# 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

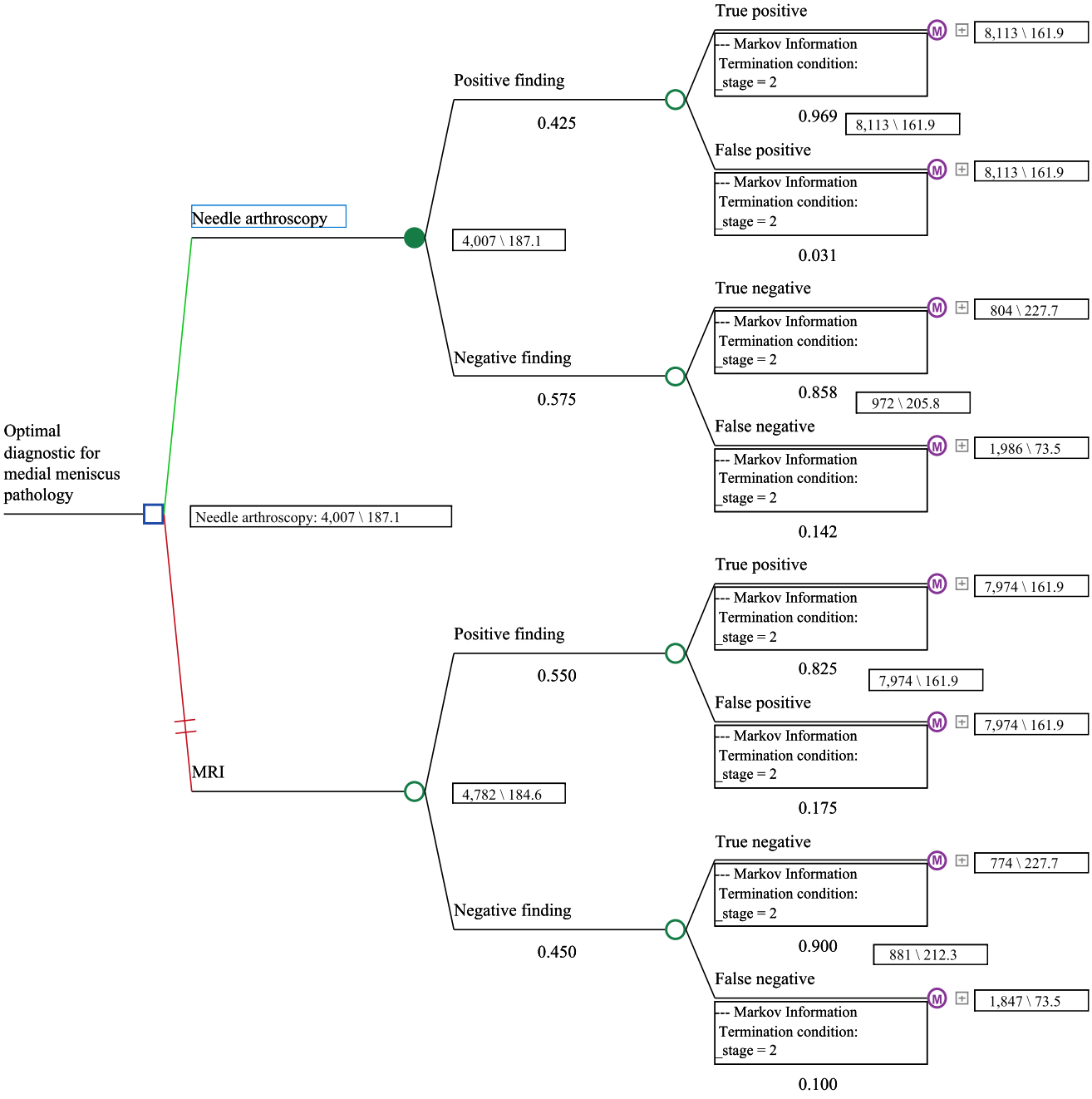


**Fig 1.** Decision tree comparing use of needle arthroscopy to magnetic resonance imaging as a diagnostic prior to surgery.

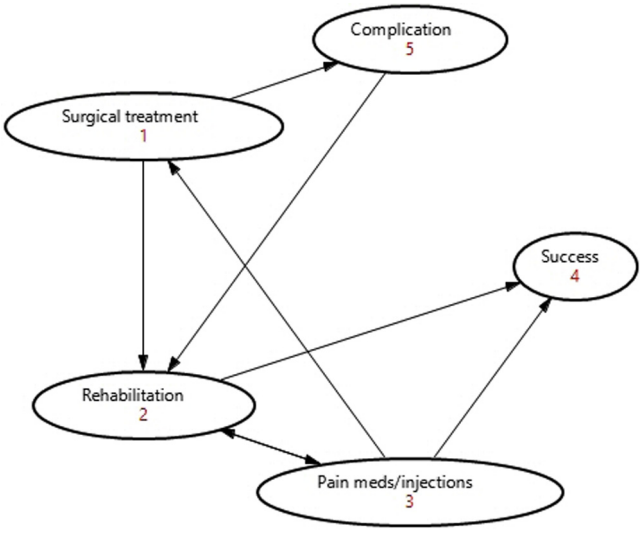


**Fig 2.** Transition state diagram of a false positive magnetic resonance imaging finding and resultant care based on that finding.

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.

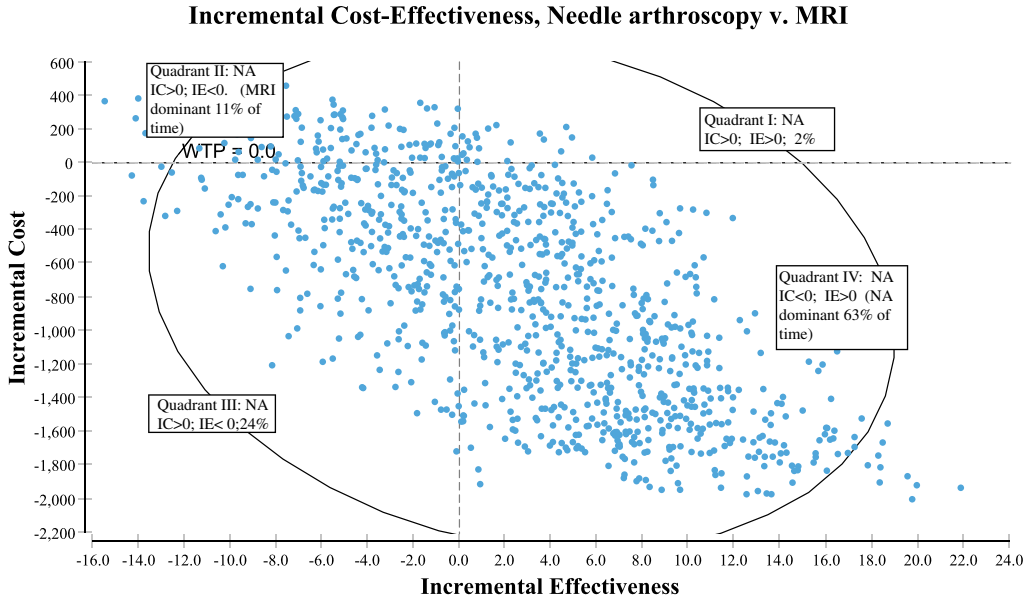


**Fig 3.** Medial meniscus Medicare incremental cost-effectiveness scatterplot examining the probabilities of incrementally lower or higher costs and knee injury and osteoarthritis outcome scores in using needle arthroscopy versus magnetic resonance imaging.

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.

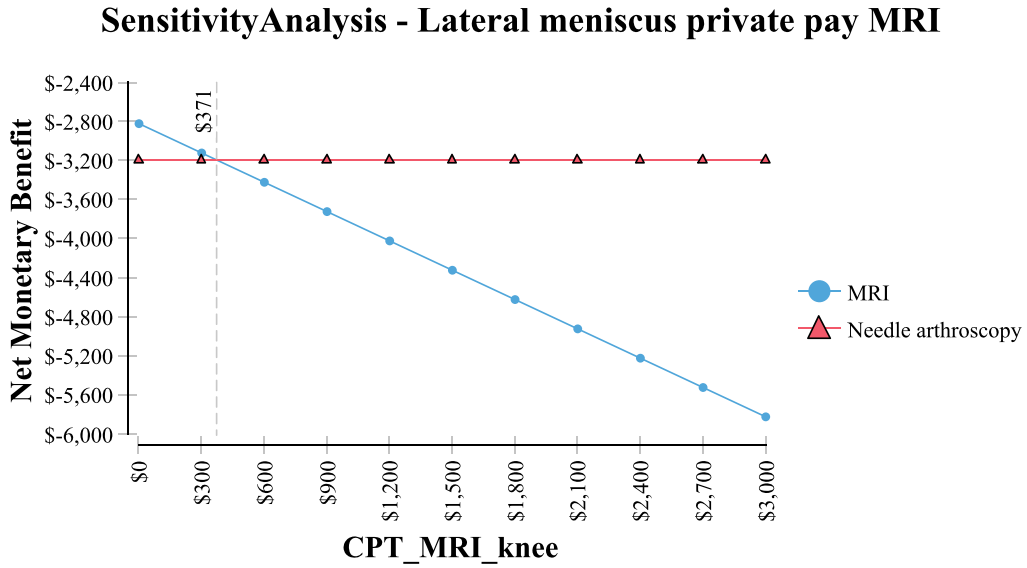




**Fig 4.** Sensitivity analysis of cost of magnetic resonance imaging (private pay rate) in evaluating a lateral meniscus lesion.

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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