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Ulf Böckenholt and Elke U. Weber

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# Use of Formal Methods in Medical Decision Making:

## A Survey and Analysis

ULF BÖCKENHOLT, PhD, ELKE U. WEBER, PhD

Apparent low usage of formal decision techniques by general clinicians has raised questions about dissemination methods and about the techniques' perceived usefulness. Two literature searches examined whether use of formal decision techniques among clinicians had indeed failed to increase from the 1970s to the 1980s. A general MEDLINE search for the period 1983–87 relative to 1973–77 indicated that usage of formal decision techniques had more than doubled. This increase, however, was due to increased coverage of formal decision techniques in specialist methods journals. A manual search of seven major clinical journals and a MEDLINE search restricted to the clinical journals of the manual search disclosed *no* increase in overall usage for the same time periods. MEDLINE detected only a small subset of the actual instances of formal method usage found by the manual search. Individual medical subspecialties were found to utilize different formal decision techniques to different degrees. The authors suggest interventions that may increase the usage of formal decision techniques among general clinicians. *Key words*: decision analysis; decision automation; decision trees; Bayes' theorem; sensitivity analysis; ROC analysis; formal modeling. (*Med Decis Making* 1992;12:298–306)

The last 30 years have seen the introduction of a variety of quantitative and otherwise formal modeling approaches into medical decision making. Advertised as powerful and helpful tools for the medical practitioner in an increasingly complex decision environment, techniques such as Bayesian updating and utility assessment were intended to supplement physicians' intuitive reasoning and decision making. Evidence continues to accumulate that physicians' intuitive judgments are often fundamentally flawed.<sup>1</sup> Examples include the neglect of base rate and other statistical information,<sup>2,3</sup> the overvaluation of certainty,<sup>4</sup> and the inappropriate use of surgical procedures.<sup>5</sup> However, usage of formal decision methods among practicing physicians seems to have remained disappointingly low.

The optimism of the 1970s and early 1980s about the potential of decision-analytic techniques<sup>6,7</sup> has recently given way to a more balanced realism,<sup>8–10</sup> as well as to some soul-searching about ways to boost

acceptance and usage.<sup>11</sup> Thus, the Society for Medical Decision Making convened a retreat to consider "educational strategies for decision analysis" that would improve clinicians' exposure to techniques for incorporating quantitative information in an organized and logical fashion.<sup>12</sup>

Opinions about the reasons for the apparent reluctance of the medical community to use formal decision methods differ. Some argue that such reluctance is due to insufficient education.<sup>13</sup> Others attribute it to perceptions among practitioners that the techniques are inappropriate.<sup>14,15</sup> Still others claim that the techniques are slowly being adopted, but that observers' expectations about the speed with which such innovations can be accepted are too high.<sup>12</sup>

These attributions address critical components in the process of inducing a physician to use a formal approach to decision making. First, a physician must know about the existence of a method or technique and about its potential benefits before he or she will contemplate using it. Second, the physician must be motivated to change the way he or she is currently making investigative, diagnostic, or treatment decisions. Such motivation may arise from seeing convincing evidence that current methods are not in the patients' or in the doctor's best interest. Third, if a formal approach is attempted, it must prove itself *useful*. That is, perceived benefits must outweigh the costs, where both costs (e.g., accessibility of the method, ease of use) and benefits (e.g., patient welfare, health care costs) will most likely be multidimensional.

Low usage of formal decision approaches can be

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due to problems at any of the three stages. Courses on medical decision making that introduce decision analysis and other formal approaches to medical students are of recent origin and still not very widespread. Lusted's pioneering textbook appeared only in 1968,<sup>16</sup> and as recently as 1981, only 15% of all institutions surveyed by the Society for Medical Decision Making<sup>17</sup> offered some type of educational program in medical decision making. Older physicians have had to depend on self-education or on short continuing education seminars offered at professional meetings such as those of the American College of Physicians.

Little is known about clinicians' motivation. The main motivation for physicians to learn about or use formal decision approaches currently appears to be external. There is increasing pressure on them from above (HMOs; Medicare) to become more cost-effective diagnosticians<sup>18–20</sup> and from below (more sophisticated and litigious patients) for greater accountability. However, despite these external pressures to improve their intuitive decision-making procedures, there seems to be little overt manifestation of concern among physicians about decision errors or inefficiency and thus little motivation for experimenting with new, formal methods.

Evaluating the utility of formal decision methods is no easy task. Routine clinical decision making does not provide for a control group, and a physician will rarely know what the outcome would have been if a particular method had or had not been used. In addition, the criteria for deciding on the quality of intuitive vs. formal/aided decision making are controversial.<sup>14</sup> This makes it hard to convince clinicians of the benefit of formal decision methods at an individual level. At the aggregate level, however, studies such as those by the RAND corporation (e.g., Chassin et al.<sup>5</sup>) continue to show large percentages of suboptimal diagnostic and treatment decisions when physicians are left to their intuitive devices.

Finally, there is concern not just among physicians but also among a segment of the decision research community that the assumptions underlying current formal methods are too restrictive and unrealistic, that methods are designed for situations that are too static,<sup>21</sup> that they fail to capture or go against the way information is available to and/or is processed by physicians,<sup>15</sup> that utility assessment is too labile,<sup>22</sup> and that important variables are being left out.<sup>23</sup> According to this reasoning, the current generation of formal methods may not be relevant in the great majority of decision situations encountered in a clinical context, and it may be doctors' awareness of these inadequacies that keeps them from using the methods.

#### THE PRESENT STUDY

Current perceptions among members of the MDM community about the continuing reluctance of general

**Table 1** • Clinical Practice Journals Included in the Review of References to Formal Decision Methods

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<i>American Journal of Cardiology</i>
<i>American Journal of Medicine</i>
<i>American Review of Respiratory Disease</i>
<i>Annals of Internal Medicine</i>
<i>Archives of Internal Medicine</i>
<i>JAMA</i>
<i>New England Journal of Medicine</i>

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clinicians to employ formal decision methods are largely based on subjective impressions. The present study attempts to provide more objective evidence about general trends in the acceptance of formal decision methods. It is difficult to assess actual utilization rates in clinical practice. One can think of a variety of variables, however, that may be related to (and thus indicative of) utilization rates. There is, for example, some evidence that increased utilization of theories or techniques in clinical practice results in their being mentioned more frequently in clinical journal articles.<sup>24</sup> Moreover, usage of formal methods in journal articles widely read by clinical practitioners may not only be a reflection of but also a *contribution to* greater acceptance and utilization of such techniques. Thus, for purposes of this paper, we assume that the relative frequency with which formal decision methods are being used or discussed in mainstream clinical journal articles can serve as a proxy for the perceived usefulness and utilization of these techniques among clinical practitioners. If it is true that greater acceptance of formal modeling approaches will eventually result from a slow (but steady) diffusion process, one should expect to see an increasing trend in use over time. To detect such a trend, this study compared the frequency of references to formal decision method usage in seven clinical journals (table 1) over a five-year period during the mid-70s with that in the corresponding period during the mid-80s.

The present study has also investigated possible *reasons* for a lack of growth in usage of formal decision techniques among clinicians, e.g., the possibility that formal methods are not being accepted because of their perceived limitations. Politser<sup>14</sup> provides an extensive review of the relative strengths and weaknesses of a variety of formal decision-analytic approaches for medical decisions, a discussion that need not be repeated here. The present study looks at differential usage rates for different techniques, with the assumption that the usage rate may reflect the perceived usefulness of the technique.\* Along the same lines, the paper also compares acceptance of formal modeling

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\*There are, of course, factors other than perceived usefulness that also determine the usage rate of a method. Methods differ, for example, in the breadths of their domains of application. (Just as, in statistics, there are more opportunities to use a t-test than a factor analysis.)

**Table 2** • Medical Subspecialties Used in the Classification of References to Formal Decision Methods

Cardiology	Medical ethics
Ear, nose, and throat	Nephrology
Endocrinology	Neurology
Family medicine	Nutrition
Gastroenterology	Ob/gyn
General medicine	Oncology
Hematology	Pediatrics
Immunology	Psychiatry
Infectious disease	Pulmonary
Internal medicine	Radiology
Legal medicine	Surgery

approaches in different subspecialties of medicine. Differences on this dimension may be instructive in pointing out differential usefulness of formal methods as a function of characteristics of the clinical decision task or domain (e.g., differential complexity, different types of data, or different decision criteria).

## Method

### MODELS

To categorize the formal methods used in medical decision making, we followed the classification of Pauker and Kassirer,<sup>25</sup> who differentiate between 1) methods dealing with the updating of probability information (including Bayes' theorem and ROC analysis); 2) problem structuring with the help of decision trees; 3) sensitivity analysis; 4) utility assessment; and 5) decision automation (including flowcharts and expert systems). With the exclusion of the last category, the same classification scheme was used in the review of Kassirer et al.,<sup>10</sup> and a similar categorization is found in Lusted.<sup>26</sup>

### MEDICAL SUBSPECIALTY

With the help of the *Merck Manual*<sup>27</sup> and in consultation with two psychiatrists, articles containing formal modeling techniques were classified as belonging to one of the 20 medical subspecialties listed in table 2.

### JOURNALS

Since we were interested in assessing changes in the acceptance of formal decision methods in the United States, our survey was restricted to U.S. publications. Given the labor intensity of our manual search (see below), we restricted the survey to seven important and widely read clinical practice journals. This sampling of journals introduced an element of subjectivity, i.e., we could have sampled different journals. Our selection of journals (table 1) was made a priori in

consultation with a medical librarian at the University of Illinois. The main selection criterion was whether the journal had a broad readership among general clinicians. Our selection included the journals containing the largest numbers of the most frequently cited articles in medical decision making (i.e., *New England Journal of Medicine*, *Annals of Internal Medicine*, *American Journal of Medicine*, *JAMA*) according to a citation analysis for the years 1959–1985 by Pyle et al.<sup>28</sup> Furthermore, all the journals met the criteria set by Wellers<sup>29</sup> for a prestigious medical title. The inclusion of prestigious and sophisticated outlets for the publication of clinical studies was meant to ensure that we would not underestimate the use of formal modeling techniques. Since our main objective was to make *relative comparisons* between usage rates, we assumed that changes in the use of formal methods over time or between subdisciplines would be representatively reflected by our sample of journals.

The 1980s saw an increase in the number of specialized medical methods journals, including the new journal published by the Society for Medical Decision Making. Specialized medical decision making or artificial intelligence/programming methods journals were not included in the manual search (but are included in the full MEDLINE search), since most general clinicians may not routinely read or contribute to such specialized sources.

### TIME PERIODS

For all of the journals listed in table 1, every issue during the central five-year periods of the 1970s (1973–1977) and the 1980s (1983–1987) was examined. For every year and every journal, we counted the number of articles containing any of the formal decision techniques listed in table 3. To compensate for differences in the numbers of articles published in different jour-

**Table 3** • Key Words Used in Literature Search Grouped by Formal Decision Methods

Method	Key word
Bayesian probability models	Bayes' theorem ROC Nomogram
Decision tree structuring	Decision tree Subtree Markov
Sensitivity analysis	Sensitivity curve Monte Carlo
Utility assessment	Assessment Interview
Decision automation	Expert system Flowchart

**Table 4** • Relative Frequencies of Formal Decision Method Usage during the 1970s and 1980s, as Determined by Manual Search, MEDLINE Searches of the Clinical Journal Subset, and Unrestricted MEDLINE Search

Method	Manual (%)		MEDLINE Subset (%)		MEDLINE Full (%)	
	1970s	1980s	1970s	1980s	1970s	1980s
Bayesian updating	1.4	1.1	1.2	1.0	0.024	0.049
Decision automation	1.4	1.3	0.0	0.4	0.008	0.017
Decision trees	1.1	0.6	0.0	0.1	0.011	0.033
Utility assessment	0.9	0.7	0.0	0.3	0.001	0.001
Sensitivity analysis	0.2	0.8	0.2	0.4	0.003	0.019

nals and in different years, we computed relative frequencies by standardizing the number of articles containing a particular modeling approach for a particular medical subspecialty in a particular journal based on the total number of articles in that journal issue. In addition, we kept a separate count of the number of such articles appearing in *Medical Decision Making* during the five-year period of the 1980s.

#### MANUAL LITERATURE SEARCH

For every issue of every journal listed in table 1, all major and minor articles and research notes were analyzed (approximately 11,000 articles for the 1970s and 19,000 articles for the 1980s). The articles were searched for the mention or usage of any formal method in the abstract or the text, as well as for the presence of diagnostic graphs, plots, tables, mathematical equations, or flowcharts. Starting in 1984, when key-word classification of articles first appeared, we also searched for the occurrence of any of the key words shown in table 3 or synonyms.

#### MEDLINE SEARCH

To check the generality of any conclusions on the basis of our sample of clinical practice journals, we also conducted a general MEDLINE search for the same time periods and key words used in the manual search. Just as for the manual search, the total number of articles found to contain a key word corresponding to a particular formal method in a given year was standardized based on the total number of articles searched. The total numbers of articles searched for the individual years ranged from approximately 227,000 in 1973 to 335,000 in 1987. To obtain an indication of the "hit rate" of a MEDLINE search relative to our manual search, we also restricted the MEDLINE search to the same journals analyzed in our manual search.

method. Table 4 shows the percentages of articles that used the five different types of formal approaches in the two decades, with separate results for the manual search and the two MEDLINE searches.

In both decades, Bayesian updating and decision automation were the formal methods used the most frequently. Sensitivity analysis was used the least frequently especially during the 1970s. The results of the manual search seem to suggest a decrease in the relative frequency of formal method usage over the two decades. However, this trend is not statistically significant.

The results of the general MEDLINE search are quite different from those of the searches restricted to the seven clinical journals. On the one hand, the percentage of articles containing any formal decision modeling key word is even lower (on average only 0.01% for the 1970s and 0.02% for the 1980s). However, across all journals contained in the MEDLINE database, the relative frequency of usage of formal methods appeared to have more than doubled from the 1970s to the 1980s. Visual inspection of the articles identified in the general MEDLINE search placed them into the following four categories: 1) articles in specialist/methods journals; 2) articles in foreign journals; 3) misinterpretations of the key words (e.g., "rod and cone sensitivity" rather than mathematical sensitivity analysis); and 4) identification of the usage of a formal method in a clinical practice journal. The last category, the focus of our study, accounted for only a very small percentage of the articles identified by the general MEDLINE search.

In the MEDLINE subset search that was restricted to the clinical journals of the manual search, the detection rate of articles identified by the manual search as describing studies using formal decision methods was low, since MEDLINE is limited to the detection

## Results

The most striking finding was the *infrequency* of references to usage of formal decision methods in the clinical literature. The manual search of the clinical practice journals disclosed that *less than 1%* of the articles mentioned the use of or discussed any formal

**Table 5** • Formal Decision Method Usage for Four Medical Subspecialties (Summed over Different Methods) during the 1970s and 1980s

	1970s (%)	1980s (%)
Infectious disease	1.6	0.9
General medicine	1.3	1.1
Cardiology	0.8	0.9
Other	1.5	1.6



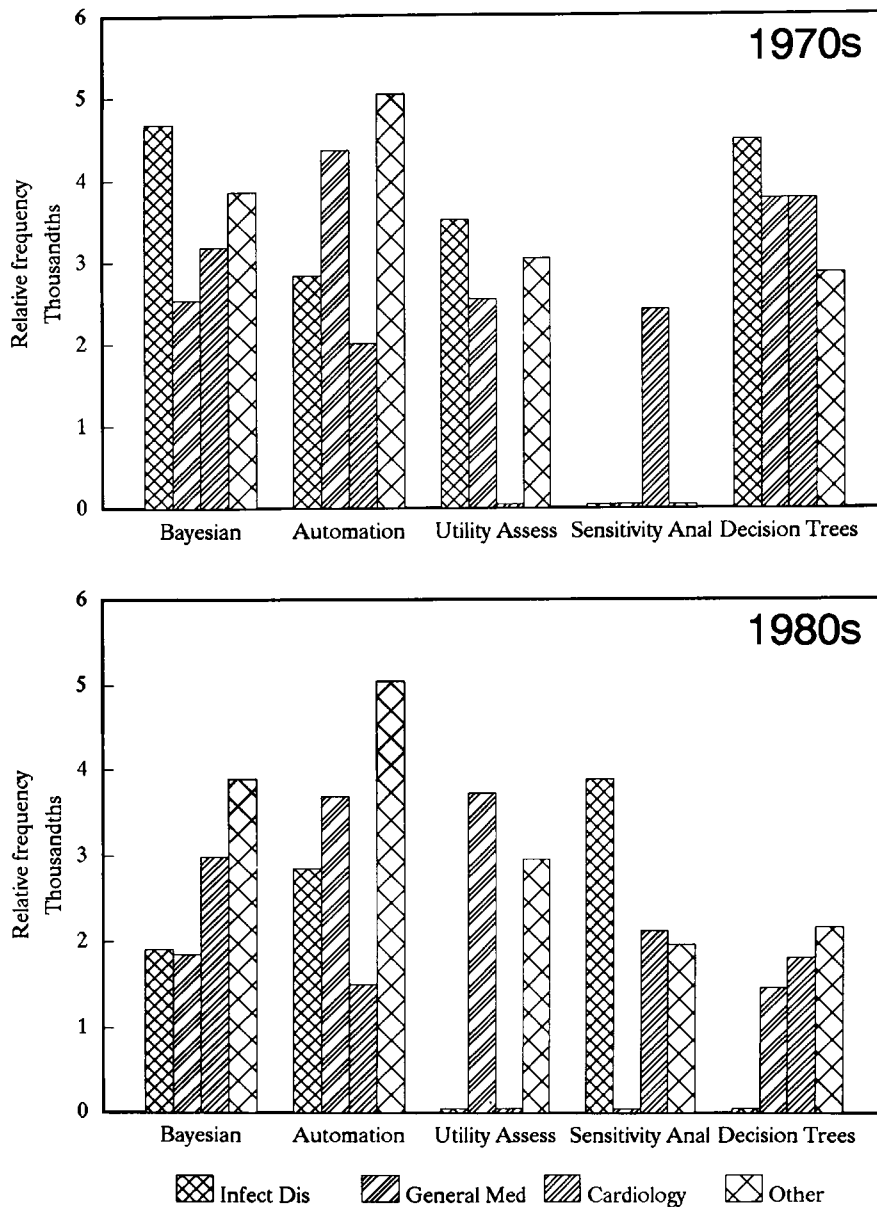


FIGURE 1. Relative frequencies of usage of different formal decision methods as a function of medical subspecialty and decade.

of key words in the titles and abstracts of articles. MEDLINE's "hit rate" was reasonable for Bayesian updating (80%), but only between 0% and 50% for the remaining four types of methods. Thus we used the results of the manual search in all further analyses.

Table 5 shows the percentages of formal decision method usage in four medical subspecialties for the two decades. Because the frequencies of formal modeling were very small for most of the subspecialties listed in table 2, only the three with the most frequent use of formal modeling (cardiology, infectious disease, and general medicine) are shown separately, with the remaining 18 combined (summed) into the category "other." This classification was used in all further analyses. "General medicine" refers to articles of general relevance to medicine, without reference to any specific subspecialty. Figure 1 shows the relative frequencies with which the five methods were used by the

four medical subspecialty groups, which are represented by differently shaded bars. Thus, for example, sensitivity analysis was used in approximately four out of a thousand reported studies dealing with infectious disease in the 1980s.

Table 6 provides a distribution of formal decision method usage across the seven journals. *Annals of Internal Medicine* and *JAMA* had the largest percentages of formal decision method usage. *JAMA*, the *New England Journal of Medicine*, and the *American Journal of Medicine* showed higher percentages during the 1970s than during the 1980s.

One possible explanation for the decrease in the frequencies of articles containing references to formal decision approaches in some of the clinical journals during the 1980s is the appearance in 1981 of the journal *Medical Decision Making (MDM)*. This seems particularly plausible since the biggest decreases oc-

curred for those journals with large coverage of general medicine topics, a category that accounts for a large proportion of the formal modeling articles that appear in *MDM*. This is particularly true for the most common formal modeling technique, Bayesian updating, for which 21.6% of all articles appearing in *MDM* during the five central years of the 1980s fell into the general medicine category (as opposed to 4.2% for our sample of clinical journals).

Table 7 shows the relative distribution of different formal decision methods covered in articles appearing in *MDM* in comparison with the distribution in our sample of clinical journals. There are clear differences in relative emphasis. Problem structuring with the help of decision trees accounts for a larger percentage of the articles in *MDM*. On the other hand, decision automation accounts for larger percentages of the articles in the clinical journals.

#### STATISTICAL ANALYSES

A regression of the relative frequencies of formal decision method usage with type of Method, Medical Subspecialty, Journal, and Year of Publication as predictor variables was conducted separately for the 1970s and the 1980s.<sup>†</sup> Of the four predictor variables, Journal had the strongest effect on the relative frequency of formal method usage. Type of Method and Medical

Subspecialty had only marginally significant effects. Year of Publication (within each decade) was not significant. The regression accounted for 45% of the variance in method usage for the 1970s and for 47% of the variance for the 1980s.<sup>‡</sup> Moderate multicollinearity in the set of predictor variables made it difficult to analyze the data for interaction effects.<sup>§</sup>

In a combined analysis of the data for the 1970s and 1980s, Decade was added to the set of predictor variables. Decade was not significant as a main effect. Journal again showed the strongest effect on relative frequency of formal method usage, followed by Medical Subspecialty. Of the two-way interactions, the Decade-by-Journal and Type-by-Subspecialty interactions were significant. The Decade-by-Journal interaction (mainly due to a Decade-by-American *Journal of Medicine* effect) confirms our impression from table 6 that some journals (but not others) showed significant decreases in the frequencies of formal decision method usage. In particular, the *American Journal of Medicine* had a much reduced frequency of formal method usage for the 1980s relative to the 1970s. The Type-by-Subspecialty interaction (mainly due to a Utility-by-Cardiology effect) confirms our impressions from figure 1 that different types of formal methods are differentially used by the different medical subspecialties. Cardiology was the only subspecialty with no usage of utility assessment in either decade.

**Table 6** • Distribution of Formal Decision Method Usage (Summed over Different Methods) across Seven Journals during the 1970s and 1980s

	1970s (%)	1980s (%)
<i>Annals of Internal Medicine</i>	25.6	31.7
<i>JAMA</i>	23.0	19.8
<i>New England Journal of Medicine</i>	18.7	9.5
<i>American Journal of Medicine</i>	13.9	5.6
<i>Archives of Internal Medicine</i>	12.1	15.0
<i>American Journal of Cardiology</i>	3.5	12.4
<i>American Review of Respiratory Disease</i>	3.2	6.0
TOTAL	100	100

**Table 7** • Distribution of Coverage of Formal Decision Methods in Clinical Journals vs *Medical Decision Making* (MDM) in the 1980s

Method	Clinical Journals (%)	MDM (%)
Bayesian updating	24.2	28.3
Decision automation	29.9	4.1
Utility assessment	15.3	17.5
Sensitivity analysis	18.3	14.8
Decision trees	12.6	35.1
TOTAL	100	100

#### Discussion

Current pessimism about the absence of any measurable increase in the utilization of formal decision techniques among general clinicians seems to be well justified. While a general MEDLINE search indicated that usage of formal methods more than doubled from the 1970s to the 1980s, this increase was mainly due to increased coverage of formal decision techniques in specialist methods journals. A manual search of a sample of major clinical practice journals found no evidence of an increase in overall usage of formal decision techniques between the two decades. If anything, the trend appeared to be decreasing, which can probably be attributed to the redirection of general

<sup>†</sup>Predictor variables were effect-coded. The dependent variable underwent an arcsine transformation.

<sup>‡</sup>All  $R^2$  values reported are significant at the 0.0001 level. Further statistical details are available on request.

<sup>§</sup>Multicollinearity was due to an unbalanced design caused by the survey results and was amplified within the set of interaction vectors. When analyzed as sets of interaction variables (e.g., containing all Type-by-Subspecialty interaction vectors), none of the two-way interactions was significant for either the 1970s or the 1980s. Using stepwise regression that allowed only significant components of two-way interactions to enter the analysis, the (sensitivity analysis)  $\times$  (cardiology) component of the T  $\times$  S interaction was significant for the 1970s. As can be seen in figure 1, cardiology was the subspecialty that employed sensitivity analysis during the 1970s.



medicine articles containing formal modeling techniques away from clinical journals to specialist journals such as *Medical Decision Making*.

Bayesian updating (including ROC analysis) and decision automation dominated other formal decision methods in articles appearing in clinical journals. Entries in the latter category were largely due to a large number of "if-then" flowcharts. While formalizing diagnostic reasoning in a fashion, decision automation does not necessarily provide for a way to incorporate quantitative or statistical information, one of the main deficiencies in physicians' diagnostic performances.<sup>30,31</sup>

The results of a MEDLINE search proved unsatisfactory for the purposes of this study. When restricted to the set of clinical journals for which the results of our manual search were available for comparison, MEDLINE was able to detect only a small fraction of those articles that described studies that had actually utilized some formal decision method. One exception was Bayesian updating, for which MEDLINE detected 80% of actual usage. These results are similar to those found by Pyle et al.<sup>28</sup> in their attempt to update a citation analysis of medical decision making. Among the three methods that they employed to add articles published between 1978 to 1981 to the prior core list, the MEDLINE search identified only 5% of all new entries. MEDLINE's reliance on the titles and abstracts of articles biases a search using formal decision method key words towards the detection of those articles that are explicit treatments or tutorials of those methods and will lead to the underdetection of clinical articles that may describe the use of these methods as "normal" tools (as one might use statistics), which does not warrant mentioning them in the article's abstract.

There was some evidence to lend support to a key assumption of this study, namely that general trends in the acceptance and utilization of formal decision methods may, among other things, be reflected by the frequency with which they appear in clinical journal articles. Fryback<sup>32</sup> distinguishes between two "waves" of analytic approaches to medical decision making: the first wave (during the 1960s) consisting mainly of applications of probability theory (Bayesian techniques), and the second wave (during the 1980s) consisting of more complex analyses such as sensitivity analyses, made possible by advances in computer hardware and software. Figure 1 shows that this trend in clinical usage was paralleled by an increase in the relative frequency of clinical journal articles citing the use of sensitivity analysis from the 1970s to the 1980s.

Some medical subspecialties (in particular, infectious disease and cardiology) stand out by having much higher frequencies of formal method usage than other subspecialties. One explanation may be the existence of some established tradition of formal decision modeling use. Much reasoning in the field of infectious disease, for example, is based on the statistical foun-

ation of epidemiology. Another explanation may be that problems in some subspecialties are more structured than those in others or are otherwise more amenable to formal decision methods. Clinical image readings, for example, as in the interpretation of electrocardiograms, are textbook cases for the application of ROC analysis. It is probably not coincidental that two major proponents of formal decision approaches, Stephen Pauker and Hal Sox, are cardiologists.<sup>6</sup>

Yet another explanation could be the availability of resources to develop formal decision tools. Medical expert systems, for example, have been largely developed in those areas of medicine that have generous funding, e.g., cancer treatment and antibiotic medication selection.

## Recommendations

A comparison of the relative frequencies of usage of formal decision methods in studies reported in mainstream clinical journal articles during the 1970s and the 1980s has confirmed the subjective impression of members of the MDM community that there has been no appreciable increase in usage over time. The continued reluctance of practitioners to use formal decision methods is probably due to a variety of factors, some of which may be addressable by attitudinal or motivational interventions, technical innovations, and continued educational efforts.

Motivational interventions may prove useful in increasing the usage of formal decision methods among general clinicians. If consensus exists that increased usage of formal and quantitative reasoning and decision-making methods by practitioners would be a net benefit, the MDM community may want to think about ways in which rewards for the utilization of such methods or disincentives for the lack of utilization can be introduced into clinicians' evaluation and incentive schemes. Increased pressure from paying agencies to become more cost-effective, for example, may send physicians searching for methods to accomplish such goals with the least decrement in quality of care. In conjunction with continuing education initiatives that increase familiarity with formal decision methods, such top-down approaches may increase physicians' willingness to modify habitual intuitive judgment and decision methods. Paying agencies could influence clinicians both directly and in indirect ways, e.g., through changes in certification requirements to include some evidence of competence in logical and quantitative evaluation and reasoning procedures. Any such changes

<sup>6</sup>The increase in the relative frequency of formal decision model usage from the 1970s to the 1980s in the *American Journal of Cardiology* (table 6), however, is not attributable to a large number of publications from these two authors.

in certification requirements would, of course, be followed or accompanied by more rapid changes in medical education.

The benefits of formal decision methods might be more salient to paying agencies (as well as practitioners) if they were expressed in cost–effectiveness terms. Instead, current articles that introduce formal methods or demonstrate their applications tend to focus on the fact that these methods provide for “better” decisions. This difference in perspectives between researchers and users of formal decision methods is probably compounded by the fact that it is easier to document that a given approach has a greater chance of providing the “correct” diagnosis, decision, or treatment than it is to quantify the costs and benefits of these approaches. However, greater acceptance of formal methods by clinicians as well as greater willingness by funding and paying agencies to mandate and finance the development and usage of such methods may depend on such demonstrations of increased cost–effectiveness. Thus, members of the MDM community may be well advised to think about innovative ways to provide such estimates.

Continued reluctance by practitioners to adopt formal decision methods can also, at least partially, be taken as an indication that available techniques have not yet been sufficiently tailored to their needs. Without exception, these methods were developed outside medicine. Only recently have members of the medical community started to adopt these techniques and adapt them to clinical problems, a process in which the SMDM and its journal will clearly continue to play a primary role. Dawson and Cebul<sup>8</sup> and Kassirer et al.<sup>10</sup> outline a variety of technical issues that still plague the application of quantitative techniques to medical decision making.

Technical innovations, in the form of software programs for microcomputers or large medical databases with standardized information, will facilitate broader use of formal decision methods by addressing two concerns of practitioners, namely computational complexity and data availability. Many such programs and databases had already started to appear in the mid- and late 1980s (for a review see Dawson and Cebul<sup>8</sup>). Further development of user-friendly computer programs and standardized databases with built-in software components will make formal decision methods easier to apply and thus decrease the costs to practitioners.

In addition to motivational and technical innovations, continued educational efforts should prove useful in promoting the usage of formal decision methods. The medical subspecialties that showed the highest frequencies of usage of formal decision methods in our survey were those that had stronger quantitative traditions and offered more evident demonstrations of the utility of formal methods.

Cebul<sup>33</sup> suggests that more “showcase” clinical ar-

ticles on practical problems that incorporate formal decision methods should be published to promote wider adoption of medical decision analysis. Such suggestions lie perhaps at the root of the large number of articles demonstrating the use of formal methods that appear in *MDM*. However, given the specialized readership of *MDM*, such articles might be better placed in journals read by general clinicians.

There is a natural tendency for prestigious, widely read publications such as *JAMA*, the *New England Journal of Medicine*, and the *American Journal of Medicine* to cover primarily “new” issues or discoveries in medicine, including only novel formal decision-making techniques. As topics become more established, treatments of them tend to migrate to more specialized and less widely read journals. To the extent that members of the MDM community feel that formal decision approaches have not yet received optimal exposure or acceptance, it may be fruitful to think of ways by which a wider familiarity with formal decision methods among general clinicians can be fostered on a continuing basis. The American Statistical Association, for example, in its monthly newsletter *Amstat News*, publishes a summary of recent noteworthy articles that have appeared in statistical journals less widely read than its own flagship publication *JASA*. Another way to expose practicing clinicians to the process and results of formal decision methods is by the dissemination of information such as the decision trees for the management of Hodgkin’s disease developed by an NIH-funded Consensus Committee in 1979 and updated in 1988, and distributed by the American College of Radiology in form of a newsletter<sup>34</sup> to radiation oncologists worldwide.

Our analysis suggests that the appearance of *MDM* in the 1980s had a negative net effect on the number of articles about studies using formal decision methods that are seen by general clinicians. Articles of a general nature that previously might have appeared in the widely read *American Journal of Medicine* now seem to be sent to *MDM* or other specialist methods journals. Given that it would be difficult to encourage a wider cross section of clinicians to read specialist journals, one implication of the present analysis seems to be that proponents of formal modeling methods should publish more illustrative or tutorial articles in outlets targeted at clinicians. More articles that demonstrate the relevance, applicability, and ease of use of formal decision methods to applied clinical problems, in journals regularly read by practitioners, would go a long way toward counteracting the impression among clinicians that such methods are impractical or inappropriate for the complexity of clinical situations.

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