COST-EFFECTIVENESS OF MAGNETIC RESONANCE IMAGING AND ENTEROCLYSIS IN THE DIAGNOSTIC IMAGING OF CROHN'S DISEASE

Margrit Ebinger
Andrea Rieber
Reiner Leidl
University of Ulm

Abstract

Objectives: To compare the cost-effectiveness of magnetic resonance imaging (MRI) and enteroclysis in patients with Crohn's disease (CD).
Methods: A decision analytic model was performed considering the correct diagnoses of CD and complications such as fistulas and abscesses as effects. Costs were estimated in Euro (€) using German fee schedules.
Results: MRI was more effective and more costly compared with enteroclysis. Incremental cost-effectiveness of MRI versus enteroclysis was €1,595 per additional correctly diagnosed patient.
Conclusions: The use of MRI in the work-up of patients with CD cannot be generally recommended from an economical perspective, but results of sensitivity analysis suggest that in patients with high prevalence of complications, MRI becomes as cost-effective as enteroclysis, which is accepted standard diagnostic imaging.

Keywords: Cost-effectiveness analysis, Crohn's disease, Magnetic resonance imaging, Enteroclysis

Crohn's disease (CD) is a chronic inflammatory bowel disease. In the course of the disease, up to 50% of patients develop intestinal complications such as fistulas and abscesses (16). Conventional enteroclysis (EC) is the gold standard in the diagnostic of CD. Recently, however, magnetic resonance imaging (MRI) is increasingly being used in the work-up of patients with CD, despite being a highly cost-intensive radiologic procedure. Our objective was to compare the cost-effectiveness of MRI and EC in patients with CD regarding the diagnoses of complications such as fistulas or abscesses. A cost-effectiveness analysis (CEA) of MRI and EC in the work-up of patients with CD was performed, using data from a clinical study in a department of diagnostic radiology (24). We developed a decision model that integrated all three possible diagnoses (CD, fistula, abscess) as a study endpoint. A further aim of the analysis was to derive clinically useful information from the economic results of the model and to discuss them in the context of decision making. These data may be useful in developing recommendations for treatment guidelines for a physician using MRI or EC in patients with CD.

METHODS

The economic evaluation accompanied a clinical trial that compared the diagnostic value of EC and MRI (24). For EC, double contrast was achieved by barium sulfate and methylcellulose solution following transnasal intubation. MRI examinations were performed using a 1.5-tesla system (Magnetom, Siemens AG) and intravenous application of gadolinium DTPA (Magnevist, Schering, Berlin, 0.1 mmol/kg weight). Positive contrast agent was used (Magnevist enteral, Schering, Berlin), which was added to methylcellulose in a 1:10 solution during EC. A total of 84 patients with confirmed CD and suspected complications were enrolled in the study. In all patients, histologic findings obtained from endoscopy of the terminal ileum served as a reference standard. The diagnoses of fistulas and abscesses were confirmed by surgery. The patients were aged 19–81 years (mean: 38 years) and 54.7% were women.

CEA was performed using a decision-analytic approach considering suggested quality standards of economic modeling (26). A decision-tree model was constructed (Decision Analysis by TreeAge, DATA; version 3.0.3) and incremental cost-effectiveness ratios (ICER) were computed. All work-up options were considered, depending on whether the physician chose to use MRI or EC. According to clinical relevance, the following order was used: diagnostic testing for CD, afterwards considering additional findings such as abscesses, and thereafter fistulas. Prevalence, sensitivity, and specificity from the clinical study are shown in Table 1.

Measuring Effectiveness

Effectiveness was measured in terms of a correctly diagnosed patient, including the correct negative or positive diagnosis of inflammatory lesions (CD), abscesses, and fistulas simultaneously. Because of clinical and economic considerations, a true-positive test result was equally weighted as a true negative test result. It was assumed that the right information in each case leads to appropriate patient management. In the case of a true-positive test, appropriate treatment (medical treatment, surgery) can be started. In the case of a true-negative test, unnecessary medication or even operative procedure are prevented. The effect (E) variable can only assume the value of 0 or +1. If all three diagnoses were completely correct, the value of +1 was assigned. The value was defined as zero, if at least one of the three diagnoses was incorrect, either false-positive or false-negative.

Table 1. Model Parameters and Range of Sensitivity Analysis

Parameter	Base case (24)	Range	Reference
Probabilities			
Prevalence of CD in patients suspected of CD	1.0	0.2–1.0	4;19;24;25;30
Prevalence of fistulas in CD	0.2	0.1–0.7	3;7;8;12;21;22;25
Prevalence of abscesses in CD	0.1	0.1–0.3	7;18;21;22;28
Test performance			
Sensitivity (CD) of EC	0.85	0.66–1.0	6;19;20;29
Specificity (CD) of EC	0.77	0.82–0.98	1;19;20;29
Sensitivity (CD) of MRI	0.95	0.94–1.0	27;30
Specificity (CD) of MRI	0.93	0.95–1.0	11;30
Sensitivity (fistula) of EC	0.18	Not found	
Specificity (fistula) of EC	1.0	Not found	
Sensitivity (fistula) of MRI	0.71	0.48–1.0	11;15;23
Specificity (fistula) of MRI	1.0	0.71–1.0	2;17
Sensitivity (abscess) of EC	0	Not found	
Specificity (abscess) of EC	1.0	Not found	
Sensitivity (abscess) of MRI	0.78	0.55–1.0	17;23
Specificity (abscess) of MRI	1.0	0.77–1.0	17;23
Costs			
Conventional EC	€180	€180–€240	Assumed (5)
MR imaging	€560	€560–€770	Assumed (5)

Measuring Costs

Cost estimates exclusively used direct medical costs of both diagnostic strategies, whereas costs following the diagnostics were not considered. A standard set of services was defined using specifications from the department of radiology. Costs for medical services were estimated in Euro (€), based on standard charges for German hospitals using German fee schedules (5). Materials were calculated using hospital prices. Physician fees were included. Total amounts were estimated for both procedures and inserted in the model as cost variables. Finally, ICER was defined as outcome: costs per correctly diagnosed patient.

Sensitivity Analysis

To test the stability of the results and to handle uncertainty of the parameter values, multiway sensitivity analyses were conducted for model assumptions on prevalence and on test performance. Parameter ranges were taken from the literature. Threshold values were calculated where no information from literature could be obtained (e.g., test performance of EC diagnosing abscesses and fistulas). For cost parameters, ranges for possible sets of services were defined by expert opinion from physicians in the department of radiology. An optimal scenario (scenario 4) compiled all variables (prevalence, test characteristics, and costs) in favor of MRI. Table 1 shows the parameters for the base case and the range of sensitivity analysis.

RESULTS

Enteric fistulas were diagnosed in 17 patients (prevalence: 0.2). Only 3 of 17 patients with fistulas were diagnosed using EC, while MRI showed intestinal fistula formation in 12 patients of 17. Abdominal abscesses were diagnosed in 9 of 84 patients (prevalence: 0.1). EC failed in all cases, whereas seven abscesses could be found in MRI.

Base Case

MRI costs an additional €380 per diagnostic investigation compared with conventional EC. ICER of MRI amounts to €1,595 compared with EC (€283). All costs and effects are summarized in Table 2.

Sensitivity Analysis

At a lower prevalence of CD, fistulas, and abscesses (Table 3, scenario 1a), one additional correctly diagnosed patient using MRI costs about 40% more compared with the base case, whereas a higher prevalence in the study population (scenario 1b) is −50%. In this case the ICER for MRI has about the same order of magnitude as EC in this scenario. A variation of test performance in favor of MRI (scenario 2a) resulted in a higher ICER for EC compared with the more effective MRI. This result is called extended dominance (13;14). ICER of MRI was about 75% lower compared with the base case. For scenario 2b, a threshold analysis was performed. The threshold value was 0.68 for sensitivity and specificity, 0.69 showing clear

Table 2. Base Case Results and ICER

Strategy	Total cost	Incremental cost	Total effects	Incremental effects	Cost-effectiveness ratio	Cost per effect gained (ICER)
EC vs. no diagnostics	€180	€180	0.635 E	0.635 E	€283/E	€283/E
MRI vs. EC	€560	€380	0.874 E	0.239 E	€641/E	€1,595/E

Table 3. Sensitivity Analysis on ICER (MRI vs. EC, EC vs. No Diagnostics)

1. *Sensitivity analysis of prevalence of CD, abscesses, and fistulas on ICER*		
Scenario 1a	Lower limit of prevalence in each diagnosis (CD, A, F)	€2,302/E (MRI) €238/E (EC)
Scenario 1b	Upper limit of prevalence in each diagnosis (CD, A, F)	€841/E (MRI) €710/E (EC)
2. *Sensitivity analysis of test performance on ICER*		
Scenario 2a	Best test characteristics for MRI Worst test characteristics for EC	€380/E (MRI) >€180,000,000/E (EC) (extended dominance for MRI)
Scenario 2b (Threshold analysis)	Best test characteristics for EC Worst test characteristics for MRI	Threshold value: 0.68 for sensitivity and specificity in diagnosing F/A
3. *Sensitivity Analysis of cost on ICER*		
Scenario 3a	Lowest cost assumptions for MRI Highest cost assumptions for EC	€1,344/E (MRI) €377/E (EC)
Scenario 3b	Lowest cost assumptions for EC Highest cost assumptions for MRI	€2,472/E (MRI) €283/E (EC)
4. *Best case assumptions for MRI in all parameters*		
Scenario 4	Upper limit of prevalence, best test characteristics for MRI, worst test characteristics for EC, lowest cost assumptions for MRI, highest cost assumptions for EC	€321/E (MRI) >€239,000,000/E (EC) (extended dominance for MRI)

For parameters and ranges, see Table 1. The base case renders an ICER of €1,595/E for MRI and of €283/E for EC.

dominance of EC regarding the diagnosis of fistulas and abscesses. Using cost assumptions in favor of MRI (scenario 3a), the ICER was reduced about 15%; however, cost assumptions in favor of EC (scenario 3b) increased the ratio by more than 55% compared with the base case. Inserting the model optimal values for MRI and worst parameters for EC in all fields resulted in a lower ICER for MRI compared with EC and a total reduction of about 80% in the ICER of MRI compared with the base case. Thus, MRI was more effective at a lower ICER compared with EC if probabilities, test performance, and costs were varied in favor of MRI (extended dominance of MRI).

DISCUSSION

The clinical effectiveness of using MRI in the work-up of patients with CD has been demonstrated (24). Consistent with other studies, MRI adds information of clinical and therapeutical relevance in cases where no abnormalities were seen using conventional EC. Recommending certain diagnostic strategy availability, costs, preferences of patients, and relevance for therapy are decisive as well as diagnostic accuracy. Besides limited availability, high costs arc often seen as a disadvantage of MRI. To our knowledge, our study is the first to compare the cost-effectiveness of MRI and EC in the work-up of patients with CD. In the base case analysis, the ICER of MRI versus EC was €1,595 per correctly diagnosed patient compared with €283 for EC versus no diagnostics (Figure 1). This means that approximately €1,600 have to be paid for one additional patient, who could be correctly staged regarding all three possible diagnoses, namely CD, abscesses, and fistulas. To assess if the likely diagnostic benefits are worth the costs, we transferred the concept of number needed to treat (NNT) from measuring effects of therapy to measure diagnostic outcomes (number needed to be treated to prevent one event [NNT] = 1/{baseline risk (control group) − risk (therapy group)} = 1/absolute risk reduction; number needed

https://doi.org/10.1017/S0266462302000521 Published online by Cambridge University Press

to be diagnosed to gain one effect = 1/{effects (new imaging method) − effects (standard imaging method)} = 1/marginal effects). Our results indicate that about four patients have to be investigated using MRI instead of EC to correctly diagnose one additional patient (1/0.239 = 4.18).

Sensitivity analysis identified three possible ranges of outcomes regarding the cost-effectiveness of MRI versus EC. First, in patients with a higher prevalence of CD, abscesses, and fistulas than in the base case, ICER for MRI and EC became nearly identical. Figure 1 illustrates changes in ICER when prevalence of disease (CD) and additional findings (A, F) are modified. In every case ICER declines when prevalence rises. Starting from the prevalence in a treatment group, a physician could read the corresponding ICER by using this figure.

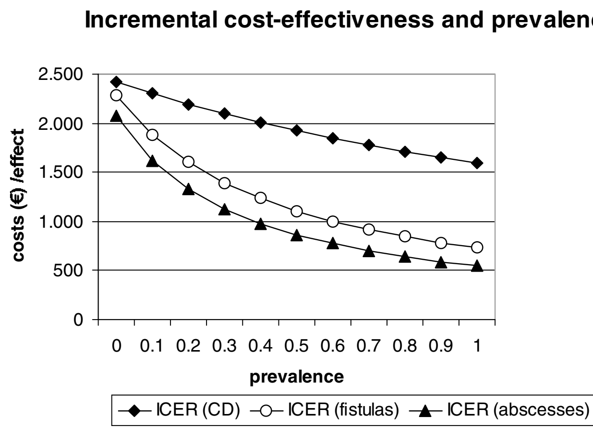

Figure 1. Changes in ICER in dependence of prevalence. For each diagnosis (CD, fistulas, and abscesses) prevalence was varied from 0 to 1, whereas the prevalence of the other two diagnoses remained.

Second, extended dominance of MRI could be seen in two different scenarios: ICER of MRI was lower compared with EC when sensitivity and specificity could be improved and test characteristics of EC were worse than in our study (scenario 2a) and in the best case scenario (scenario 4). However, both scenarios are not very realistic. Our base case estimates of MRI/EC test performance were obtained from a high-quality clinical study performed by experienced radiologists. Some published reports suggest that MRI has a sensitivity/specificity of 1.0 (30). We have found no published data on diagnostic accuracy of EC for fistulas and abscesses. Hence, a threshold analysis was performed. We found that for EC, a sensitivity/specificity of 0.69 resulted in a clear dominance. Whereas the value of 0.69 could be reached in the work-up of CD (maximum of sensitivity and specificity of 0.82 in published literature) (Table 1), a sensitivity of 0.69 diagnosing abscesses or fistulas using EC could hardly be achieved (sensitivity for fistulas: 0.18; sensitivity for abscesses: 0) (Table 1).

Third, the ICER of MRI relative to EC consistently remained in a range of €1,300 to €2,400 per correctly diagnosed patient. Even assuming an efficient use of MRI at low costs, the ICER did not fall below €1,000 and was higher than that of EC.

A strict dominance (with higher effects and lower costs) could not be found in any scenario tested. To formulate a special treatment policy, the use of MRI nevertheless is acceptable when the ICER is lower than an accepted threshold price. Decision makers therefore should value the additional benefit provided by the diagnostic imaging (9). Often a program is defined as cost-effective if its cost-effectiveness ratio compares favorably with that of an already used and thus widely accepted program (10). For some types of investigations that have been evaluated in terms of quality-adjusted life-years or gained life-years, comparative thresholds may exist (10). Data for the endpoint "correctly diagnosed patient" are lacking so far.

CONCLUSION AND POLICY IMPLICATIONS

On the basis of the economic evaluation presented here, it could not conclusively be determined whether MRI should be generally recommended in the work-up of CD in terms of dominance. EC as accepted standard diagnostic imaging is less costly but, regarding the diagnosis of fistulas and abscesses, is also less effective. From an economic point of view, the use of the more expensive but more effective technology, MRI, in the work-up of CD is acceptable for planning treatment policies. Sensitivity analysis, however, identified three possibilities regarding the cost-effectiveness of MRI versus EC. First, in patients with CD and a high probability of fistulas and abscesses, the use of MRI could be recommended, because of the costs for an additional effect range in the same order of magnitude as EC. Second, under optimal assumptions for MRI in terms of prevalence, test characteristics, and costs, one effect event is less costly compared with EC, but this is not a realistic case. Third, additional effects gained by MRI are more costly compared with EC. Costs of about €1,595 have to be paid for an additional correctly diagnosed patient. In these cases, the choice between MRI and EC depends on whether the ICER is considered acceptable. To establish a useful decision rule as to whether MRI or EC should be used as imaging method, decision makers' willingness to pay per unit of effectiveness has to be determined. The results of our CEA could support decision makers with respect to treatment policy for imaging patients with CD in a radiology department or for third-party payers making reimbursement decisions. For certain subgroups of patients, MRI may very well be considered as cost-effective diagnostic strategy in the work-up of CD.

REFERENCES

1. Barloon TJ, Yang CJ, Berbaum KS, et al. Plasma electrolyte status following enteroclysis in patients with partial small-bowel obstruction. *Invest Radiol.* 1989;24:616-618.
2. Beckingham IJ, Spencer JA, Ward J, et al. Prospective evaluation of dynamic contrast enhanced magnetic resonance imaging in the evaluation of fistula in ano. *Br J Surg.* 1996;83:1396-1398.
3. Canin-Endres J, Salky B, Gattorno F, Edye M. Laparoscopically assisted intestinal resection in 88 patients with Crohn's disease. *Surg Endosc.* 1999;13:595-599.
4. Chernish SM, Maglinte DD, O'Connor K. Evaluation of the small intestine by enteroclysis for Crohn's disease. *Am J Gastroenterol.* 1992;87:696-701.
5. Deutsche Krankenhausgesellschaft. *DKG-NT, Tarif der Deutschen Krankenhausgesellschaft für die Abrechnung erbrachter Leistungen und für die Kostenerstattung vom Arzt an das Krankenhaus.* Stuttgart: Verlag W. Kohlhammer; 1997.
6. Dixon PM, Roulston ME, Nolan DJ. The small bowel enema: a ten year review. *Clin Radiol.* 1993;47:46-48.
7. Gasche C, Moser G, Turetschek K, et al. Transabdominal bowel sonography for the detection of intestinal complications in Crohn's disease. *Gut.* 1999;44:112-117.
8. Harper PH, Fazio VW, Lavery IC, et al. The long-term outcome in Crohn's disease. *Dis Colon Rectum.* 1987;30:174-179.
9. Hirth RA, Bloom BS, Chernew ME, Fendrick AM. Willingness to pay for diagnostic certainty: Comparing patients, physicians, and managed care executives. *J Gen Intern Med.* 1999;14:193-195.
10. Hirth RA, Chernew ME, Miller E, et al. Willingness to pay for a quality-adjusted life year: In search of a standard. *Med Decis Making.* 2000;20:332-342.
11. Holzknecht N, Helmberger T, von Ritter C, et al. MRI of the small intestine with rapid MRI sequences in Crohn disease after enteroclysis with oral iron particles. *Radiologe.* 1998;38:29-36.

12. Hussain SM, Outwater EK, Joekes EC, et al. Clinical and MR imaging features of cryptoglandular and Crohn's fistulas and abscesses. *Abdom Imaging.* 2000;25:67-74.
13. Johannesson M, Weinstein MC. On the decision rules of cost-effectiveness analysis. *J Health Econ.* 1993;12:459-467.
14. Karlsson G, Johannesson M. The decision rules of cost-effectiveness analysis. *Pharmacoeconomics.* 1996;9:113-120.
15. Koelbel G, Schmiedl U, Majer MC, et al. Diagnosis of fistulae and sinus tracts in patients with Crohn disease: Value of MR imaging. *Am J Roentgenol.* 1989;152:999-1003.
16. Laniado M, Makowiec F, Dammann F, et al. Perianal complications of Crohn disease: MR imaging findings. *Eur Radiol.* 1997;7:1035-1042.
17. Lunniss PJ, Barker PG, Sultan AH, et al. Magnetic resonance imaging of fistula-in-ano. *Dis Colon Rectum.* 1994;37:708-718.
18. Madsen SM, Thomsen HS, Munkholm P, et al. Active Crohn's disease and ulcerative colitis evaluated by low-field magnetic resonance imaging. *Scand J Gastroenterol.* 1998;33:1193-1200.
19. Maglinte DD, Chernish SM, Kelvin FM, et al. Crohn disease of the small intestine: Accuracy and relevance of enteroclysis. *Radiology.* 1992;184:541-545.
20. Maglinte DD, Kelvin FM, O'Connor K, et al. Current status of small bowel radiography. *Abdom Imaging.* 1996;21:247-257.
21. Marcos HB, Semelka RC. Evaluation of Crohn's disease using half-fourier RARE and gadolinium-enhanced SGE sequences: Initial results. *Magn Reson Imaging.* 2000;18:263-268.
22. Michelassi F, Stella M, Balestracci T, et al. Incidence, diagnosis, and treatment of enteric and colorectal fistulae in patients with Crohn's disease. *Ann Surg.* 1993;218:660-666.
23. Orsoni P, Barthet M, Portier F, et al. Prospective comparison of endosonography, magnetic resonance imaging and surgical findings in anorectal fistula and abscess complicating Crohn's disease. *Br J Surg.* 1999;86:360-364.
24. Rieber A, Wruk D, Potthast S, et al. Diagnostic imaging in Crohn's disease: Comparison of magnetic resonance imaging and conventional imaging methods. *Int J Colorectal Dis.* 2000;15:176-181.
25. Schunk K, Kern A, Heussel CP, et al. Hydro-MRT with fast sequences in Crohn's disease: A comparison with fractionated gastrointestinal passage. *Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr.* 1999;170:338-346.
26. Sculpher M, Fenwick E, Claxton K. Assessing quality in decision analytic cost-effectiveness models: A suggested framework and example of application. *Pharmacoeconomics.* 2000;17:461-477.
27. Shoenut JP, Semelka RC, Magro CM, et al. Comparison of magnetic resonance imaging and endoscopy in distinguishing the type and severity of inflammatory bowel disease. *J Clin Gastroenterol.* 1994;19:31-35.
28. Stetter M, Schuster E, Knoflach P. Long-term follow-up of Crohn disease. *Z Gastroenterol.* 1992;30:454-458.
29. Tribl B, Turetschek K, Mostbeck G, et al. Conflicting results of ileoscopy and small bowel double-contrast barium examination in patients with Crohn's disease. *Endoscopy.* 1998;30:339-344.
30. Umschaden HW, Szolar D, Gasser J, et al. Small-bowel disease: comparison of MR enteroclysis images with conventional enteroclysis and surgical findings. *Radiology.* 2000;215:717-725.