonetheless, strategies involving arthroscopic partial meniscectomy appear to be preferable at higher willingness-to-pay thresholds to a strategy involving only PT. The cost-effectiveness of PT + optional surgery was sensitive to diminishing the efficacy of optional surgery as compared with immediate surgery (Figure 2A), as was the cost-effectiveness of immediate surgery (Figure 2B). In this sensitivity analysis, PT + optional surgery remained cost-effective at a $150,000 per QALY willingness-to-pay threshold in all tested scenarios, suggesting that any clinician suspicion of surgery efficacy decreasing with delay does not push the PT + optional surgery incremental cost-effectiveness ratio outside an acceptable range. And the results of our probabilistic sensitivity analysis (Figure 3) suggest that the certainty with which we can claim PT + optional surgery as the preferred treatment strategy is relatively low and diminishes as the willingness-to-pay threshold increases.

Previously published cost-effectiveness analyses, though limited in their ability to assess the cost-effectiveness of immediate arthroscopic partial meniscectomy versus a true PT-only treatment, have similarly found that immediate surgery is not cost-effective compared with either no surgery or physical therapy at standard societal willingness-to-pay thresholds of less than $100,000 per QALY (26) but does yield higher QOL outcomes (25–27). These results add credence to our finding that immediate surgery yielded the highest costs and QALYs of the three treatment strategies. In the only cost-effectiveness analysis considering three treatment strategies, including true PT-only, arthroscopic partial meniscectomy offered only if pain persists following initial PT, and immediate surgery, Losina et al (26) found that, based on 2-year data from the MeTeOR trial, delayed arthroscopic partial meniscectomy is cost-effective at a $50,000 per QALY willingness-to-pay threshold (incremental cost-effectiveness ratio: $12,900 per QALY) and concluded that PT alone was unlikely to be the preferred strategy. The similarity of these findings to ours is reassuring given the parallels in study design. Of note, our study's incorporation of longer-term follow-up data from the MeTeOR trial allowed us to appreciate the potential increased risk of structural knee OA progression and total knee replacement among those undergoing surgery. By incorporating these data, our analysis has yielded an incremental cost-effectiveness ratio of PT + optional surgery that is nearly double that of delayed arthroscopic partial meniscectomy in the study by Losina et al.

Our analysis should be viewed given certain limitations. Our input data are specific to adult patients with meniscal tear and OA, and our results are not generalizable beyond this population (eg, those with only meniscal tear or meniscal tear onset before 45 years of age). Our cost data were derived from sources within the US health care system and may not be generalizable to other geographic settings. We assume arthroscopic partial meniscectomy has short-term efficacy capable of being captured in our 5-year time horizon; however, the potential for detrimental effects of heightened OA progression following arthroscopic partial meniscectomy may extend beyond this period. Consistent with MeTeOR data, we assumed that participants whose pain did not return within 1 year of starting a treatment would maintain their pain decrement for the entire 5-year period (ie, pain failure was only possible within the first year of starting treatment). The MeTeOR trial, our primary data source, showed notable (>30%) crossover from PT to surgical treatment and significant (24%) discontinuation or loss to follow-up at 5 years (29). As such, we cannot know the true efficacy of PT-only or long-term patient outcomes based on currently available trial data. We also do not consider intra-articular injections in any of our treatment strategies. Finally, our analysis is modeled after the MeTeOR cohort, which may not be representative of the average patient with meniscal tear. The willingness of MeTeOR participants, who were recruited at large urban academic medical centers, to crossover to arthroscopic partial meniscectomy or undergo total knee replacement may be different from that of the general population. Their adherence to prescribed PT courses and reported health care costs during the treatment period may also differ.

In the absence of definitive guidance from professional societies on arthroscopic partial meniscectomy as treatment for meniscal tear and knee OA, this analysis may inform decision-making of physicians, payers, and policy makers. Our results indicate that arthroscopic partial meniscectomy is likely to be cost-effective if it is offered to patients whose pain persists following an initial course of standard PT (28) but is unlikely to be cost-effective if offered as a first-line treatment. Our deterministic sensitivity analyses indicate that these findings are robust, even when second-line arthroscopic partial meniscectomy is made dramatically less efficacious than first-line arthroscopic partial meniscectomy. For physicians, our findings may inform the process of shared decision-making with patients with meniscal tear and OA. Patients should be counseled that arthroscopic partial meniscectomy surgery may provide symptom relief but that it is of greatest value after PT has failed to do so. Furthermore, patients concerned that delaying arthroscopic partial meniscectomy may minimize its effect should be reassured that the option of surgery only if PT fails is as effective as immediate arthroscopic partial meniscectomy and involves surgery for only a third of patients. For payers and policy makers, our findings may inform insurance coverage decisions. Our analyses suggest that arthroscopic partial meniscectomy can be a high-value treatment option for patients with meniscal tear and OA when performed following an initial PT course and should remain a covered treatment option under these circumstances. Removing arthroscopic partial meniscectomy entirely as a treatment option for patients with meniscal tear and OA would preclude a therapy that improves QOL at costs most societies find acceptable.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Ms. Williams had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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