Magnetic resonance imaging of the knee is greater than 90% accurate in detecting intraarticular disease when performed and interpreted by musculoskeletal magnetic resonance imaging specialists in specialized medical centers. However, independent imaging institutions often offer less expensive services to health insurers. We wondered if the magnetic resonance imaging performed in our community is of equivalent quality and accuracy. We studied a homogenous group of healthy, young, and fit military recruits to represent a cross section of our country’s population. We analyzed all knee magnetic resonance images of soldiers who subsequently had primary arthroscopic knee surgery within a 3-month period from 1997–1998. The results were compared with surgical findings of four structures: medial meniscus, lateral meniscus, anterior cruciate ligament, and articular cartilage. Of the 1185 arthroscopies and 633 magnetic resonance images of the knee performed in 14 institutions, 139 paired magnetic resonance imaging arthroscopic reports met our inclusion criteria. The results showed a false positive rate of 65% for the medial meniscus, 43% for the lateral meniscus, 47.2% for the anterior cruciate ligament, and 41.7% for articular cartilage disease when compared with surgical findings. Accuracy rates were 52%, 82%, 80%, and 77%, respectively. Thirty-seven percent of the operations supported by a significant disorder on magnetic resonance imaging were unjustified. Our findings highlight the consequences that may occur when basing medical care on cost rather than quality of care.

Level of Evidence: Diagnostic study, Level III (study of non-consecutive patients; without consistently applied reference “gold” standard). See the Guidelines for Authors for a complete description of levels of evidence.

Orthopaedic surgeons commonly examine patients with knee pain. Although a frequent presenting symptom, precisely diagnosing an intraarticular cause of pain is difficult. Magnetic resonance imaging (MRI) of the knee often is used to aid in diagnosing disorders in and around the knee because the high soft tissue resolution allows precise imaging of intraarticular structures such as ligaments, cartilage, and menisci. Accuracy rates greater than 90% have been reported in studies performed at large medical centers by musculoskeletal radiologists specializing in MRI of the knee. Under these conditions, MRI of the knee can accurately predict the presence of soft tissue lesions remediable by arthroscopic surgery.

In our community practice, the treating orthopaedic surgeon does not control where the MRI is performed or who will interpret the images. The patient’s health insurer dictates where the patient is referred. Health insurers refer many patients to independent imaging institutions because their services are less costly.

The factors affecting the quality of MRI examinations in different institutions include the radiologist’s experience, the technical properties of the MRI equipment and available MRI modalities, subtraction techniques, and specific protocols. Our orthopaedic surgery department is part of a large university-affiliated tertiary care medical center. Although our dedicated musculoskeletal radiologist (GF [not an author]) provided high-quality imaging services, the majority of knee MRI results we received from other imaging institutions were below the levels of accuracy reported in the literature.

Most series correlating MRI with arthroscopy have been performed at single specialized medical centers with dedicated musculoskeletal radiologists.
We designed our study to determine the average knee MRI accuracy rate in our community versus accuracy at the different imaging institutions across the country. We aimed to determine the false positive rate that led to surgery on knees found to be normal during arthroscopy. We wanted to know how many of our patients were referred by their health insurer to MRI facilities where a musculoskeletal specialist in MRI of the knee supervised the performance and interpretation. We wanted to determine if there was a difference in cost between the different imaging institutions, and whether insurers also consider MRI quality and accuracy when deciding where to refer patients.

MATERIALS AND METHODS

We obtained the medical records of all soldiers who had knee symptoms requiring MRI and/or arthroscopy from 1997–1998. We retrospectively reviewed these records to compare the MRI results with patients’ corresponding arthroscopic reports.

Of the 633 MR images of knees and 1185 arthroscopies performed from 1997–1998 on soldiers with persistent knee symptoms, 139 paired MRI arthroscopic reports met our inclusion criteria. The inclusion criteria were arthroscopic knee surgery done after MRI, and the interval between MRI and arthroscopic surgery had to be no longer than 3 months. Soldiers included in our study were those banned from physical activity between MRI and arthroscopy. We excluded soldiers with previous knee disorders or intraarticular surgery, those who had arthroscopic surgery performed before the knee MRI or more than 3 months after MRI, and those who returned to duty and physical activities during the interval between MRI and arthroscopy. The soldiers’ average age was 21 years (range, 18–44 years). The average time between MRI and arthroscopy was 68 days (range, 19–93 days).

Because military service is mandatory in our country and all young men and women are recruited, the studied population reflects a cross section of our whole society. By choosing new recruits and career soldiers of our country’s conscript military service during two consecutive years (1997–1998), we had the opportunity to study a homogeneous population group of young, healthy, and physically fit subjects. Because all soldiers were screened periodically by military physicians before and after knee injuries, access to their medical records ensured that soldiers meeting our inclusion criteria constituted a consecutive study group. Because of military medical policy, when an MRI was requested for these patients, it was because their clinical findings, as assessed by an orthopaedic surgeon, were equivocal for an acute knee insult causing continuous symptoms that suggested an intraarticular disorder.

Magnetic resonance imaging was performed in civilian imaging institutions and hospitals. The choice of imaging facility was controlled by medical insurers, and was not influenced by surgeon preference. The MRI results were collected from five imaging institutions, and surgery was performed at 14 different hospitals. Twelve board certified radiologists interpreted all of the MR images. All arthroscopies were performed or supervised by 19 board certified orthopaedic surgeons who were specialists in sports medicine and experienced arthroscopic surgeons. The orthopaedic surgeons performed the arthroscopies with the intent of finding and treating the specific abnormalities identified by MRI. Different entry portals were used, including the posterior-medial portal when suitable to observe the posterior horn of the meniscus.

We obtained information regarding the surgical findings and MRI reports directly from the soldiers’ medical charts. These included the original surgical reports. The MRI interpretations were compared with the surgical reports of four structures: the medial meniscus, lateral meniscus, anterior cruciate ligament (ACL), and articular cartilage. Each structure was evaluated separately and statistically analyzed for false positive and negative rates, positive and negative predictive values, sensitivity, specificity, and accuracy rates.

There were major differences in the technical parameters and sequences used by the different imaging institutions. Because the descriptive terminology differed considerably between radiologists and the descriptions provided in the surgical reports, we were obliged to consider any meniscal tear, regardless of location, type, or grade (when specified by the radiologist only Grades 3 and 4 were considered tears), as a positive pathologic finding. Cartilage damage and ACL tears were also considered pathologic findings regardless of type or extent.

To assess the source of MRI misdiagnoses, and to identify the reasons for discrepancies between surgical reports and imaging interpretations, we reviewed the reports of the MRI studies in which disorders in knees were diagnosed but were found as normal on arthroscopy. We examined the qualifications of the participating radiologists and obtained estimated costs of knee MRI studies. Hospital reimbursement for overall costs of arthroscopic knee surgery (day surgery—with same-day hospital discharge) is standardized by the ministry of health. These costs were obtained for the same time period.

Every citizen in our country is entitled to full medical coverage by one of several health insurance providers. We contacted these companies by telephone to learn how they decided where to send patients for knee MRI ordered by physicians.

RESULTS

The average accuracy rates for knee MRI in our community were considerably lower than those reported in the literature and had an alarmingly high false-positive rate.2,5–11 The average knee MRI accuracy rates ranged from 52% for the medial meniscus to 82% for the lateral meniscus. The false positive values ranged from 65% for the medial meniscus to 42% for the articular cartilage (Table 1). Full correlation between MRI reports and surgical reports on all four assessed structures (true-positive results) were found in only 43 knees (30.9%).

During the arthroscopic surgery, many knees with supposedly gross disorders, as suggested by the MRI reports, were found to be normal. Forty-four (32%) of the surgically treated knees with gross pathologic findings on MRI were normal, and in eight (5%) additional knees, surgical
findings revealed only minimal cartilage damage that did not warrant treatment.

Of the 139 MR images, only three were referred by the medical insurers to be performed, supervised, and interpreted by a qualified musculoskeletal radiologist. The other 136 MR images were interpreted by board certified general radiologists.

Medical insurers paid a substantially higher price for MRI at specialized medical centers and for interpretation by a qualified musculoskeletal radiologist. The charge of knee MRI at the specialized facilities averaged $520, whereas in independent imaging institutions, the charge was as low as $430. The highest radiologist fee ($28 for each MR image interpretation) was charged by the musculoskeletal radiology specialist (GF, who worked at the most expensive imaging institution) participating in this study. The average estimated cost of the diagnostic arthroscopic knee procedures for all these patients was $550.

The replies to our telephone queries consistently showed that referrals to the imaging institution and consultant radiologists were based solely on cost. The accuracy and quality of imaging and interpretation were not considered during decision making. We were unable to obtain an explanation for the three exceptional referrals to the musculoskeletal specialist who participated in our study (GF). The results of MRI reports for three soldiers whose MRIs were supervised and interpreted by the musculoskeletal radiology specialist were confirmed at surgery.

Other misdiagnoses included disorders observed on MRIs interpreted by radiologists that were completely different (in different structures) than the findings during surgery. Eighty-seven patients had abnormalities during surgery. Six (7%) of these patients’ abnormalities were completely different than disorders suggested by their MRI reports.

Assessment of the frequency of misdiagnoses by location showed that false-positive MRI diagnoses most commonly involved the medial meniscus (65%), followed by the lateral meniscus (16.8%), the anterior cruciate ligament (11.4%), and the articular cartilage (6.8%). False-positive medial meniscal tears almost always were attributed to the posterior horn of the medial meniscus.

**DISCUSSION**

New laboratory and imaging examinations are invaluable tools for supplementing physicians’ clinical diagnostic skills. Magnetic resonance imaging of the knee is common because of having greater than 90% accuracy when imaging intraarticular structures such as ligaments, menisci, and cartilage. This makes MRI a highly useful tool for establishing an accurate diagnosis of knee symptoms. Magnetic resonance imaging may play a major role in the selection process of candidates for surgical or conservative management. Unfortunately, application and interpretation of these imaging modalities are vulnerable to nonaltruistic factors, including the economic forces influencing choices made by healthcare providers. Our results raise concern regarding the consequences of basing the selection of medical care on cost rather than quality.

Although providing some insight on how economic choices negatively influence application and interpretation of MRI studies of the knee, our study does have limitations. Being retrospective, it is not a controlled-comparative trial, but rather an analysis describing a common reality. We could not assess the difference between accuracy of MRI as obtained by experienced musculoskeletal radiologists to accuracy of those performed and interpreted by general radiologists.

Although our findings may be indicative of a generalized problem, they represent one country’s experience in a select patient population. More studies should be done to further validate the effect of basing medical care on economic factors without ensuring quality. Another limitation is related to how normal arthroscopic findings may be found in the presence of pathologic Grades 1 and 2 intramural meniscal MRI signals. We dealt with this by considering true meniscal tears as Grades 3 and 4. Some radiologists suggested a meniscal tear without specifying grade; these were considered true meniscal tears. Although the former may have represented low-grade intramural

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<th>False-Negative</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
<th>Sensitivity</th>
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TABLE 1. Results of MRI of the Knee (n = 139) Versus Arthroscopic Findings
meniscal tears, they all eventually led to arthroscopy because of the combination of equivocal clinical signs and the radiologist’s interpretation. The paucity of specialist radiologists is beyond the scope of our study.

The 90% accuracy rate for MRI of the knee was achieved mostly in patients treated at single centers staffed by experienced musculoskeletal radiologists using the latest and most expensive protocols and hardware.\(^\text{2-5}\) Our study is unique because it accurately reflects reality by assessing the countrywide average accuracy rates of referred MRI of the knee. The imaging institutions that these patients were referred to included large medical centers with dedicated musculoskeletal radiologists using the latest and most expensive equipment, and independent imaging institutions.

Another unique feature of our study is that the inclusion criteria included only patients with a diagnostic dilemma: MRI was ordered by the examining orthopaedic surgeon because of equivocal clinical findings in patients with persistent complaints suggestive of intraarticular disorders. The examining orthopaedic surgeons requested MRI hoping that it would provide accurate diagnostic information. Although the orthopaedic sports medicine specialists had training and experience in interpretation of MRI of the knee, the combination of patients’ persistent complaints and the radiologists’ interpretations suggesting major intraarticular disorders helped sway the orthopaedic surgeons’ decision to perform diagnostic arthroscopy.

The treating orthopaedic surgeons used the most appropriate entry portals and technical means (including posteromedial viewing though the notch and posteromedial portals for viewing the posterior horn of the medial meniscus) to best observe the specific disorder. However, 44 (32%) of the knees with MRI reports suggesting abnormalities were normal on arthroscopy, and eight knees (5%) had minimal cartilage damage that did not warrant treatment. We found no correlation between MRI findings and arthroscopic results in six (7%) of 87 of the patients who had surgery. The MRI results were misleading in 58 (41%) of the patients. Mistakes in interpretation of MR images have been reported, especially regarding the region of the posterior horn of the medial meniscus.\(^\text{5,8}\) Although occasional misinterpretations will occur, an overall 65% false-positive value for medial meniscal tears is alarming. The MRI results were not diagnostically helpful and invariably influenced the decision to operate when clinical signs were inconclusive.\(^\text{2-5,11}\)

The reports that document excellent accuracy for detection of intraarticular disorders by knee MRI have been generated mostly in single centers staffed by experienced musculoskeletal radiologists using the latest and most expensive protocols and hardware.\(^\text{2-5,11}\) It would be unrealistic to expect that all medical institutions and independent imaging institutions have such facilities and staff.

Because of the high costs involved, it should not be surprising that medical insurers often refer their patients to less expensive imaging facilities. Magnetic resonance imaging often is performed at independent imaging institutions and interpreted later by general radiologists; therefore, it is not surprising that accuracy rates were less than the gold standard set by musculoskeletal radiologists specializing in knee MRI. We contend that economic considerations commonly outweigh quality medicine. Healthcare legislators and administrators should be informed that shifting medical management to health insurance companies may lead to economic considerations taking precedence over imaging quality.

Of 139 patients with substantial knee symptoms, only three were referred to an imaging facility where a specialist musculoskeletal radiologist supervised the imaging and interpretation. Our experience reflects the common reality of medical insurers’ economic considerations outweighing quality assurance. Paradoxically, 37% of the unnecessary operations also were paid for by the same referring insurers. Had they originally invested in quality diagnosis, the savings in surgery, hospitalization, and rehabilitation would have been greater.

Our results are an important reminder that accurate clinical examinations are vital in medical and surgical decision making. To be of value, MRI of injured knees should follow specific protocols and be performed, supervised, and interpreted by experienced specialized musculoskeletal radiologists. A qualitative feedback relationship between the radiologist and treating physician is essential for quality assurance.

Acknowledgment

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References