THE COST-EFFECTIVENESS OF MAGNETIC RESONANCE IMAGING FOR PATIENTS WITH EQUIVOCAL NEUROLOGICAL SYMPTOMS

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Abstract
Objective: To determine the incremental cost-effectiveness of magnetic resonance imaging (MRI) and computed tomography (CT) in young adults presenting with equivocal neurological signs and symptoms. Designs and methods: A decision analysis of long-term survival using accuracy data from a diagnostic technology assessment of MRI and CT in patients with suspected multiple sclerosis, information from the medical literature, and clinical assumptions. Main results: In the baseline analysis, at 30% likelihood of an underlying neurologic disease, MRI use has an incremental cost of $101,570 for each additional quality-adjusted life-year saved compared with $20,290 for CT use. As the probability of disease increases, further MRI use becomes a cost-effective alternative costing $30,000 for each quality-adjusted life-year saved. If a negative MRI result provides reassurance, the incremental costs of immediate MRI use decreases and falls below $25,000 for each quality-adjusted life-year saved no matter the likelihood of disease. Conclusions: For most individuals with neurological symptoms or signs, CT imaging is cost-effective while MR imaging is not. The cost-effectiveness of MRI use, however, improves as the likelihood of an underlying neurological disease increases. For selected patients who highly value diagnostic information, MRI is a reasonable and cost-effective use of medical resources when even the likelihood of disease is quite low (5%).

Magnetic resonance imaging (MRI) has diffused rapidly in the United States. Over 2,700 inpatient and outpatient MR scanners are in clinical use. Through the 1980s...
and into the 1990s the number of MRI installations has grown, utilization rates have increased, efficiency has improved, and expenditures for the procedure have continued to rise (10;14). Neuroimaging exams are the most common MRI procedures ordered by both generalists and specialists (7).

The technical superiority of MRI over computed tomography (CT) scanning has been established. However, there are not studies showing that MRI favorably impacts patient outcomes, or what has been termed “societal efficacy” (13;21;40). Because assessment has lagged behind its diffusion and adoption, we are now faced with a multi-billion dollar a year industry with scant evidence-based research to help guide MRI’s proper role and use.

Large variations in the use of MRI attest to this uncertainty. Such variations occur across nations (36), across regions in the United States (5), across cities, and among ordering physicians (39). Little is known about the causes of this variation, but its magnitude cannot be attributed simply to “noise” in the system. It is clear, however, that variations in MRI use is of high economic importance (34).

We chose a specific clinical situation that frequently confronts both general physicians and specialists, and developed a decision analysis to determine the cost-effectiveness of MRI of the head relative to two alternatives: double contrast-enhanced head CT and no imaging. Decision analysis provides a framework for evaluating diagnostic imaging techniques estimating the costs and potential benefits. Rather than posing the logistical and ethical difficulties of a prospective randomized trial, it represents a feasible alternative for technology assessment (35). To date, only one other formal cost-effectiveness analysis evaluating the diagnostic value of MRI and CT exists, and it was done for evaluation of demented patients (37).

When the patient's symptoms are due to a neurological disease, such as multiple sclerosis (MS), cerebrovascular disease, or a central nervous system (CNS) neoplasm, neuroimaging is helpful for proper diagnosis and treatment. The physician must also consider, however, that many patients presenting with equivocal neurological symptoms do not have an underlying neurological disease. Their symptoms may result from anxiety, chronic hyperventilation, mood disorders, or hypochondriasis. In these conditions, neuroimaging is generally not critical for medical management. Neuroimaging may, however, provide reassurance, allay fears, and consequently improve patient well-being.

In young individuals presenting with equivocal neurological symptoms, the decision is usually to obtain a head CT or head MRI, or to provide verbal reassurance and follow the patient's clinical course. At what point does the extra money spent on MRI provide such a small marginal benefit to call its use questionable? Would the other options of ordering a CT or providing verbal reassurance and following the clinical course of disease suffice? What factors can guide physicians to use this technology more efficiently?

A complete cost-effectiveness analysis must not only consider the medical information provided by MRI but also the potential psychological value of information to the patient (2). We examined the effects of selected parameters, particularly the prior probability of disease and the psychological value obtained from a head MRI scan, on its incremental cost-effectiveness.

METHODS

Decision Analysis

We constructed a decision model based on a hypothetical 35-year-old woman presenting to her physician with a single episode of an asymmetric neurological symptom.
Cost-effectiveness of MRI

Strategies and Outcomes in Patients with Equivocal Neurological Symptoms

TPms: treated
FPms: labeled only

TPocclusive: treated
TPaneurysm/avm: treated

TPloma: treated
TPastrocytoma: treated
TPbenign: treated

FNms: dx by clinical course
FNcvd
FNtumor
TN: reassure(MRI)

Figure 1. Strategies and outcomes in patients with equivocal neurological symptoms. TP = true positive; FP = false positive; FN = false negative; TN = true negative; F/U = follow clinical course without testing; MS = multiple sclerosis; CVD = occlusive vascular disease, arteriovenous malformation, aneurysm; AVM = arteriovenous malformation; Tumor = glioblastoma multiforme, astrocytoma, benign tumor.

suggesting the possibility of a neurologic disorder such as multiple sclerosis (MS). The physician performs a neurological examination to find evidence for a central nervous system lesion corresponding to the patient’s complaint. We exclude patients with symmetric sensory symptoms or weakness, pain syndromes, bladder dysfunction, neurobehavioral abnormalities, or seizures. Examples of symptoms include asymmetric sensory syndromes (i.e., paresthesias or numbness), weakness or clumsiness of a limb, unilateral partial visual loss, unsteadiness, vertigo, or diplopia. The major disease possibilities include MS, primary brain tumor, or cerebrovascular disease. In patients who have no underlying neurological disease, diagnostic possibilities include anxiety, mood disorder, chronic hyperventilation, hypochondriasis, or conversion disorder. Examples of neurological signs indicating potential central nervous system pathology include a unilateral plantar extensor response, unilateral hyperreflexia, limb ataxia, gait ataxia, and an afferent pupillary defect.

The model considers the long-term survival and the costs from a societal perspective of the following diagnostic strategies: advise no imaging tests but follow the patient for a diagnosis based on the clinical course, order a head CT, or order a head MRI (Figure 1). A detailed description of this decision analytic Markov simulation model has been published previously, along with a summary of the literature and information that provided the basis for our estimates of treatment effects, disease progression, test accuracy, and costs (28). We calculated the incremental cost-effectiveness for the MRI strategy compared with the CT strategy and the incremental cost-effectiveness for the CT strategy compared with the strategy of following the
clinical course. We performed separate analysis for patients with varying levels of suspicion of an underlying neurologic disease.

Probabilities

Prior Probability of Disease. The likelihood of underlying neurological disease in our baseline analysis is 30%. This was based on the probabilities of disease from our study assessing the impact of ancillary testing on the diagnosis of patients with suspected MS (15). In that study, patients presenting with neurological symptoms were categorized by the neurologists as “unlikely,” “possible,” or “probable” for the diagnosis of MS. Thirty percent of those with “possible” MS eventually developed MS or some other neurological disease. The probability of disease in the “unlikely” group was found to be 5% and in the “probable group” it was 80%. The effect of varying this prior probability on the incremental cost-effectiveness analysis is examined in the sensitivity analyses.

We assumed the chance of having cerebrovascular disease (CVD) or a primary brain tumor is 4% of the prior probability of MS, based on the ratios of MS to tumor and MS to cerebrovascular disease found in the same study sample (15). Of those individuals with primary brain tumors, we assumed that 33% were benign, 47% were intermediate risk, and 20% were high risk (4). We assumed that 90% of those individuals with cerebrovascular disease have transient cerebral ischemia from occlusive vascular disease, and the remaining 10% have cerebral aneurysms or an arteriovenous malformation.

Accuracy of Diagnostic Imaging. The accuracy of diagnostic imaging in patients with suspected MS is based on our recent technology assessment of head MRI and head CT scans in this same population (29). The MRI scans were performed on a 1.5-T scanner (GE Medical Systems, Milwaukee, WI) and the CT scans were performed on a third generation scanner. In that study, a positive MRI for MS (read as “probable MS” or “definitely MS”) had a sensitivity of 58% and a false-positive rate of 9%. A positive CT (“possibly MS”, “probably MS,” or “definitely MS”) had a sensitivity of 25% and a false-positive rate of 5% (area under the receiver operating characteristic [ROC] curve no better than chance alone). For tumors, we assigned both MRI and CT a sensitivity of 93% and a false-positive rate of 0% (22). For CVD, we assumed MRI has a sensitivity of 100% and a false-positive rate of 0%, and CT has a sensitivity of 88% and a false-positive rate of 5%. Although these low false-positive rates are probably not achieved in actual practice, they are the best estimates available from the literature. Also, since any “positive” for CVD or tumor would likely be followed by a more definitive test (angiography), the long-term consequences of false positives for these diagnoses would be minimal.

Diagnosis by Following the Clinical Course. Using this strategy, MS could be diagnosed only by the clinical course of the disease. We assumed that 90% of patients with exacerbating-remitting symptoms would eventually be correctly identified as having MS and that 10% would elude accurate diagnosis. In patients initially presenting in the chronic progressive stage of MS, we estimated that only 50% would be diagnosed correctly without imaging. Once diagnosed, we assumed that patients with chronic progressive MS would undergo treatment that would postpone their clinical progression for 6 months. We assumed that people with cerebrovascular disease would be diagnosed without imaging only when they went on to have a cerebrovascular event. Without imaging, all people with brain tumors would have progressive symptoms leading to diagnosis and treatment after a 6-month delay.
Neurological Events and Life Expectancy. We assumed that all patients destined to have MS develop either the exacerbating-remitting stage of MS or the chronic-progressive stage within 5 years of their initial presentation and that the proportion progressing to these stages over 5 years' time is constant. Approximately 2% of MS patients every 6 months will develop the chronic progressive form of the disease. We assumed that chronic progressive MS was associated with a small increase in mortality over the baseline rate (26) and that cyclophosphamide treatment would be initiated and would postpone any morbidity and increased mortality by approximately 6 months. Patients with transient cerebral ischemia from occlusive vascular disease face a 1% per year risk of infarction, 15% of which are fat (9;16). If diagnosed early, preventive stroke measures are used (e.g., blood pressure reduction, anticoagulants, antiplatelet agents, vascular surgery), reducing the risk of subsequent stroke by 30% (25). Cerebral aneurysms and arteriovenous malformations causing symptoms, if diagnosed early, are assumed to be cured after a neurosurgical procedure. If not diagnosed and treated, these patients face a 2.2% per year risk of having a neurological event, 67% of which are fatal (31;42).

Patients without neurological disease were assumed to have a normal life expectancy as were patients only progressing to exacerbating-remitting MS (23). We assumed that benign primary brain tumors (e.g., acoustic neuromas and meningiomas) had a good outcome with no change in life expectancy even if the diagnosis was delayed 6 months. In those with intermediate-risk tumors (e.g., astrocytomas), a delay in diagnosis has serious consequences, decreasing average survival from 6.9 years to 3 years (1;18). The life expectancy of those with high-risk tumors (e.g., glioblastoma multiforme) was estimated to be 1 year regardless of an early or delayed diagnosis (1;43).

Quality Adjustments for Long-Term Survival
We calculated outcomes in terms of quality-adjusted life-years (QALYs). These were derived by multiplying the life expectancy in a particular health state by a multiplier that reflects the quality of life (QOL) while in that state. The quality of life adjustments were derived from the work of Torrance et al. (41) and reflect psychological as well as physical well-being. They range from zero (representing death) to one (representing perfect health). For example, the investigators, by matching to these standardized scales, judged that the clinical scenario of exacerbating-remitting MS lead to a health state with a quality of life found by Torrance to equal 0.79.

Similar estimates were derived for each health state in the model. Those with severe MS (chronic progressive, nonambulatory) matched to a QOL of 0.36, and individuals with a nonfatal stroke to 0.79. For people without neurological disease, their QOL was 0.94 because symptoms had occurred and the suspicion of an underlying disease had been raised; after a normal MRI or after 5 years without the development of symptoms, their QOL returns to 1.0.

Costs
Beside the costs of diagnostic tests themselves (US $972 for MRI, US $540 for CT, in 1993 dollars), the health care costs associated with the diagnostic results were derived from a variety of sources, including the anticipated costs of further tests, long-term care, treatment, and physicians' fees. The procedures used for estimating cost are described in our previous report (28). Our analysis considers the societal perspective since we included all costs no matter how or by whom they would be
paid. We discounted both benefits and costs at a rate of 5% per year and inflated 1989 costs to 1993 dollars by using the Consumer Price Index for medical care prices.

**Incremental Cost-Effectiveness Ratios**

The probability of each outcome was multiplied by the QALYs associated with that health state, to arrive at an average expected utility for each clinical strategy. We performed a similar calculation to estimate the costs of each strategy. Based on the average QALYs and costs associated with each option, we calculated the incremental effectiveness (in QALYs), incremental costs, and incremental cost-effectiveness ratios associated with each strategy. For example, for the MRI strategy compared with the CT strategy, the incremental effectiveness is equal to the effectiveness of the MRI strategy minus the effectiveness of the CT strategy. We calculated a similar incremental change associated with each strategy’s costs. The incremental CE ratio for the MRI strategy compared with the CT strategy equals:

\[
\frac{\text{Cost of MRI strategy} - \text{Cost of CT strategy}}{\text{Effectiveness of MRI strategy} - \text{Effectiveness of CT strategy}}
\]

In situations where the incremental cost-effectiveness ratio was lower for the MRI strategy compared with the CT strategy, the CT strategy was excluded by the principle of extended dominance (12). By excluding the CT strategy, the incremental cost-effectiveness ratio for the MRI strategy was recalculated compared with the strategy of following the clinical course.

**Sensitivity Analysis**

We performed sensitivity analyses on selected variables. First, we varied the likelihood of an underlying neurological disease from 5% to 80%. Second, we varied the cost of MRI scan from $675 to $1,485, given the regional variation in the cost of this procedure. Third, by varying the quality-of-life adjustment for patients with exacerbating-remitting and exacerbating-progressive MS, we attempted to capture the projected effect that B-interferon might have on the results of the analysis.

Last, we examined one way in which patients respond to diagnostic information based on our study of the effects of information on patients with suspected MS (30). A negative MRI may improve patient well-being by reassuring the patient and thereby increase their quality of life. We estimated the impact of this effect by increasing the utility of the health state while waiting for test information from 0.94 to 1.0 by increments of 0.01. Therefore, the potential utility gained from a negative test ranges from zero (the base case analysis) to 0.06 (restoring perfect health). A negative CT could not carry this beneficial informational value since its accuracy for MS is no better than chance alone. In the analysis, we ascribed no “beneficial” effects to what turned out to be false-negative tests results, in part because most of the diseases falsely “undiagnosed” would progress and be detected clinically. Since all individuals with positive tests remained at a lower health state than normal, the model incorporated a negative impact of false-positive test results.

**RESULTS**

**Baseline Analysis**

Table 1 shows the implications of each diagnostic strategy in terms of benefits and associated costs for patients with a baseline 30% likelihood of an underlying neurological disease. The use of MRI improves the quality-adjusted life expectancy over both
Table 1. Baseline Cost-effectiveness Analysis (Probability of Neurological Disease = 0.30)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost ($)</th>
<th>Effectiveness (QALYs)</th>
<th>Incremental cost ($)</th>
<th>Incremental effectiveness (QALYs)</th>
<th>Incremental cost-effectiveness ($/QALY saved)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow clinical course</td>
<td>96,831</td>
<td>23.9005</td>
<td>804</td>
<td>.0396</td>
<td>20,303</td>
</tr>
<tr>
<td>CT</td>
<td>97,635</td>
<td>23.9401</td>
<td>427</td>
<td>.0042</td>
<td>101,670</td>
</tr>
<tr>
<td>MRI</td>
<td>98,062</td>
<td>23.9443</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Incremental Effects and Costs of Imaging at Different Likelihoods of Underlying Neurological Disease

<table>
<thead>
<tr>
<th>Likelihood of disease</th>
<th>Clinical strategy</th>
<th>Incremental* effectiveness (quality-adjusted days saved)</th>
<th>Incremental costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>CT</td>
<td>3</td>
<td>625</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td>less than 1</td>
<td>471</td>
</tr>
<tr>
<td>30%</td>
<td>CT</td>
<td>15</td>
<td>804</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td>2</td>
<td>427</td>
</tr>
<tr>
<td>55%</td>
<td>CT</td>
<td>26.5</td>
<td>983</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td>3</td>
<td>385</td>
</tr>
<tr>
<td>80%</td>
<td>CT</td>
<td>39</td>
<td>1163</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
<td>4</td>
<td>342</td>
</tr>
</tbody>
</table>

* CT strategy is incremental to the follow-up alternative, and MRI is incremental to the CT strategy.

The CT and the follow clinical course strategy; however, the costs are also higher. The incremental costs for an additional QALY saved (incremental cost-effectiveness ratio) for the MRI strategy compared with the CT strategy is $101,670. The incremental costs per additional QALY gained for the CT strategy compared with the follow clinical course strategy is $20,303. Using a criterion for a cost-effective medical intervention of $50,000 per QALY, imaging with CT is clearly cost-effective while MRI is not.

Sensitivity Analyses

We performed univariate sensitivity analyses to study the stability of the results and to examine the policy implications of imaging over a wide range of clinical situations. For each analysis, we varied one parameter while keeping the others at their baseline values. We then assessed whether this changed the incremental cost-effectiveness ratios or the preferred diagnostic strategy.

Table 2 shows the incremental effects and costs of imaging in various clinical circumstances represented by patients having different probabilities of underlying neurological disease. The MRI strategy retains its quality and length-of-life advantages over both the CT and the follow clinical course strategy for a wide range of patients (likelihood of neurological disease ranging from 5% to 80%). The additional benefits gained over the CT strategy are quite small and considerably lower than those achieved by the CT strategy over the follow clinical course strategy. The incremental gains for the MRI strategy over the CT strategy are less than 1 day, 2 days, 3 days, and 4 days at 5%, 30%, 55%, and 80%, respectively, likelihoods of underlying neurological disease. In addition, the cost of the MRI strategy is always higher than the CT strategy, indicating that the MRI strategy is never cost saving.
As the probability of an underlying neurological disease increases, the incremental cost-effectiveness ratios associated with the imaging strategies decline because the benefits of imaging increase more than the costs (Figure 2). For example, when the likelihood of disease is only 5%, the cost-effectiveness ratios of the CT and MRI strategy are $94,600 and $672,900, respectively. If the likelihood of an underlying neurologic disease is as high as 80%, the cost-effectiveness ratios of the CT and MRI strategy are only $11,000 and $30,000, respectively. Imaging with MRI becomes an attractive alternative to CT from a cost-effectiveness perspective since the incremental cost-effectiveness ratio of the MRI strategy meets or is lower than a cost-effectiveness threshold of approximately $50,000 per QALY. It equals this when the likelihood of an underlying neurological disease is 55%.

Varying the cost of MRI has a substantial impact on its incremental cost-effectiveness (top 2 bars, Figure 3). As the cost of MRI increases above baseline, the incremental cost-effectiveness ratio for MRI rises considerably, making it cost ineffective in most clinical circumstances, even in those with a high likelihood of a neurological disorder.

The incremental cost-effectiveness ratios and, therefore, the cost-effectiveness of MRI were dramatically affected by the potential psychological benefit resulting from a negative MRI exam (middle bars, Figure 3). As expected, this effect is most dramatic in clinical situations and for patients in whom the likelihood of disease is low (5%). If a negative MRI produces reassurance (i.e., restores patients back to
Figure 3. The incremental cost-effectiveness of MRI. Sensitivity analysis for selected variables. The horizontal axis represents the incremental cost-effectiveness (cost per quality-adjusted life-year saved) for the MRI strategy compared with the CT strategy. Each bar represents the range of cost-effectiveness ratios obtained by varying each variable over the specified range.

their prior health status), its use at all probabilities of disease becomes clearly cost-effective. If therapies like B-interferon increase the quality of life associated with exacerbating-remitting and exacerbating-progressive MS, this would favorably influence the cost-effectiveness ratios for the MRI strategy. For example, if we assume that B-interferon could have a maximal impact by restoring the quality of life completely back to normal (bottom bar, Figure 3), the incremental cost-effectiveness ratios for the MRI strategy decreases from $101,670 to $15,377, making MRI a highly cost-effective technology.

Figure 4 further illustrates the impact that the psychological value of diagnostic information could have on the incremental cost-effectiveness ratios. If a negative MRI result would have even a minimal benefit to the patient by partially reassuring them of the absence of an underlying neurologic disease, its use becomes attractive from an economic perspective. The cost-effectiveness ratios at every underlying probability of disease rapidly fall below $50,000 per QALY. They then favor the use of MRI at any level of clinical suspicion of an underlying neurological disease.

DISCUSSION

The cost-effectiveness of imaging with MRI or CT in patients presenting with neurological signs and symptoms depends on the likelihood of an underlying neurological disease, the costs of the test, and the psychological effects of imaging. In patients with a low probability of disease, neither MRI nor CT is cost-effective when looked at only from the standpoint of a survival benefit. However, if there is a clear need for reassurance that only imaging with MRI can meet, then its use may be quite
Figure 4. The influence of benefit gained from a negative MRI result on its cost-effectiveness. Sensitivity analysis of the utility gained from a negative MRI result at the three different probabilities of neurological disease. The slanted axis represents the incremental increase in the utility of the health state associated with a negative MRI result. The y-axis represents the incremental cost-effectiveness ratio of the MRI strategy compared with the CT strategy.

appropriate from a cost-effectiveness viewpoint. At high likelihoods of disease (over 50%), diagnostic imaging using either CT or MRI results in favorable incremental cost-effectiveness ratios even without these psychological considerations.

Cost-effectiveness analysis may help to elucidate the most efficient use of new technologies. If performed over a wide range of possible clinical applications, it provides an overall picture of a technology's value and its role. Unfortunately, only one other analysis of the cost effectiveness of MRI has been published. Simon and Lubin (37) performed a cost-effectiveness analysis of CT and MRI in patients presenting with dementia. For a 70-year-old demented individual, they found that MRI was not cost-effective compared with CT since the incremental cost-effectiveness ratios ranged from $61,000 to $146,000 per QALY gained (in 1982 US dollars). Clearly then, whether MRI provides a cost-effective alternative to the purchase and use of other neuroimaging modalities over a wide range of uses remains to be determined.

Few published decision analyses have extended their estimates of utility and thereby of cost-effectiveness beyond functional outcome. There are, however, an accumulating number of studies showing that including patient references and psychological effects can critically influence treatment decisions and the use of diagnostic tests (6;11;20;27;33). Cost-effectiveness analyses of diagnostic tests or procedures that fail to incorporate their informational value may not accurately represent the true cost and affect trade-offs. Furthermore, there is mounting evidence that diagnostic tests have real and important psychological effects. Marton et al. (24) showed
that patients with dyspepsia place a high value on an upper gastrointestinal series and on tests in general. The desire for certainty was an important reason why patients wanted the procedure. Sox et al. (38) in their study of patients with chest pain suggested that electrocardiographic testing may accelerate the resolution of symptoms through its psychological effects. Berwick and Weinstein (8) studied the informational value women placed on obstetrical ultrasound. They found that 44% of the value of the test was in addition to its effect on medical decision making. We showed previously that the diagnostic workup benefits patients with suspected MS and improves their sense of well-being (30). O'Connor and colleagues (32) also found beneficial changes in patients with suspected MS, and concluded that "given that MS is an incurable disorder, the observed changes in health attitudes associated with the workup represent one of the few interventions in this disease where beneficial effects can be identified and measured" (32).

Asch and colleagues (3) illustrated a way to incorporate the utility of diagnostic and prognostic information into decision analyses of diagnostic interventions. This approach challenged basic decision theory, which supported diagnostic testing only when the results alter treatment. If patients value information, the decision to test may be justified even if it does not lead to a change in treatment. Our analysis suggests strongly that this is the case for patients with suspected neurological disease.

These results also highlight the difficulty with establishing practice guidelines without taking the individual patient's perspective into consideration. For those patients who require and depend on reassurance from a negative test result, testing is a reasonable and cost-effective alternative. However, when this is not the case, the test may not be indicated. Others have begun to point out the difficulty with establishing broad practice parameters and the need to individualize practice guidelines based on similar concerns (2). Our study is among the first to empirically demonstrate the importance of developing methods to do this and the hazards of proceeding without it. In the absence of such "flexible" guidelines, making decisions for the variety of patients seen in office practice will continue to require informed clinical judgment.

This study has several limitations. The decision analysis, by necessity, is an oversimplification of the clinical situation confronting the physician. Generalizations and assumptions had to be made in the construction of the model. The usefulness of the approach, however, lies not in the exactness of these estimates, but in the insights and general guidance for diagnostic test uses in this clinical situation that it provides. This study also illustrates the difficulties of performing a technology assessment in an ever-changing and dynamic medical environment. For example, we attempted to capture the potential effects B-interferon may have in patients with early MS by varying the health states most likely affected by the introduction of this new medication. The actual impact of B-interferon on a patient's quality of life is not yet known (19). The model will permit the incorporation of new information into this complex decision as it becomes available. Also, we purposely excluded from this analysis the opting of the patient to a subspecialist to make a decision about the need for imaging. Although the capabilities of certain subspecialty physicians (e.g., neurologists) in evaluating such patients may justify referral, their ability to do so remains unquantified, and many physicians rely on MRI scans for this clinical problem (3). Our analysis provides information on MRI's cost-effectiveness regardless of who suggests or orders it. Finally, the efficacy of the new generation MRI scanners has improved, creating a "moving target" for technology assessment (17). How improvements in image quality, including the use of gadolinium enhancement, translate into
improved diagnostic accuracy is also not yet known. Again, the availability of this model should facilitate reanalysis when this is better defined.

In summary, this analysis shows that the cost-effectiveness of MRI in patients who present with neurological signs and symptoms depends on the likelihood of an underlying disease and the value the patient places on diagnostic information. The use of MRI in patients with low probability disease is generally cost ineffective unless the physician believes the patient will benefit from the reassurance of a negative test.

Neuroradiological procedures account for most of the current use of MRI, and as it becomes even more accessible, the potential for expanded use will be great. This analysis should help to improve individual decisions about the use of this expensive medical resource.

REFERENCES
Cost-effectiveness of MRI


