Cost-Effectiveness Analysis of Needle Arthroscopy Versus Magnetic Resonance Imaging in the Diagnosis and Treatment of Meniscal Tears of the Knee

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Purpose: To determine whether needle arthroscopy (NA) compared with magnetic resonance imaging (MRI) in the diagnosis and treatment of meniscal tears is cost-effective when evaluated over a 2-year period via patient-reported outcomes. The hypothesis is that improved diagnostic accuracy with NA would lead to less costly care and similar outcomes. **Methods:** A Markov model/decision tree analysis was performed using TreeAge Pro 2017 software. Patients were evaluated for degenerative and traumatic damage to the lateral/medial meniscus. Assumed sensitivities and specificities were derived from the medical literature. The direct costs for care were derived from the 2017 Medicare fee schedule and from private payer reimbursement rates. Costs for care included procedures performed for false-positive findings and for care for false-negative findings. Effectiveness was examined using the global knee injury and osteoarthritis outcome score (KOOS). Patients were evaluated over 2 years for costs and outcomes, including complications. Dominance and incremental cost-effectiveness were evaluated, and 1- to 2-way sensitivity analysis was performed to determine those variables that had the greatest effect. The consolidated economics evaluation and reporting standards checklist for reporting economic evaluations was used. **Results:** NA was less costly and had similar KOOS versus MRI for both the medial/lateral meniscus with private pay. Costs were less for both Medicare and private pay for medial meniscus, $780 to $1,862, and lateral meniscus, $314 to $1,256, respectively. **Conclusions:** Based on the reported MRI incidence of false positives with the medial meniscus and false negatives with the lateral meniscus and based on assumed standards of care, more costly care is provided when using MRI compared with NA. Outcomes were similar with NA compared with MRI. **Level of Evidence:** Level II, economic and decision analysis.

See commentary on page 563

Magnetic resonance imaging (MRI) is the predominant diagnostic modality in assessing soft tissue knee pathology. One of the main issues with the use of MRI is the rate of false positive (FP) and false negative (FN) findings,[1,2] which may result in unnecessary arthroscopic surgeries (for FPs) or in the delay of therapies (for FNs) for pain relief.

Arthroscopy is the gold standard against which other imaging technologies are compared.[3] However, arthroscopy is rarely used as a diagnostic tool and has been replaced by MRI.[4]

Recently introduced, needle arthroscopy (NA) has demonstrated equivalent accuracy to standard arthroscopies in the diagnosis of meniscal[5,6] and femoral condylar lesions.[5] Some of the advantages in using NA in the physician's office are convenience and immediacy of diagnosis as it can be performed as part of an initial patient visit.[7]

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Table 1. Sensitivities/Specificities (%) Used in the Markov Model

Condition	Needle Arthroscopy	Magnetic Resonance Imaging
Medial meniscus	95/97[5]	90/81[14]
Lateral meniscus	93/90[5]	75/94[14]

The purpose of this analysis is to determine whether NA compared with MRI in the diagnosis and treatment of meniscal tears is cost-effective when evaluated over a 2-year period via patient-reported outcomes. The hypothesis is that improved diagnostic accuracy with NA would lead to less costly care and similar outcomes.

Methods

Literature searches were performed on November 9 and 10, 2017, using the following search terms in PubMed: ((((Quality) AND Life) AND Instruments) AND arthroscopy) AND knee (11 articles identified; 2 articles obtained); PubMed: (((MRI) AND knee) AND quality) AND life (95 articles identified; 6 articles

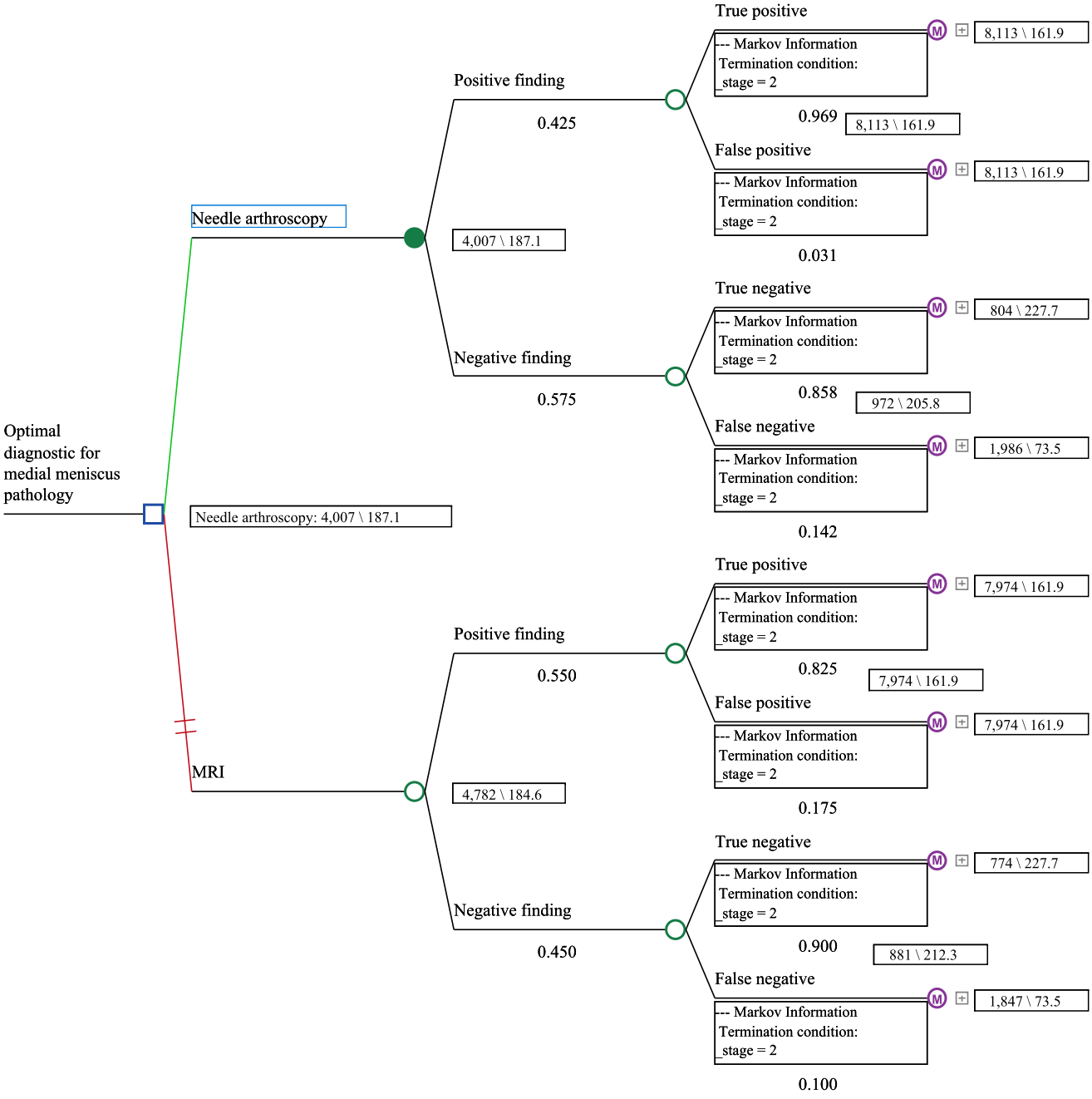

Fig 1. Decision tree comparing use of needle arthroscopy to magnetic resonance imaging as a diagnostic prior to surgery.

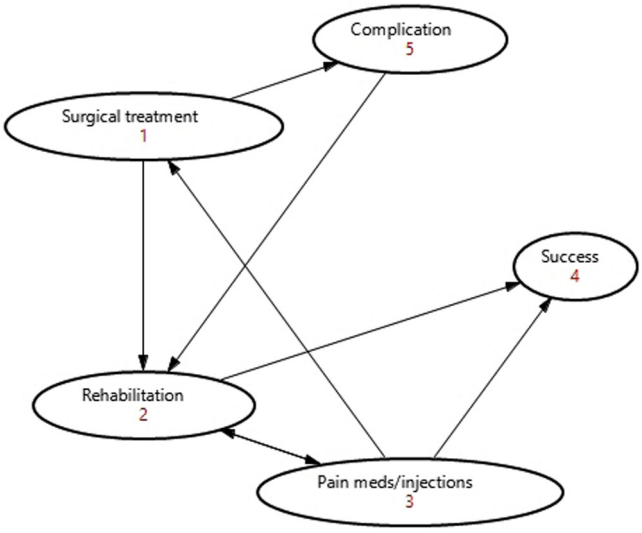

Fig 2. Transition state diagram of a false positive magnetic resonance imaging finding and resultant care based on that finding.

obtained); PubMed: (((knee) AND arthroscopy) AND cost) AND effectiveness (62 articles identified; 4 articles obtained); EBSCO: Quality of Life AND knee AND arthroscopy (100 articles identified; 4 articles obtained).

The base case population evaluated middle-age (mid to late 40s to the early 50s) adults with intra-articular knee damage (medial and/or lateral meniscal damage) presenting with symptoms indicative of a meniscal lesion, who were not contraindicated to completing an MRI, who did not have an infection, and who presented to an orthopaedic physician specializing in arthroscopy with knee pain for several months. Based on clinical work-up, an MRI versus in-office diagnostic NA was indicated. A decision to treat or not was made on the MRI or NA diagnosis.

Modeling the Condition

TreeAge Pro 2017 Markov modeling software was used to evaluate the cost and effectiveness of NA versus MRI in the diagnoses and subsequent treatment based on the findings of both diagnostic modalities based on results in the medical literature. TreeAge Pro is a decision support model accepted by such organizations as the National Institutes for Health and Clinical Excellence (United Kingdom).[8]

Diagnoses and Treatment(s)

The following diagnoses were evaluated: medial and lateral meniscus pathology. Treatment for each condition occurred for true positive (TP) and FP for both NA and MRI findings. For meniscus pathology it was assumed that a partial meniscectomy (medial or lateral; CPT 29881) was performed in symptomatic patients without severe degenerative knee pathology and that subsequent follow-up care provided including physical therapy. The reason a partial meniscectomy was chosen was for simplicity's sake and owing to the fact that it is the dominant procedure performed. True negative (TN) findings were not treated, and it was assumed the patient had no follow-up clinical care. FN findings were followed up with physical therapy first and, if this failed, hyaluronic acid (HA) injections were administered.[9-11] HA was administered if patients were in pain or had degenerative disease (e.g., early-stage osteoarthritis); HA treatments are found to be the safest and longest lasting for lowering the pain.[12] This treatment paradigm attempted to follow current practice patterns, coverage policies of the major private payers, and appropriate use criteria.[13] If these failed, patients went on to surgery (CPT 29881). The sensitivities and specificities used in the Markov model are found in Table 1.

Inputs

Evaluation of Outcomes

Outcomes for patients undergoing therapy (or not) for suspected knee damage were evaluated for effectiveness using the knee injury and osteoarthritis outcome score (KOOS). KOOS is an instrument mainly used for evaluating osteoarthritis but has also been validated for knee injury.[15] $KOOS_4$ (mean score for four of five KOOS subscale scores: pain, other symptoms, function in sport and recreation, and knee related quality of life) was used in the model to evaluate the various outcome states the patient exhibited over a 2-year period from baseline. KOOS scores at each time frame were then totaled for an aggregate outcome score. Appendix Table 1 shows the relevant $KOOS_4$ values used in the Markov model at baseline and 1 and 2 years. Outcomes were discounted at 3%.[16]

Evaluation of Costs

The direct costs for diagnosis and treatment were based on the 2017 Medicare national average fee

Table 2. Medicare

Condition	NA (Costs/$KOOS_4$)	Magnetic Resonance Imaging (Costs/$KOOS_4$)	Cost Savings With NA	Cost-Effectiveness
Medial meniscus	3,996/187	4,776/185	780	NA dominant
Lateral meniscus	2,324/206	2,638/201	314	NA dominant

NOTE. All costs are in dollars.
KOOS, knee injury and osteoarthritis outcome score; NA, needle arthroscopy.

Table 3. Private Payer Payment Rates

Condition	NA (Costs/$KOOS_4$)	Magnetic Resonance Imaging (Costs/$KOOS_4$)	Cost Savings With NA	Cost-Effectiveness
Medialmeniscus	5,361/187	7,223/185	1,862	NA dominant
Lateral meniscus	3,193/206	4,449/201	1,256	NA dominant

NOTE. All costs are in dollars.
KOOS, knee injury and osteoarthritis outcome score; NA, needle arthroscopy.

schedule and are found in Appendix Table 1. MRI and NA private payer reimbursement rates were based on available data.[17] Private payment rates were based on an assumed premium of 30% over Medicare rates. Surgical procedures were assumed to take place in the hospital outpatient setting. MRI was assumed to take place in the hospital outpatient setting as well (CPT 73721 + APC 5523; $240 + $219 = $459 for Medicare[18] and $1,628 for private pay[17]) or in a freestanding MRI facility (private pay at $1,050).[7] NA was assumed to take place in the physician office setting and was reimbursed using CPT 29870 ($598 for Medicare[18] and $958 for private pay [Data on file: VisionScope Technologies]). The costs of performing CPT 29870 in the physician office setting are included in CPT 29870 and reflect such expenses as needle arthroscope, cost of the dressing/injection/anesthetic, cost of administration and preparation of the medication and the room (practice expenses), and the time to perform the procedure (physician work). All of these costs are embedded in the relative value units for both physician work and practice expense.[19] Additionally, it was assumed that the patient population would represent a typical enrollee of either private insurer or Medicare. Complications were also factored into surgical procedures and included deep vein thrombosis, pulmonary embolism, venous thromboembolism, and any other complication requiring a patient be admitted to the hospital. These costs and their incidence were derived from the medical literature.[20,21] Costs were discounted at 3%.[16]

Running the Model

Based on the probability of a finding of a TP or FP, patients were surgically treated and corresponding health states were assumed postprocedure relating to complications, rehabilitation, and outcome. For FN findings, it was assumed patient first underwent physical rehabilitation. If this failed, patients underwent HA injections, and if those failed, they ultimately underwent surgery[9-11,22,23] Figure 1 shows the Markov model for diagnosis and treatment for the medial meniscus. Figure 2 shows the structure for Markov state transition diagram for an FP finding. One- and 2-way sensitivity analyses were performed to determine which variables had the greatest effect on overall cost for care. Each variable was varied at least ±25% to determine strength of the findings and to determine the point at which MRI or NA was the preferred diagnostic based on overall costs. Incremental cost effect scatterplot analysis using Monte Carlo simulation (sampling probabilistic sensitivity, run 10,000 times) was performed to determine the percentage of time therapies that were dominant (resulted in overall lower cost with improved outcomes) for each condition. All probabilities of events occurring are identified in Appendix Table 1 for medial meniscus pathology. Four different Markov models were developed: medial and lateral meniscus (using Medicare or private pay information) with appropriate therapeutic follow-up. These models differed slightly based on specificities and sensitivities for MRI and NA (as per Table 1) and for surgical therapy for meniscal damage as well.

Last, the consolidated economics evaluation and reporting standards checklist[24] was used to ensure recommended items were included in the economic evaluation (Appendix Figure 1).

Results

Baseline 2-year costs and outcomes derived from each Markov model for Medicare and for private pay are shown in Tables 2 and 3.

Appendix Table 2 shows each of the stages (years 0 to 2; with "0" being the initial encounter/procedure) and state transitions for NA and MRI for TP, FP, TN, and FN findings. Each of these stages has an associated probability of occurring, an associated cost, and outcome as measured by $KOOS_4$. The values identified in Appendix Table 2 are for a medial meniscus tear using Medicare costs. Furthermore, each of the TPs, FPs, TNs, and FNs also has an associated probability of occurring based on the literature.[15,25]

The incremental cost-effectiveness (ICE) scatterplots in Monte Carlo simulation with respect to NA versus MRI dominance using Medicare data are summarized

Table 4. Medicare Data

Condition	Needle Arthroscopy Dominant % of Time	Magnetic Resonance Imaging Dominant % of Time	ICER Ratio for NA
Medial meniscus	61	9	N/A
Lateral meniscus	80	5	N/A

ICER, incremental cost effectiveness ratio; N/A, not applicable.

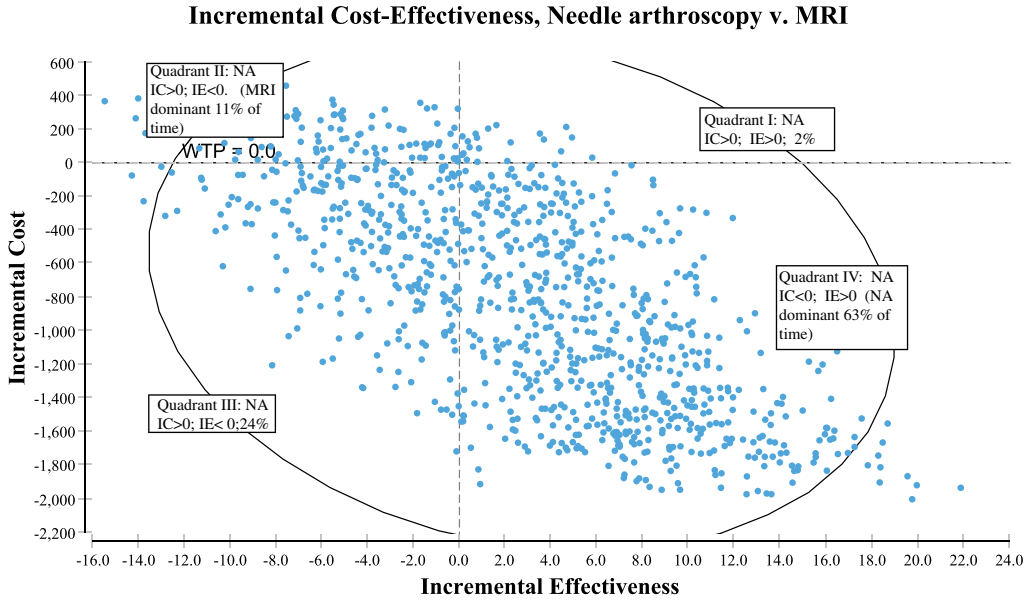

Fig 3. Medial meniscus Medicare incremental cost-effectiveness scatterplot examining the probabilities of incrementally lower or higher costs and knee injury and osteoarthritis outcome scores in using needle arthroscopy versus magnetic resonance imaging.

in Table 4 and in Figure 3 (used as an example of an ICE scatterplot). ICE scatterplots in Monte Carlo simulation showed that with private pay rates, NA was dominant to MRI the majority of the time (Table 5). Two-way sensitivity analysis demonstrated that at various costs for both MRI and NA, NA was the less costly alternative in the majority of cases (Table 6). One-way sensitivity demonstrated that the following variables and thresholds affected the model, resulting in a lower cost for MRI versus NA based on Medicare payment amounts (Table 7) and private pay payment amounts (Table 8): cost of NA, cost of MRI, percentage of MRI positives, and percentage of NA positives. Note that all parameters/ranges used can be found in Appendix Table 1 for Medicare (medial meniscus only) and Appendix Table 3 for private pay (medial meniscus only).

Discussion

In analyzing the cost-effectiveness of NA using Markov modeling, NA was found to be less costly than MRI while providing for "equivalent/improved" outcomes. With private payers, MRI reimbursement for the lower limb without contrast, from a recent analysis surveying 1,584 hospitals (and from 3 large private insurers: Aetna, Humana, and United Healthcare), averaged $1,332 ± 509 (2011 data, inflated to 2017 using hospital outpatient medical CPI $1,628 ± $622).[17] In contrast, internal data collected on CPT 29870 (diagnostic knee arthroscopy; physician office setting) for private payers (Aetna, BCBS, CIGNA, Humana, United Healthcare mainly in the following states: CA, CT, GA, IL, NJ, MA) estimated a reimbursement rate of $958 ± $317 (data available from VisionScope Technologies and consistent with Truven data, $1,175). When using these values in the models, NA dominated MRI.

For this analysis, it was assumed that an MRI for a private pay patient would be performed in the hospital outpatient setting, where reimbursement is highest, $1,628. This is compared with an approximate $1,050 reimbursement rate for an MRI performed in a free-standing MRI facility.[7] If the MRI value of $1,050 were used in the analysis, NA still would be the least costly in all lesions examined with savings of $1,284 (medial meniscus) and $678 (lateral meniscus). In other words, no matter the setting for an MRI under private pay, NA

Table 5. Private Payer Data

Condition	Needle Arthroscopy Dominant % of Time	Magnetic Resonance Imaging Dominant % of Time	ICER Ratio for NA
Medial meniscus	64	2.8	N/A
Lateral meniscus	86	1.2	N/A

ICER, incremental cost effectiveness ratio; N/A, not applicable.

Table 6. Two-Way Sensitivity

Condition	Difference in Cost for MRI to Be Preferred
Medial meniscus	NA >$919 more costly than MRI ($1,378 less $459); NA is the less costly alternative.
Lateral meniscus	NA >$453 more costly than MRI ($912 less $459); NA is the less costly alternative.

MRI, magnetic resonance imaging; NA, needle arthroscopy.

Table 7. One-Way Sensitivity Analysis of Variables that Most Affected the Markov Model (Medicare)

Variable (also Appendix Table 1)	Medial Meniscus	Lateral Meniscus
Cost of NA (CPT 29870) = $598	>1,378	>912
Percentage of MRIs positive of MRIs performed (positive + negative findings)	<43	<21
Percentage of NAs positive of all NAs performed (positive + negative findings)	>54	>24

NOTE. Values above or below those shown resulted in either NA or MRI being the more costly option.
MRI, magnetic resonance imaging; NA, needle arthroscopy.

was the least costly alternative and provided for "equivalent/improved" outcomes. Although the reimbursement rate for MRI and NA may vary across the United States based on negotiated rates between providers and insurers, the private pay reimbursement rates for NA and MRI in this analysis were derived from large data sets and from large payers (Data on file: VisionScope Technologies; Truven 2017 data). In a separate sensitivity analysis of the cost of an MRI (Table 8), the following MRI private pay reimbursements would need to be met for MRI to be the less costly alternative: for the medial meniscus, NA is always the less costly alternative no matter the MRI reimbursement (ranges evaluated in sensitivity analysis $0 to $3,000); for the lateral meniscus, MRI would need to be <$371 (Fig 4).

In all clinical scenarios, NA produced superior outcomes versus MRI as measured by $KOOS_4$. The $KOOS_4$ scores as evaluated in this analysis assumed a given treatment paradigm (e.g., all FPs were treated with surgical arthroscopy, and all FNs were treated via surgical arthroscopy if PT and HA injections were first not successful), which may not be the case in actual practice. Specifically, some clinicians may not treat FP findings and FN findings may not deteriorate to the point of requiring an intervention. Thus, the $KOOS_4$ outcomes findings herein may be subject to debate.

Gill et al.[5] published the accuracies (sensitivities and specificities) used in the model. These accuracies were in line with other studies.[6,26] It should also be noted that in the Gill et al.[5] study, the kappa statistics comparing NA with surgical diagnostic arthroscopy (standard bore size arthroscope) were very high, indicating no significant difference between the 2 modalities.

In 1-way sensitivity analysis, MRI has always been more sensitive in medial versus lateral pathology.[27] Thus, the overall positive finding threshold (TP + FP) for preferring MRI to NA is higher with medial versus lateral pathology (Tables 7 and 8). The lateral meniscus presents challenges based on the oblique orientation of the posterior horn with its sloping upward course at its attachment and small radial curvature. This makes tears of the posterior horn and tears involving less than one-third of the lateral meniscus difficult to identify on MRI.[28,29] This lower sensitivity has also not improved, despite improvements in magnet technology.[6] It was also independent of the duration of the tear.[28] Based on inconclusive data presented from MRI, the vast majority of these tears tend to be ultimately be treated surgically.[29] In these cases, it is likely that the initial use of NA (vs MRI) would have resulted in a more timely treatment of the tear, perhaps with less patient pain over time.

From clinical practice, health policy, and patient satisfaction standpoints, NA may present advantages. NA is a diagnostic procedure that can be performed with the patient awake in a physician's office setting. A diagnosis can then be made by the clinician at that point, with 1 encounter establishing definitive diagnosis and treatment.

Further, considering there can be a significant number of patients who are missed with MRI (i.e., FN findings) for the lateral meniscus pathology,[5,14] inappropriate care may be delivered. Additionally, based on the relatively high incidence of FP findings in medial meniscus pathology, there is the potential for unnecessary surgical treatment. There has been a push recently by policy makers and the medical community to ensure appropriate care is being delivered in all care settings, including emphasizing individual patient needs as the top priority.[30] Thus, NA may be an alternative for delivering more appropriate care.

The current analysis differs from a prior analysis that focused on Medicare costs only and was examined over the acute phase of care.[31] This analysis includes private

Table 8. One-Way Sensitivity Analysis of Variables that Most Affected the Markov Model (Private Pay)

Variable (also Appendix Table 3)	Medial Meniscus	Lateral Meniscus
Cost ($) of MRI (CPT 73721) (model assumes cost of $1,628 ± $622 [facility] and $1,050 [nonfacility]	MRI always more expensive	<371
Cost ($) of NA (CPT 29870) (model assumes cost of $958 ± $317)	>2,820	>2,215
Percentage of MRIs positive of MRIs performed (positive + negative findings)	<35	<11
Percentage of NAs positive of all NAs performed (positive + negative findings)	>63	>33

NOTE. Values above or below those shown resulted in either NA or MRI being the more costly option.
MRI, magnetic resonance imaging; NA, needle arthroscopy.

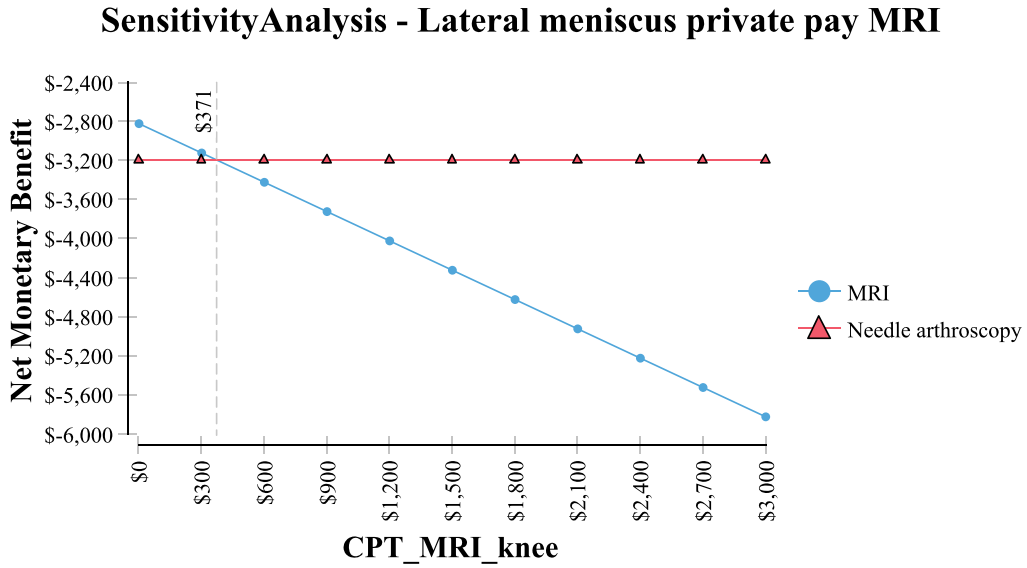

Fig 4. Sensitivity analysis of cost of magnetic resonance imaging (private pay rate) in evaluating a lateral meniscus lesion.

pay reimbursement and outcomes ($KOOS_4$) and examines a patient over a 2-year period. This study also adds further clarity to the effect of NA on private insurers, where the majority of this type of condition is evaluated and treated.

Limitations

Indirect costs were not factored into this analysis. These costs include time absent from work, loss of productivity (owing to pain), out-of-pocket expenses related to transportation, travel time, assistive devices, and time spent on follow-up.[32,33]

MRI results that were obtained from the literature were derived from academic medical centers where more advanced MRI technology (i.e., higher resolution of intra-articular disease) is available and generally where more experienced musculoskeletal radiologists reside.[34] MRI results from community practices have demonstrated lower accuracy.[11]

$KOOS_4$ was used as a proxy for outcome. This was a global score using 4 of the 5 subscale scores for patient with meniscal tears and osteoarthritis (pain, other symptoms, function in sports and recreation, and knee quality of life). The $KOOS_4$ data were derived from a randomized controlled trial recently completed in middle-age patients (which was the population for this cost-effectiveness evaluation).[35]

It was assumed that all patients in the analysis would be willing to undergo NA in the office. This may not be the case, and there may crossover to MRI assessment owing to its noninvasive nature. This crossover was not accounted for in the analysis.

It was assumed that symptomatic patients with TP and FP (with diagnosed pathology—either MRI or NA) were treated arthroscopically for a meniscectomy. This was based on an evidence-based review of meniscal tears after surgery with short-term satisfactory results occurring in approximately 90% of patients.[36] In other words, there is a high likelihood that patients will benefit from a surgical intervention. Additionally, with respect to FP MRI findings and our assumption that FP went on to surgery, Medicare CPT historical use data for the years 2000 to 2015 have shown a consistency of use for codes 29870 (diagnostic knee arthroscopy) and CPT 29880 plus 29881. CPT codes 29880/29881 have made up 73% to 75% of all surgical knee arthroscopies over this time frame.[37] CPT 29870 has also made up 1.2% to 1.3% of the 29880/29881 total. Since FPs in MRI are in the 10% to 15% range, the historical use of CPT 29870 should be much higher. It is therefore the assumption that FP MRI results are being treated surgically in everyday practice.

The negative predictive value of MRI and NA has been shown to be quite high in meniscal tears,[5,38] and unless the patient had clinical symptoms indicative of a meniscal tear (along with a negative MRI and NA), follow-on arthroscopy was not performed. Since this occurs infrequently, surgery was not accounted for in TN findings.

It was assumed patients were treated conservatively at first based on an FN finding. This was based on the standards of care for treating pain.[39-41] Ultimately if the patient outcome did not improve, that patient underwent a surgical arthroscopic procedure.

The use of MRI in patients with suspected bony edema (and with joint effusion) may be the more appropriate diagnostic modality versus NA because a differential diagnosis can be obtained. In patients with acute trauma with joint effusion, MRI can provide additional diagnostic capabilities regarding the condition of subchondral bone

and alternative treatment(s).[42] This was not evaluated in this analysis and is a limitation of the data evaluated.

Last, the cost analysis covers 2 years only. Therefore, the findings of cost savings should be restricted to this time frame.

Conclusions

Based on the reported MRI incidence of FPs with the medial meniscus and FNs with the lateral meniscus based on assumed standards of care, more costly care is provided when using MRI compared with NA. Outcomes were similar with NA compared with MRI.

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Appendix

Appendix Table 1. Variables and Distributions Used in the Markov Model for Medicare

Variables Used in the Model: Medial Meniscus Assessment/Treatment						
Name	Description	Formula	Value	Low	High	Comment
Anesthesia_outpatient_meniscectomy	CPT 01400: anesthesia for a 30-minute arthroscopic meniscectomy hospital outpatient setting	$132	$132	$0	$132	Base units = 4; 1 unit each for 15 minutes of patient being under; total of 6 units. CMS 2017 CF = $22.05. Therefore, 6 units × $22.05 = $132.30
APC_arthroscopic_meniscectomy	APC 5113: facility payment for surgical meniscectomy	$2,425	$2,425	$0	$2,425	APC 5113: for use with CPT 29881. Medicare 2017 fee schedule.
Corticosteroid_injection	CPT 20610: arthrocentesis and/or corticosteroid injection	$62	$62	$0	$62	Medicare 2017 national average payment amount for arthrocentesis and/or corticosteroid injection.
Cost_DVT	Cost to treat a DVT over a 12-month period	$16,322	$16,322	$0	$0	Source: Spyropoulos AC, Lin J. Direct medical costs of VTE and subsequent hospital readmission rates: An administrative claims analysis form 30 managed care organizations. *J Manag Care Pharma* 2007;13:475-486. Costs inflated using medical CPT from 2007 to 2017.
Cost_orthopedic_readmit_comp	Cost orthopedic readmit owing to comp: DRG 565	$6,623	$6,623	$0	$12,000	Medicare 2017 national average payment for DRG 565: OTHER MUSCULOSKELETAL SYS & CONNECTIVE TISSUE DIAGNOSES W CC
Cost_PE	Cost to treat a PE over a 12-month period	$25,144	$25,144	$0	$40,000	Source: Spyropoulos AC, et al. (2007). Costs inflated using medical CPT from 2007 to 2017.
Cost_VTE	Cost to treat a VTE over a 12-month period	Cost_complication_VTE	$25,730	$0	$40,000	Source: Lin J, Lingohr-Smith M, Kowng WJ. Incremental health care resource utilization and economic burden of venous thromboembolism recurrence from a US payer perspective. *Jrl Manag Care Pharm* 2014;20:174-186.
Cost_Wound_comp_ arthroscopic_lavage_drainage	CPT 29871: arthroscopic lavage and drainage for infection + APC 5113	$2,956	$2,956	$0	$5,000	Medicare 2017 national average payment rate for arthroscopic lavage and drainage: infection plus APC 5113 at $2,425.
CPT_arthroscopic_meniscectomy	CPT 29881: partial meniscectomy, medial or lateral	$558	$558	$0	$1,000	Medicare 2017 national average payment amount for a meniscectomy of the knee: medial or lateral; facility setting.
CPT_diagnostic_ arthroscopy_knee_Medicare	CPT 29870: diagnostic knee arthroscopy physician office, Medicare	$598	$598	$0	$1,500	Medicare 2017 national average payment amount for a diagnostic knee arthroscopy: physician office setting.

(continued)

Appendix Table 1. Continued

Variables Used in the Model: Medial Meniscus Assessment/Treatment						
Name	Description	Formula	Value	Low	High	Comment
CPT_diagnostic_arthroscopy_knee_PP	CPT 29870: diagnostic knee arthroscopy physician office, private pay	$958	$958	$0	$3,000	Average private payer rates for NA obtained from explanation of benefits for various payers, including Blue Cross Blue Shield, Aetna, United, CIGNA, Harvard Pilgrim Health Plan. Mean ± SD = $958 ± $317.
CPT_Evaluation_Mgmt_Existing	CPT code for a follow-up evaluation and management on an existing patient	$109	$109	$0	$200	Medicare 2017 national average payment amount for a 30-minute physical examination: existing patient.
CPT_Evaluation_Mgmt_existing_injection	Cost E&M for injection corticosteroid: CPT 99212	$44	$44	$0	$100	Medicare 2017 national average payment rate: CPT 99212.
CPT_Evaluation_Mgmt_New	CPT code for evaluation and management: patient history and examination	$166	$166	$0	$300	Medicare 2017 national average payment amount for a 30-minute physical examination: new patient.
CPT_MRI_knee_Medicare	CPT 73721: MRI knee without contrast, Medicare	$240	$240	$0	$1,500	Medicare 2017 national average payment amount for an MRI of the knee without contrast.
CPT_MRI_Knee_PP	CPT 73721: MRI knee without contrast, private pay	$1,628	$1,628	$0	$3,000	Cooper Z, Craig SV, Gaynor M, Van Reenen J. The price ain't right? Hospital prices and health spending on the privately insured. Working paper 21815. National Bureau of Economic Research. Published December 2015. Revised May 2018. The 2011 reimbursement rates are inflated to 2017.
CPT_Xray_knee	CPT 73564 x-ray knee: 4 views	$40	$40	$0	$80	Medicare 2017 national average payment amount for x-rays of the knee: 4 views.
KOOS4_baseline_score		KOOS4_baseline	56.95	0	85	Source: Kise NJ, Risberg MA, Stensrud S, Ranstam J, Engebretsen L, Roos EM. Exercise therapy versus arthroscopic partial meniscectomy for degenerative meniscal tear in middle aged patients: randomised controlled trial with two year follow-up. *BMJ* 2016;354:i3740.
KOOS4_one_year_exercise		KOOS4_excercise_one_year	82.53	0	90	Source: Kise NJ, et al. (2016).
KOOS4_one_year_meniscectomy		KOOS4_meniscectomy_one_year	86.93	0	95	Source: Kise NJ, et al. (2016).
KOOS4_two_year_exercise		KOOS4_exercise_two_years	88.2	0	95	Source: Kise NJ, et al. (2016).
KOOS4_two_year_meniscectomy		KOOS4_meniscectomy_two_years	87.4	0	95	Source: Kise NJ, et al. (2016).
MRI_positives	MRI positive findings out of all findings (positive + negative)	Positive_findings_MRI	55%	0%	99%	Crawford R, Walley G, Bridgman S, Mafulli N. Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: A systematic review. *Br Med Bull* 2007;84:5-23.

(continued)

Appendix Table 1. Continued

Variables Used in the Model: Medial Meniscus Assessment/Treatment

Name	Description	Formula	Value	Low	High	Comment
NA_positives	Needle arthroscopy positive findings out of all NA findings (positive + negative)	Positive_findings_NA	43%	0%	99%	Based on VisionScope NA findings. Data on file.
Physical_therapy_cost_week	Cost physical therapy per week	$660	$660	$0	$15,000	CPT 97110 pays at $33 per 15-minute session. Assume 4 sessions per day; 5 days per week. Therefore, $33 × 4 × 5 = $660 per week.
Physical_therapy_initial_evaluation	CPT 97162: initial evaluation for physical therapy	$83	$83	$0	$150	Medicare 2017 national average payment for CPT 97162: initial evaluation for physical therapy.
Physical_therapy_knee	Physical therapy knee: assume 3-6 weeks	Physical_therapy _duration_post_surg	4.5	0	9	Assumed course of physical therapy based on coverage determinations of Medicare and private payers.
Probability_comp_DVT	Probability DVT meniscal surgical arthroscopic procedure	0.12%	0.12%	0%	1%	Source: Jameson SS, Dowen D, James P, Serrano-Pedraza I, Reed MR, Deehan DJ. The burden of arthroscopy of the knee: a contemporary analysis of data from the English NHS. *J Bone Joint Surg Br* 2011;93:1327-1333.
Probability_comp_PE	Probability PE meniscal surgical arthroscopic procedure	0.08%	0.08%	0%	0.2%	Source: Jameson SS, et al. (2011).
Probability_comp_readmit	Probability readmit owing to meniscal surgical arthroscopic procedure	0.45%	0.45%	0%	1%	Source: Jameson SS, et al. (2011).
Probability_comp_VTE	Probability VTE meniscal arthroscopic surgical procedure	0.19%	0.19%	0%	0.5%	Source: Jameson SS, et al. (2011).
Probability_comp_wound	Probability wound complication meniscal arthroscopic surgical procedure	0.11%	0.11%	0%	0.5%	Source: Jameson SS, et al. (2011).
Probability_complication	Probability complication post knee surgery	Probability_complication _knee_arthroscopy	1%	0%	2%	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month time frame. Derived from the medical literature and inflated to 2017.
Probability_pain_meds_success	Probability corticosteroid injections relived pain symptoms	50%	50%	0%	90%	Estimated.
Probability_rehab_post_med_failure	Probability exercise rehabilitation post medication failure	85%	85%	0%	95%	Source: Cavanaugh JT, Killian SE. Rehabilitation following meniscal repair. *Curr Rev Musculoskelet Med* 2012;5:46-58.
Probability_rehab_success	Probability rehab success post meniscectomy	Probability_meniscal _repair_success	80%	0%	90%	Source: Cavanaugh JT, et al. (2012)
TN_MRI		True_negatives_MRI	90%	0%	95%	Crawford R, et al. (2007).
TN_NA		True_Negatives_NA	86%	0%	99%	Based on VisionScope NA findings. Data on file.
TP_MRI		True_positives_MRI	83%	0%	95%	Crawford R, et al. (2007).

(continued)

Appendix Table 1. Continued

Variables Used in the Model: Medial Meniscus Assessment/Treatment						
Name	Description	Formula	Value	Low	High	Comment
TP_NA		True_positives_NA	97%	0%	99%	Based on VisionScope NA findings. Data on file.
Weighted_average_complication_cost		Weighted_average_cost_complication	$12,804	$0	$20,000	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month time frame. Derived from the medical literature and inflated to 2017.

Distributions Used in the Model				
Description	Type	Parameters	EV	Comment
Physical therapy in weeks after arthroscopic meniscal surgery	Uniform	Subtype: 2, low: 3, high: 6	4.5	Assumed course of physical therapy based on coverage determinations of Medicare and private payers.
Cost of treating a VTE over a 12-month period, Medicare	Normal	Mean: 25730; SD: 40,250	$25,730	Source: Lin J, et al. (2014).
Weighted average cost of a complication post arthroscopy	Normal	Mean: 12804; SD: 10,000	$12,804	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month time frame. Derived from the medical literature and inflated to 2017.
Percentage of positive findings on MRI vs total findings	Uniform	Subtype: 2; low: 0.4; high: 0.7	55%	Assumed positive findings for medial meniscus pathology for MRI.
Percentage of TNs of all negative findings MRI (TN + FN)	Uniform	Subtype: 2; low: 0.85; high: 0.95	90%	Assumed negative findings for medial meniscus pathology for MRI.
$KOOS_4$ at 2-year exercise group	Triangular	Min: 81.1; likeliest: 85; max: 98.5	88.2	Source: Kise NJ, et al. (2016).
Probability of meniscus repair success post rehab	Uniform	Subtype: 2; low: 0.7; high: 0.9	80.0%	Source: Cavanaugh JT, et al. (2012).
Percentage of positive findings of all findings NA (TP + FP)	Uniform	Subtype: 2; low: 0.4; high: 0.45	42.5%	Based on VisionScope NA findings. Data on file.
Probability knee complication	Triangular	Min: 0.001; likeliest: 0.0095; max: 0.02	1.02%	Probability of a complication based on all complications summed up: 0.95%
Percentage of TN NA of all negatives (TN + FN)	Triangular	Min: 0.725; likeliest: 0.882; max: 0.967	85.8%	Based on VisionScope NA findings. Data on file.
$KOOS_4$ at 1-year exercise	Triangular	Min: 74.9; likeliest: 79.5; max: 93.2	82.53	Source: Kise NJ, et al. (2016).
Percentage of TPs of all positives (TP + FP)	Triangular	Min: 0.922; likeliest: 0.986; max: 1	96.9%	Based on VisionScope NA findings. Data on file.
Percentage of TPs of all positive MRI findings (TP + FP)	Uniform	Subtype: 2; low: 0.8; high: 0.85	82.5%	Crawford R, et al. (2007).
$KOOS_4$ at 2-year meniscectomy	Triangular	Min: 80.4; likeliest: 84.1; max: 97.7	87.4	Source: Kise NJ, et al. (2016).
$KOOS_4$ at 1-year meniscectomy	Triangular	Min: 79.9; likeliest: 83.7; max: 97.2	86.93	Source: Kise NJ, et al. (2016).
$KOOS_4$ baseline score meniscus damage	Normal	Mean: 56.95; SD: 16.37	56.95	Source: Kise NJ, et al. (2016). Combined mean from exercise and meniscectomy groups: N = 70 both groups; mean ± SD exercise: 54.3 ± 18.2 and meniscectomy: 59.6 ± 13.8.

APT, Ambulatory Payment Classification; CPT, Current Procedure Terminology; DRG, Diagnosis Related Group; DVT, deep vein thrombosis; E&M, evaluation and management; EV, expected value; FN, false negative; FP, false positive; KOOS, knee injury and osteoarthritis outcome score; MRI, magnetic resonance imaging; NA, needle arthroscopy; PE, pulmonary embolism; SD, standard deviation; TN, true negative; TP, true positive; VTE, venous thromboembolism.

Appendix Table 2. Medicare Costs Over 2-Year Time Frame by Diagnostic Modality and Subsequent Treatment

True Positive, Needle Arthroscopy, Medical Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effect	Total Effect
0	Surgical treatment	100.00	3,919	3,919	3,919	56.95	56.95	56.95
0	Rehabilitation	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Pain meds/injections	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Success	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Complication	0.00	0	3,919	3,919	0.00	56.95	56.95
1	Surgical treatment	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Rehabilitation	98.98	4,002	4,132	8,051	86.05	86.63	143.58
1	Pain meds/injections	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Success	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Complication	1.02	130	4,132	8,051	0.58	86.63	143.58
2	Surgical treatment	0.00	0	62	8,113	0.00	18.35	161.93
2	Rehabilitation	1.02	41	62	8,113	0.89	18.35	161.93
2	Pain meds/injections	19.810	21	62	8,113	17.46	18.35	161.93
2	Success	79.19	0	62	8,113	0.00	18.35	161.93
2	Complication	0.00	0	62	8,113	0.00	18.35	161.93

False Positive, Needle Arthroscopy, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effect	Total Effect
0	Surgical treatment	100.00	3,919	3,919	3,919	56.95	56.95	56.95
0	Rehabilitation	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Pain meds/injections	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Success	0.00	0	3,919	3,919	0.00	56.95	56.95
0	Complication	0.00	0	3,919	3,919	0.00	56.95	56.95
1	Surgical treatment	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Rehabilitation	98.98	4,002	4,132	8,051	86.05	86.63	143.58
1	Pain meds/injections	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Success	0.00	0	4,132	8,051	0.00	86.63	143.58
1	Complication	1.02	130	4,132	8,051	0.58	86.63	143.58
2	Surgical treatment	0.00	0	62	8,113	0.00	18.35	161.93
2	Rehabilitation	1.02	41	62	8,113	0.89	18.35	161.93
2	Pain meds/injections	19.810	21	62	8,113	17.46	18.35	161.93
2	Success	79.19	0	62	8,113	0.00	18.35	161.93
2	Complication	0.00	0	62	8,113	0.00	18.35	161.93

True Negative, Needle Arthroscopy, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effect	Total Effect
0	Negative finding	100.00	804	804	804	56.95	56.95	56.95
1	Negative finding	100.00	0	0	804	82.53	82.53	139.48
2	Negative finding	100.00	0	0	804	88.20	88.20	227.68

False Negative, Needle Arthroscopy, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effective	Stage Effective	Total Effective
0	Rehabilitation	100.00	1,547	1,547	1,547	56.95	56.95	56.95
0	Sodium hyaluronate injections	0.00	0	1,547	1,547	0.00	56.95	56.95
0	Surgical treatment	0.00	0	1,547	1,547	0.00	56.95	56.95
0	Success	0.00	0	1,547	1,547	0.00	56.95	56.95
0	Complication	0.00	0	1,547	1,547	0.00	56.95	56.95
1	Rehabilitation	0.00	0	157	1,704	0.00	16.51	73.46
1	Sodium hyaluronate injections	20.00	157	157	1,704	16.51	16.51	73.46
1	Surgical treatment	0.00	0	157	1,704	0.00	16.51	73.46
1	Success	80.00	0	157	1,704	0.00	16.51	73.46
1	Complication	0.00	0	157	1,704	0.00	16.51	73.46
2	Rehabilitation	0.00	0	152	1,855	0.00	0.00	73.46
2	Sodium hyaluronate injections	0.00	0	152	1,855	0.00	0.00	73.46
2	Surgical treatment	4.87	152	152	1,855	0.00	0.00	73.46
2	Success	95.13	0	152	1,855	0.00	0.00	73.46
2	Complication	0.00	0	152	1,855	0.00	0.00	73.46

(continued)

Appendix Table 2. Continued

True Positive, Magnetic Resonance Imaging, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effective	Total Effective
0	Surgical treatment	100.00	3,780	3,780	3,780	56.95	56.95	56.95
0	Rehabilitation	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Pain meds/injections	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Success	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Complication	0.00	0	3,780	3,780	0.00	56.95	56.95
1	Surgical treatment	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Rehabilitation	98.98	4,002	4,132	7,912	86.05	86.63	143.58
1	Pain meds/injections	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Success	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Complication	1.02	130	4,132	7,912	0.58	86.63	143.58
2	Surgical treatment	0.00	0	62	7,974	0.00	18.35	161.93
2	Rehabilitation	1.02	41	62	7,974	0.89	18.35	161.93
2	Pain meds/injections	19.810	21	62	7,974	17.46	18.35	161.93
2	Success	79.19	0	62	7,974	0.00	18.35	161.93
2	Complication	0.00	0	62	7,974	0.00	18.35	161.93

False Positive, Magnetic Resonance Imaging, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effective	Total Effect
0	Surgical treatment	100.00	3,780	3,780	3,780	56.95	56.95	56.95
0	Rehabilitation	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Pain meds/injections	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Success	0.00	0	3,780	3,780	0.00	56.95	56.95
0	Complication	0.00	0	3,780	3,780	0.00	56.95	56.95
1	Surgical treatment	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Rehabilitation	98.98	4,002	4,132	7,912	86.05	86.63	143.58
1	Pain meds/injections	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Success	0.00	0	4,132	7,912	0.00	86.63	143.58
1	Complication	1.02	130	4,132	7,912	0.58	86.63	143.58
2	Surgical treatment	0.00	0	62	7,974	0.00	18.35	161.93
2	Rehabilitation	1.02	41	62	7,974	0.89	18.35	161.93
2	Pain meds/injections	19.810	21	62	7,974	17.46	18.35	161.93
2	Success	79.19	0	62	7,974	0.00	18.35	161.93
2	Complication	0.00	0	62	7,974	0.00	18.35	161.93

True Negative, Magnetic Resonance Imaging, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effect	Stage Effect	Total Effect
0	Negative	100.00	774	774	774	56.95	56.95	56.95
1	Negative	100.00	0	0	774	82.53	82.53	139.48
2	Negative	100.00	0	0	774	88.20	88.20	227.68

False Negative, Magnetic Resonance Imaging, Medial Meniscus

Stage	State	Probability, %	State Cost, $	Stage Cost, $	Total Cost, $	State Effective	Stage Effective	Total Effective
0	Rehabilitation	100.00	1,408	1,408	1,408	56.95	56.95	56.95
0	Sodium hyaluronate injections	0.00	0	1,408	1,408	0.00	56.95	56.95
0	Surgical treatment	0.00	0	1,408	1,408	0.00	56.95	56.95
0	Success	0.00	0	1,408	1,408	0.00	56.95	56.95
0	Complication	0.00	0	1,408	1,408	0.00	56.95	56.95
1	Rehabilitation	0.00	0	157	1,565	0.00	16.51	73.46
1	Sodium hyaluronate injections	20.00	157	157	1,565	16.51	16.51	73.46
1	Surgical treatment	0.00	0	157	1,565	0.00	16.51	73.46
1	Success	80.00	0	157	1,565	0.00	16.51	73.46
1	Complication	0.00	0	157	1,565	0.00	16.51	73.46
2	Rehabilitation	0.00	0	152	1,716	0.00	0.00	73.46
2	Sodium hyaluronate injections	0.00	0	152	1,716	0.00	0.00	73.46
2	Surgical treatment	4.87	152	152	1,716	0.00	0.00	73.46
2	Success	95.13	0	152	1,716	0.00	0.00	73.46
2	Complication	0.00	0	152	1,716	0.00	0.00	73.46

Appendix Table 3. Variables and Distributions Used in the Private Pay Model

Private Pay Variables						
Name	Description	Formula	Value	Low	High	Comment
Anesthesia_outpatient_meniscectomy	CPT 01400: anesthesia for a 30-minute arthroscopic meniscectomy, hospital outpatient setting	$180	$180	$0	$250	Base units = 4; 1 unit each of 15 minutes of patient being under; total of 6 units. CMS 2017 CF = $22.05. Therefore, 6 units × $22.05 = $132.30. Assuming a 30% markup for private pay over Medicare = 132 × 1.3 = 180.
APC_arthroscopic_meniscectomy	APC 5113: facility payment for surgical meniscectomy	$3,153	$3,153	$0	$4,000	APC 5113: for use with CPT 29881. Assume 30% markup for private pay: $2425 × 1.3 = 3153.
Cost_HA_injection	Use of Medicare J7323 Euflexxa per dose = $155	$155	$155	$0	$500	Derived from Medicare payment rate for J7323 at $155.
CPT_arthroscopic_meniscectomy	CPT 29881: partial meniscectomy, medial or lateral	$725	$725	$0	$1,000	Medicare 2017 national average payment amount for a meniscectomy of the knee: medial or lateral; facility setting. Assume 30% markup of private pay over Medicare: $558 × 1.3 = $725.
CPT_diagnostic_arthroscopy_knee	CPT 29870: diagnostic knee arthroscopy, physician office	NA_knee	$958	$0	$3,000	Private payer national average payment amount for a diagnostic knee arthroscopy: physician office setting. Data on file VisionScope.
CPT_Evaluation_Mgmt_Existing	CPT code for a follow-up evaluation and management on an existing patient	$142	$142	$0	$180	Medicare 2017 national average payment amount for a 30-minute physical examination: existing patient. Assume 30% markup of private pay over Medicare: $109 × 1.3 = $142.
CPT_Evaluation_Mgmt _existing_injection	Cost E&M for injection corticosteroid: CPT 99212	$57	$57	$0	$100	Medicare 2017 national average payment rate: CPT 99212. Assume 30% markup of private pay over Medicare: $44 × 1.3 = $57.
CPT_Evaluation_Mgmt_New	CPT code for evaluation and management: patient history and examination	$216	$216	$0	$300	Medicare 2017 national average payment amount for a 30-minute physical examination: new patient. Assume 30% markup of private pay over Medicare: $166 × 1.3 = $216.
CPT_MRI_knee	CPT 73721: MRI knee without contrast	MRI_knee	$1,628	$0	$3,000	Private pay 2017 national average payment amount for an MRI of the knee without contrast: hospital setting. Truveen data.
CPT_Xray_knee	CPT 73564 x-ray knee: 4 views	$52	$52	$0	$100	Medicare 2017 national average payment amount for x-rays of the knee: 4 views. Assume 30% markup of private pay over Medicare rate: $40 × 1.3 = $52.

(continued)

Appendix Table 3. Continued

Private Pay Variables						
Name	Description	Formula	Value	Low	High	Comment
HA_injection	CPT 20610: arthrocentesis and/or injection	$81	$81	$0	$160	Medicare 2017 national average payment amount for arthrocentesis and/or corticosteroid injection. Assume 30% markup of private pay over Medicare: 62 × 1.3 = 81.
KOOS4_baseline_score		KOOS4_baseline	56.95	0.00	80.00	Source: Kise NJ, Risberg MA, Stensrud S, Ranstam J, Engebretsen L, Roos EM. Exercise therapy versus arthroscopic partial meniscectomy for degenerative meniscal tear in middle aged patients: randomised controlled trial with two year follow-up. *BMJ* 2016;354:i3740.
KOOS4_one_year_exercise		KOOS4_excercise_one_year	82.53	0.00	90.00	Source: Kise NJ, et al. (2016).
KOOS4_one_year_meniscectomy		KOOS4_meniscectomy_one_year	86.93	0.00	95.00	Source: Kise NJ, et al. (2016).
KOOS4_two_year_exercise		KOOS4_exercise_two_years	88.20	0.00	95.00	Source: Kise NJ, et al. (2016).
KOOS4_two_year_meniscectomy		KOOS4_meniscectomy_two_years	87.40	0.00	95.00	Source: Kise NJ, et al. (2016).
MRI_positives	MRI positive findings out of all findings (positive + negative)	Positive_findings_MRI	55.0%	0.0%	99.0%	Crawford R, Walley G, Bridgman S, Mafulli N. Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: A systematic review. *Br Med Bull* 2007;84:5-23.
NA_positives	Needle arthroscopy positive findings out of all NA findings (positive + negative)	Positive_findings_NA	42.5%	0.0%	99.0%	Based on VisionScope NA findings. Source: Gill TJ, Safran M, Mandelbaum B, Huber B, Gambardella R, Xerogeanes J. A prospective, blinded, multicenter clinical trial to compare the efficacy, accuracy, and safety of in-office diagnostic arthroscopy with magnetic resonance imaging and surgical arthroscopy. *Arthroscopy* 2018;34:2429-2435.
Physical_therapy_cost_week	Cost of physical therapy per week	858	$858	$0	$1,500	CPT 97110 pays at $33 per 15-minute session. Assume 4 sessions per day; 5 days per week. Therefore, $33 × 4 × 5 = $660 per week. Assume 30% markup of private pay over Medicare: $660 × 1.3 = $858.
Physical_therapy _initial_evaluation	CPT 97162: initial evaluation for physical therapy	108	$108	$0	$200	Medicare 2017 national average payment for CPT 97162: initial evaluation for physical therapy. Assume 30% markup of private payer over Medicare: $83 × 1.3 = $108.

(continued)

Appendix Table 3. Continued

Private Pay Variables

Name	Description	Formula	Value	Low	High	Comment
Probability_complication	Probability complication post knee surgery	Probability_complication _knee_arthroscopy	1.0%	0.0%	10.0%	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month timeframe. Derived from the medical literature and inflated to 2017.
Probability_HA_success	Probability that HA is successful in relieving pain	HA_effectiveness	75.7%	0.0%	90.0%	Source: Concoff A, Sancheti P, Niazi F, Shaw P, Rosen J. The efficacy of multiple versus single hyaluronic acid injections: A systematic review and meta-analysis. *BMC Musculoskel Disord* 2017;18(1):542.
Probability_pain_meds_success	Probability corticosteroid injections relieved pain symptoms	0.5	50.0%	0.0%	80.0%	Estimated
Probability_rehab_post_med_failure	Probability exercise rehabilitation post medication failure	0.85	85.0%	0.0%	95.0%	Source: Cavanaugh JT, Killian SE. Rehabilitation following meniscal repair. *Curr Rev Musculoskelet Med* 2012;5:46-58.
Probability_rehab_success	Probability rehab success post meniscectomy	Probability_meniscal_repair_success	80.0%	0.0%	90.0%	Source: Cavanaugh JT, et al. (2012).
TN_MRI		True_negatives_MRI	90.0%	0.0%	95.0%	Crawford R, et al. (2007).
TN_NA		True_Negatives_NA	85.8%	0.0%	99.0%	Based on VisionScope NA findings. Source: Gill TJ, et al. (2018).
TP_MRI		True_positives_MRI	82.5%	0.0%	90.0%	Crawford R, et al. (2007).
TP_NA		True_positives_NA	96.9%	0.0%	99.0%	Based on VisionScope NA findings. Source: Gill TJ, et al. (2018).
Weighted_average_complication_cost		Weighted_average_cost_complication	$12,804	$0	$20,000	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month time frame. Derived from the medical literature and inflated to 2017.

Private Pay Distributions

Name	Description	Type	Parameters	EV	Comment
Physical_therapy_duration_post_surg	Physical therapy in weeks post arthroscopic meniscal surgery	Uniform	Subtype: 2; low: 3; high: 6	4.5	Assumed course of physical therapy based on coverage determinations of Medicare and private payers.
Cost_complication_VTE	Cost of treating a VTE over a 12-month period: Medicare	Normal	Mean: 25,730; SD: 40,250	$25,730	Source: Lin J, Lingohr-Smith M, Kowng WJ. Incremental health care resource utilization and economic burden of venous thromboembolism recurrence from a US payer perspective. *Jrl Manag Care Pharm* 2014;20:174-186.

(continued)

Appendix Table 3. Continued

Private Pay Distributions					
Name	Description	Type	Parameters	EV	Comment
Weighted_average_cost_complication	Weighted average cost of a complication post arthroscopy	Normal	Mean: 12,804, standard deviation: 10000	$12,804	Weighted average cost of DVT, PE, VTE, readmit, wound complication based on the probabilities of occurrence and over a 12-month time frame. Derived from the medical literature and inflated to 2017.
Positive_findings_MRI	Percentage of positive findings on MRI vs total findings	Uniform	Subtype: 2, low: 0.4, high: 0.7	55%	Assumed positive findings for medial meniscus pathology for MRI.
True_negatives_MRI	Percentage of TNs of all negative findings MRI (TN + FN)	Uniform	Subtype: 2, low: 0.85, high: 0.95	90%	Assumed negative findings for medial meniscus pathology for MRI.
KOOS4_exercise_two_years	$KOOS_4$ at 2-year exercise group	Triangular	Min: 81.1, likeliest: 85, max: 98.5	88.2	Source: Kise NJ, et al. (2016).
HA_effectiveness	HA effectiveness in relieving pain	Triangular	Min: 0.53, likeliest: 0.76, max: 0.98	75.7%	Source: Concoff A, et al. (2017).
Probability_meniscal_repair_success	Probability of meniscus repair success post rehab	Uniform	Subtype: 2, low: 0.7, high: 0.9	80.0%	Source: Cavanaugh JT, et al. (2012.
NA_knee	Private payer amount NA POS	Normal	Mean: 958, standard deviation: 317	$958	Data on file VisionScope; 400 plus data points from private insurers.
Positive_findings_NA	Percentage of positive findings of all findings NA (TP + FP)	Uniform	Subtype: 2, low: 0.4, high: 0.45	42.50%	Source: Gill TJ, et al. (2018).
Probability_complication_knee_arthroscopy	Probability of knee complication	Triangular	Min: 0.001, likeliest: 0.0095, max: 0.02	1.02%	Probability of a complication based on all complications summed up: 0.95%.
True_Negatives_NA	Percentage of TNs NA of all negatives (TN + FN)	Triangular	Min: 0.725, likeliest: 0.882, max: 0.967	85.80%	Source: Gill TJ, et al. (2018).
KOOS4_excercise_one_year	$KOOS_4$ at 1-year exercise	Triangular	Min: 74.9, likeliest: 79.5, max: 93.2	82.533	Source: Kise NJ, et al. (2016).
True_positives_NA	Percentage of TPs of all positives (TP + FP)	Triangular	Min: 0.922, likeliest: 0.986, max: 1	96.93%	Source: Gill TJ, et al. (2018).
True_positives_MRI	Percentage of TPs of all positive MRI findings (TP + FP)	Uniform	Subtype: 2, low: 0.8, high: 0.85	82.50%	Source: Crawford R, et al. (2007).
KOOS4_meniscectomy_two_years	$KOOS_4$ at 2-year meniscectomy	Triangular	Min: 80.4, likeliest: 84.1, max: 97.7	87.4	Source: Kise NJ, et al. (2016).
KOOS4_meniscectomy_one_year	$KOOS_4$ at 1-year meniscectomy	Triangular	Min: 79.9, likeliest: 83.7, max: 97.2	86.933	Source: Kise NJ, et al. (2016).
KOOS4_baseline	$KOOS_4$ baseline score meniscus damage	Normal	Mean: 56.95, standard deviation: 16.37	56.95	Source: Kise NJ, et al. (2016). Combined mean from exercise and meniscectomy groups: N = 70 both groups. Mean ± SD exercise: 54.3 ± 18.2 and meniscectomy: 59.6 ± 13.8.
MRI_knee	Private payer rate MRI knee	Normal	Mean: 1628, standard deviation: 622	$1,628	Available from Truven Analytics.

CPT, Current Procedural Terminology; DVT, deep vein thrombosis; E&M, evaluation and management; EV, expected value; HA, hyaluronic acid; FN, false negative; FP, false positive; KOOS, knee injury and osteoarthritis and outcome score; MRI, magnetic resonance imaging; NA, needle arthroscopy; PE, pulmonary embolism; POS, physician office setting; SD, standard deviation; TN, true negative; TP, true positive; VTE, venous thromboembolism.

Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force,* provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	3
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	4
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	3-4
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	5-6
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	4
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	5
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	5-6

Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	5
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

Appendix Figure 1. CHEERS checklist.

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	3-4
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	5
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	4-6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	5-6
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	4, Figure 1
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Appendix 1
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	N/A
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Appendix 1
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	Tables 2-4
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and	
incremental effectiveness parameters, together with the impact			N/A

Appendix Figure 1. (continued).

		of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	6, Appendix 4
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	7
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	COI
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	As per journal

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

The citation for the CHEERS Task Force Report is:
Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS)—Explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231-50.

Appendix Figure 1. (continued).