Medical knowledge for clinical problem solving: a structural analysis of clinical questions

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Despite technological advances that support wide-ranging access to and transfer of knowledge, practicing physicians continue to underutilize current biomedical literature. This paper explores the nature of clinically applicable medical knowledge through a structural analysis of clinical questions. The author analyzed a set of sixty questions, based on actual online search requests of practicing physicians, for stated and unstated needs, certainty levels, implicit and explicit assumptions, decision-making processes, and type of answer required. As a result, four states of information valuable in patient care were identified: prediagnostic assessment, diagnosis, treatment choice, and learning. These states are presented in frame-like structures that integrate declarative and procedural components of medical decision making. It is concluded that clinical problem solving requires a blend of declarative and procedural knowledge. The ratio depends, in part, upon the reasoning process underway at the time of the request. Procedural knowledge required for clinical problem solving may be absent from current biomedical journal literature or difficult to identify.

Researchers and librarians commonly assume that answers to patient care questions can be found in current biomedical journal literature. Despite technological advances that support wide-ranging access and transfer, underutilization of biomedical literature by practicing physicians continues to be reported and lamented [1]. The persistence of this gap between the real and the ideal suggests that the problem may lie in the nature of the knowledge being sought rather than in access and transfer barriers. That is, there may be some feature of the information being sought for clinical problem solving—its specificity, its uniqueness, its role in the reasoning process—that discourages the physician from turning to the literature for an answer. Determining whether or not this is true requires knowledge about the kind of information the clinician is seeking. When that is known, systems and services can be tailored to support clinical problem solving.

As a first step toward evaluating the comparability of biomedical information in literature and clinical practice, this paper describes models of medical knowledge derived through an analysis of clinical questions. A set of clinical questions was examined for stated and unstated information needs and for evidence of the decision-making processes that produced the questions. The analysis uses the declarative/procedural knowledge framework employed by developers of medical decision support systems. The question analysis indicates that clinical decision making requires a mix of declarative and procedural knowledge. Limited online accessibility of procedural knowledge may deter practicing physicians from seeking literature to support clinical problem solving.

KNOWLEDGE REPRESENTATION IN BIOMEDICINE

Declarative and procedural knowledge

In a recent review, Perry noted that medical knowledge is divided into “what to know” (declarative knowledge) and “what to do” (procedural knowledge) [2]. The former encompasses facts and their relationships to theory, common sense, and world
knowledge. The latter is problem-solving knowledge: heuristics and expert judgment. Early decision support systems such as MYCIN attempted to represent all medical knowledge as sets of rules, but more recent systems store medical information (declarative knowledge) and control structures (procedural knowledge) separately within frame or network structures [3]. In the terminology used by the designers of expert systems, medical knowledge comprises a declarative store of information (knowledge base) and a procedural program (rules for organizing and using it).

Medical reasoning is described as a decision-making process wherein medical knowledge is classified and associated within a problem-solving framework [4]. Rennels et al. describe the outcome of this process as weighted associations between findings and hypotheses or between two hypotheses [5]. Other researchers have also likened diagnostic reasoning to hypothesis testing: The physician develops a disease hypothesis (diagnosis) based upon symptoms and other evidence and then tests the hypothesis by evaluating the result of the treatment [6]. The primary declarative evidence from the patient (signs, symptoms, lab results) is combined with declarative and procedural knowledge known or gathered by the physician (situation models, reference models of disease, reasoning processes). Clinical medicine can thus be characterized as a decision-making process in which a physician draws upon declarative and procedural medical knowledge to diagnose and treat medical problems.

Reasoning from literature

The structure designed for the storage of medical knowledge in computer systems parallels the schemata or mental models cognitive scientists use to describe human abilities to learn, remember, and reproduce knowledge. Patel, Evans, and Groen argue that clinicians build a situational model of the patient during the gathering of clinical evidence, a model that differs both from the functional models that basic research scientists use and from the text-based mental models that physicians build when they read biomedical literature. When the model is developed directly from medical evidence, clinicians approach medical literature differently than they do when they are trying to solve an abstract problem or seeking information. The authors conclude that basic science and clinical medicine are distinct domains distinguishable by specialized features and processes of reasoning used by medical practitioners [7].

Discussing the Roundsman system, which attempts to model the way clinicians reason from the medical literature of clinical trials, Rennels describes published experimental evidence in terms of its "publication-centered data structure," a representation of experimental design, observed outcomes, and contextual details. In a publication-centered model, knowledge is structured around studies, rather than around patients, diseases, or decision-making processes [8]. To use published information in clinical problem solving, a physician must somehow recognize data from a "publication-centered" or "basic science" structure as applicable to the situational model, then extract those data and employ them in a reasoning process. Bergman and Pantell outlined the mechanics of the final step in the process of applying data from a clinical trial:

1. Take the conditional probability reported in the trial.
2. Estimate the probability of problem in the case at hand.
3. Multiply the two together to arrive at a situational probability [9].

The resulting probability serves as the basis for a reasoned judgment about a diagnosis or proposed therapy.

If these researchers are correct, both the mental model and the reasoning process of a practicing physician require information in a different form from that in the medical research literature. Before evidence can be extracted from the literature and integrated into a decision-making process, that evidence must be recognized as relevant to the problem. If it is true that clinicians build and use mental problem-solving structures, then those structures must shape the physician's recognition and selection of relevant evidence in the published literature.

Research into medical knowledge and decision making has, to some extent, proceeded along twin paths. For example, Blois [10], Sager and Lunin, and others have discussed and modeled the organization of medical knowledge, while Patel, Rennels, and others have studied medical reasoning processes. The absence of integrated, well-rounded information-processing models impedes researchers' abilities to understand and evaluate medical knowledge within the framework of clinical problem solving. This, in turn, makes it difficult to determine how published knowledge fits in.

THE STUDY PROBLEM AND METHOD

The object of this study was to describe the kind of knowledge in practice-based clinical questions. Adopting the request-oriented approach used in indexing and online search formulation, the researcher used clinical questions to model the kind of information structure needed by a practicing physician. Unlike interview evidence gathered from medical experts for the design of expert systems, clinical questions have an immediate problem-solving applica-
tion. Thus, clinical questions offer clues to the nature (specificity, level of abstraction, etc.) of the information need.

The study set
In a 1989 study of MEDLINE's impact on medical practice, participating physicians were asked to submit some of their recent MEDLINE questions [11]. The final report contained edited examples of patient care questions. Sixty questions categorized in the original study as either diagnosis-related or treatment-related were chosen as a study set.

Neither the edited questions in the MEDLINE study nor the smaller study set selected for this paper is a scientific sample. For this reason, no attempt has been made to provide statistical analysis or predictive generalizations. The published examples are not verbatim; they only approximate the original queries, so linguistic interpretation would be inappropriate. Finally, the questions are those physicians say they submitted to MEDLINE. Earlier use studies and examples in the MEDLINE report itself suggest several possible reasons for choosing MEDLINE, which must be considered in evaluating the study set: other preferred sources were unavailable, other preferred sources did not provide a satisfactory answer, the physician had some expectation that the journal literature was an appropriate source for the requested information, or the physician doubted that an answer could be found, but searched anyway. Because of these limitations, the questions in the study set can be described as typical, but not necessarily representative, of clinical questions posed to all literature sources.

Analytic process
The analysis involved several stages. In preliminary analysis, a question was broken into decision-making components and the stated information need was extracted. Then the information need was analyzed to estimate the specific kinds of data required and to identify implicit and explicit assumptions. Appendix A provides examples of the completed analysis for questions one and forty-seven from the 1989 MEDLINE study. The structural analysis of the question set involved six steps:
1. Clausal segmentation: Each question was broken into meaningful phrases and clauses in a technique modeled on Joseph and Patel's [12].
2. Goal determination: For each question, the physician's general goal was hypothesized, along with an implementation strategy for achieving that goal. Some questions had more than one goal, and some goals more than one strategy.
3. Evidential analysis: Each question was assessed for evidence that could contribute to decision making. A level of certainty and a role were assigned to each phrase and clause identified in the segmentation process.
4. Information need: The stated information need was extracted from the question statement. The language of the published question was used where possible.
5. Assumptions: Implicit and explicit assumptions underlying each information need were stated. Although incomplete, this analysis offered a sense of the complex context from which clinical questions flow. A level of certainty was assigned to each assumption.
6. Queries: One or more queries were developed for each information need. An attempt was made with each query to characterize the relevant data that would allow the physician to make a decision or move to the next step. Declarative and procedural answer types were postulated for each query.

RESULTS AND DISCUSSION
Clinical frames
To facilitate comparison and interpretation, the results of the question analysis were grouped into four structures called frames. Although the study results could easily be configured to emphasize familiar medical concepts (e.g., a frame for diseases, a frame for treatment), the frames in this study were constructed to emphasize the integration of the declarative and procedural knowledge needed for clinical problem solving.

The frames can be thought of as organizing tools the physician uses during problem solving. Each frame consists of slots and facets. Slots are the major components, or building blocks, that make up a frame. For example, the prediagnostic assessment frame has four slots: condition, evidence, treatment, and processes. These slots exhaust the possibilities for a physician's prediagnostic assessment activities. Each slot has one or more facets or subcomponents. For example, the condition slot of the prediagnostic assessment frame contains four facets: status, features, relationships, and prognosis. The facets contain actual pieces of information (called values). For example, chronic is a status value for a disease. In addition to their role as structure elements within a frame, slots and facets serve as links among frames. For instance, the evidence slot on the diagnosis frame might have all or part of the prediagnostic assessment frame as a value in its source facet.

Of the four frames developed from the study data reported here, three are case-related, tied to the immediate need to care for specific patients. A fourth might be termed practice-related, though derived from practical experience, the frame is not part of a current patient problem but represents the physician's translation of observations and experience into learning goals. For example, a physician may observe some co-
occurrence of conditions at autopsy and wonder whether they are genetically linked. This type of information request supports continuing education, but it is clinical in the sense that the questions arise from actual experience rather than from general curiosity or professional reading.

**The prediagnostic assessment frame**

In the prediagnostic situation, a physician evaluates information for a specific patient in the absence of disease. There is not yet a reason to invoke the problem-solving frames for diagnosis and treatment, but the outcome of this evaluation might lead to that. This evaluative process will identify the need for intervention by focusing on past and present conditions, existing evidence, and past or present treatments. As noted earlier, the prediagnostic frame itself could be a slot value for the diagnostic frame. The overall reasoning process for prediagnostic assessment can be generally characterized as having four steps:

2. Pose a question about some value noted.
3. Evaluate the answer in terms of need for diagnosis or treatment.
4. Take action or stop.

At each step, facets of the frame will be filled with information values known, inferred, or gathered by the physician. Factors such as the specifics of the case and the physician's training and expertise determine the detail required for each slot. Appendix B contains the prediagnostic assessment frame.

**The diagnosis frame**

In the diagnostic situation, a physician has determined that a problem exists for a particular patient and must name the disease. The process may have been initiated by the physician (through the prediagnostic frame) or the patient (through request for assistance). The procedure for arriving at a diagnosis is both nonlinear and iterative—steps may be skipped or repeated in different sequences until a confirmation is achieved. Thus, in the process slot of the diagnosis frame, some terms appear as individual facets and also as subunits of other facets.

Diagnostic reasoning employs empirical evidence to reach a conclusion. It is a process that has been called *forward reasoning* because it moves forward from evidence to a conclusion [13]. The diagnosis frame appears in Appendix C. Although it is more complex and overlapping than prediagnostic reasoning, diagnosis can be characterized as following these steps:

1. Accept need for diagnostic action.
2. Gather evidence.
3. Review and evaluate evidence.

4. Propose a diagnosis.
5. Confirm a diagnosis.
6. Determine need for treatment action.
7. Take action or stop.

**The treatment choice frame**

In the treatment situation, a physician has confirmed the disease diagnosis and seeks to take appropriate action. Unlike diagnosis, the treatment decision involves seeking and weighing alternative solutions to a problem and choosing the best one. Although the diagnostic decision process reduces uncertainty, a treatment decision is more like a best guess. The process is more complex than diagnosis, as each piece of evidence has a constellation of context factors that weigh in the decision. The steps toward treatment choice are:

1. Accept the need for treatment based on confirmed diagnosis.
2. Determine treatment options.
3. Compare options in light of patient data.
4. Choose an option.
5. Implement treatment or stop.

The treatment choice frame, the most complex of the four frames, appears in Appendix D.

**The learning frame**

Some questions arise during clinical practice that are not related to the care of a particular patient. In this situation, the physician explores or tests ideas. The learning frame is not so much a problem-solving frame as a hypothesis-testing frame; consequently, it employs a different mix of reasoning processes from the diagnostic and treatment frames (Appendix E). The general steps are:

1. Pose a question based on practice experience.
2. Evaluate the answer in terms of need or future practice options.
3. Store or reject.

**Assumptions about the published literature**

Numerous studies have identified information needs, patterns of information use, and preferred information sources of practicing physicians. Published materials are usually included as a potential source of answers [14-16]. Virtually all studies report that textbooks are preferred over journals. Wilson, Starr-Schneidkraut, and Cooper reported that about 43% of the MEDLINE inquiries they studied involved patient care [17]. Of that group, 41% concerned diagnosis or etiology, 51% treatment or prognosis, 4% maintaining an effective doctor-patient relationship, 3% disease prevention, and 1% third-party payment. Other researchers have reported similar search purposes.
The study questions reported here provide insight into the kind of information physicians expect to find in the literature (Appendix F). Although some searches may have been initiated to rule out a possibility (that is, to prove that no information exists on a topic), it is fair to say that the study questions reflect assumptions about the content of published articles. The sixty questions indicate that physicians expect to find both declarative and procedural information in the published literature. Declarative information is more often requested during diagnosis; procedural requests are more often prompted by the treatment decision process. The declarative knowledge related to clinical information includes
- tests, test interferences, and test specificity
- diagnostic evidence for a particular condition
- standard levels and ranges
- etiology, incidence, and prognosis for specific conditions
- descriptions of a procedure
- drug actions, mechanisms, and side effects
- replacements for contraindicated treatments
- basic demographic and epidemiologic information
- current (i.e., consensus) therapeutic knowledge
- nature of statistical associations and relationships.

The procedural knowledge relevant to clinical questions includes
- interpretations of test values or images
- diagnostic specificity of a symptom
- guidelines for recognizing association or relationship
- guidelines for predicting association or relationship
- comparative interpretive or evaluative evidence
- decision factors and weights
- guidelines for long-term patient management.

**Relevance and states of information need**

Studies that measure physician satisfaction with literature search results rather than clinical applicability offer little insight into the use of literature in problem solving; such studies are not reported here. However, several recent studies have attempted to evaluate the patient care applicability of retrieved materials. Haynes et al. found that about 15% of retrieved items in their study were directly relevant to the clinical case at hand; 41% were judged to have indirect relevance; 43% were deemed irrelevant [18]. Scuca and Davidoff reported that 20% of retrieved articles affected patient management by changing a treatment decision, providing information that might change treatment in the future, or preventing certain diagnostic or therapeutic maneuvers (a stop function) [19]. Haynes et al. reported on the way relevant retrieved literature affected decisions: 37% of the articles confirmed a decision, 9% caused a new decision, and 7% caused a change in decision [20]. Wilson, Starr-Schneidkraut, and Cooper provided specifics of the kinds of decisions supported by literature [21].

As the study results reported here indicate, the clinical context shapes the question in terms of both subject matter and the form an answer must take to be applicable. Four general states of information need were represented in the frames: prediagnostic assessment, diagnosis, treatment choice, and learning. For most questions, a declarative or procedural dimension can be defined. Analytical evidence from the question set suggests that for each kind of query, the nature of relevant data (e.g., the declarative or procedural dimension of the answer) is affected by the searcher’s reasoning process, level of certainty, and underlying assumptions. For example, in an “identify” reasoning process, the physician is attempting to locate factual (declarative) information. Interpreting that information or choosing among alternatives requires the physician to assign weights and values, an activity that employs procedural information. Naturally, the physician’s experience has an effect on the relevance judgment as well. Thus, if the certainty for an “interpret” question is high, a declarative answer may be acceptable because the physician is familiar with some or all weight factors. Likewise, an inference based on assumptions that are themselves inferences generally has a lower level of certainty; a relevant answer might require both declarative and procedural information.

**Barriers to the use of published information**

Various geographic, technological, and educational impediments to literature access by practicing physicians have been diagnosed, and various treatments have been proposed and applied. One such approach proposed to increase literature use by improving the physician’s ability to evaluate critically the results of basic biomedical research [22]. Relatively little attention has been paid to the removal of barriers that may exist in the source itself, such as poor organization [23], lack of prominence of clinical information [24], lack of focus on clinical topics [25], irrelevant information [26], or variable dependability or credibility [27]. One growing trend is the publication of structured abstracts that highlight methods, sample, and analytical techniques in research articles [28]. However, one researcher found that clinicians rated research articles lowest of all information sources in clinical applicability and understandability, and most researchers have found that for solving clinical problems physicians prefer other sources of information to journal articles [29]. The study results reported here are in accord with those of Patel, Evans, and Groen; if they are correct, emphasizing scientific content will not improve literature use because the knowledge in
basic science reports will not appear clinically applicable to the information-seeking physician.

Of course, biomedical literature extends beyond basic science. In addition to research reports, most medical journals contain letters to the editor, grand-rounds-type problem-solving dialogs, and case studies described in the familiar evidence-gathering terms used by practicing physicians. Because online systems are touted as the appropriate bibliographic source for physicians seeking journal literature to support clinical decisions, procedural knowledge in items covered there is especially important. Specifically, users of the biomedical literature and the systems that provide online coverage of that literature need to know:

- Is procedural information present?
- Is the article that contains procedural information indexed online?
- Does the online citation include an abstract?
- Does the abstract indicate the presence of procedural knowledge?

Applying clinical frames to the medical literature was beyond the scope of this study. However, a small test undertaken to explore these questions searched eight typical articles from *Journal of Family Practice (JFP)* and *Annals of Internal Medicine (AIM).* The articles were selected from the subset of MEDLINE that included both journals. The results were these:

- Each article contained a considerable amount of declarative information about test values and the features and effects of conditions and treatments. Procedural information included justifications for a recommendation, interpretation of results, reasons for choosing a given method, and examples of the application of a technique.
- All *JFP* articles contained procedural information. Only one was indexed online; the presence of procedural information was indicated in the online abstract.
- Three of the four *AIM* articles contained procedural information. Three of the articles (not the same three) were indexed online. The online abstracts did not indicate the presence of procedural information.

**SUMMARY AND CONCLUSIONS**

To determine the kind of information that clinical practitioners need, a set of clinical questions was analyzed. Four states of information need were identified and characterized in frameline structures. The reasoning process used to solve problems was identified for each state. The results were as follows:

- Clinical decision making employs both procedural and declarative knowledge. Declarative information is mainly factual; procedural information consists of strategies and principles for evaluation and choice. Physicians may not recognize or articulate this difference in their requests for literature to support patient care.
- Practicing physicians use a combination of declarative and procedural knowledge to solve practice problems. Declarative knowledge is usually employed during diagnosis. Procedural knowledge is more often used for treatment decisions.
- The ratio of declarative to procedural knowledge required to answer a question adequately depends, in part, on the reasoning process underway. Specifically, the declarative/procedural balance is affected by certainty, which in turn is affected by the source of assumptions made during reasoning. The physician's own expertise also affects the certainty of any assumption.

All four information need states identified in the study encompass both declarative and procedural knowledge. The procedural knowledge required consists of support for decisions, for example, associations, weights, decision criteria, standards for evaluating outcomes, detailed case histories for comparison.

Given these observations, what strategies are available to health sciences librarians who seek to improve information services to practicing physicians?

**The problem-solving process**

Identifying the problem-solving frame of the information-seeking clinician is important because it provides insight into the mix of declarative and procedural information that might be useful. For example, if a therapeutic decision is being made, sources that provide guidance about appropriate weights and values for computing a prognosis (for example, a case study of a similar problem) might be more appropriate than a summary of the molecular mechanisms of the disease in question. On the other hand, a physician who is testing a hypothesis about the co-occurrence of two conditions might prefer a set of etiological reports containing statistics on those conditions to a case study.

**The online source**

Traditionally structured reports of basic research results are not as likely to contain procedural information as are case studies, reviews, letters, and other published accounts written by and for practicing physicians [30]. Thus, one would not expect to identify much relevant literature for procedural, clinical questions in basic science titles. Online bibliographic files like MEDLINE contain a mix of basic science and clinical titles to serve the broadest range of biomedical information seekers. Familiarity with the coverage of such online files might lead to improved search results if librarians excluded basic science journals from certain kinds of clinical searches.
Customized services

Articles published in medical journals contain varying amounts of procedural and declarative information, and indexing and representation of that knowledge in online surrogates also varies. Even when an article contains procedural information, it may not be apparent from the title or abstract. Likely sources of procedural knowledge, such as case studies and grand-rounds-type reports, are not always indexed in the online systems health sciences librarians rely upon most heavily. This suggests several actions: Librarians can press for wider indexing of these potentially valuable published reports and for improved abstracts that highlight the presence of such information. They can develop local databases and other access tools to support retrieval of unindexed matter in certain popular journals. They can also search the full text of promising articles whose titles or abstracts hint at the presence of procedural information.

Education services

Education for end-user searching often focuses on query formulation, command techniques for specific systems, and knowledge structures present in thesauri such as the MeSH. End-user training designed for clinicians might also emphasize knowledge structures in literature and their relationship to those present in clinical questions. This approach would require clinicians to be reflective about their reasoning processes in diagnosis and treatment and about the qualities a relevant answer might have.

The results reported here suggest several avenues for research. Procedural measures can be validated against both biomedical literature and the clinical judgment of physicians. Using framelike structures to describe clinically applicable information, a researcher could perform a structural match against the literature, evaluating the fit between the questions and the published knowledge. Such structures could also be used as the basis of customized indexing and abstracting, which could highlight clinically relevant data or processes. Examination of articles judged clinically applicable by physicians could provide additional insight into the way declarative and procedural knowledge is used in problem solving. For articles containing clinically relevant information, strategies such as those suggested above could be employed to improve the information’s visibility and accessibility. Such improvements can make the published literature increasingly valuable to physicians who are trying to solve practice problems.

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APPENDIX A
Detailed analysis of questions one and forty-seven

Assumptions, queries, and answer types are not in priority order, nor are all possibilities presented. Text from the questions appears in brackets. In question one, the physician attempts to confirm a diagnosis by identifying a test that provides evidence to support the provisional diagnosis.


Question 1. Had patient with [symptoms] that [could have been] [chronic granulomatous disease] and [wanted information on] [appropriate test] [to detect] this [enzyme defect in white blood cells].

Goal: confirm diagnosis Strategy: gather additional evidence

Diagnosis: [chronic granulomatous disease]
Certainty: possible Diagnostic evidence: [symptoms]
Stated need: [appropriate test] [to detect] [this enzyme defect in blood]

Assumption 1: Granulomatous disease is an enzyme defect in white blood cells.
Certainty: confirmed Basis: declarative knowledge

Assumption 2: Enzyme defects can be detected by testing.
Certainty: probable Basis: declarative knowledge

Assumption 3: Some test value is diagnostic of granulomatous disease.
Certainty: probable Basis: inference

Query 1: What is the appropriate test for detecting granulomatous disease?

Basis: inference Source: assumptions

Relevant data: report on a test that detects enzyme defects in white blood cells

Answer type: Declarative = test name, association with condition; procedural = none

Query 2: What test value is diagnostic of granulomatous disease?

Basis: inference Source: assumptions

Relevant data: strength of association between test values and confirmed diagnosis

Answer type: declarative = test value/statistical association between condition and test value; procedural = criteria for diagnostic interpretation

In question forty-seven, the physician employs two strategies: confirming diagnosis by evaluating evidence and testing a cause-and-effect hypothesis. Each strategy has underlying assumptions and queries linked to it.

Question 47. Had patient who [had been previously diagnosed] as [schizophrenic], who was [now pregnant], and whom the psychiatrist initially [misdiagnosed] as [cured] [because of a lack of symptoms], and [wanted any reports] of [estrogen as an antipsychotic drug] or [cases] where [pregnant schizophrenics] [appeared cured].

Goal: confirm diagnosis Strategy 1: evaluate conflicting evidence

Diagnosis: schizophrenia Certainty: possible

Supporting evidence: [previously diagnosed] as [schizophrenic] unstated symptoms

Conflicting evidence: [psychiatrist ... cured] [lack of symptoms]

Stated need: [cases where pregnant schizophrenics appeared cured]

Assumption 1: Schizophrenia patients may not show symptoms.
Certainty: confirmed Basis: declarative knowledge

Assumption 2: Lack of symptoms is not full evidence of cure.
Certainty: confirmed Basis: practical knowledge

Query 1: How often is schizophrenia misdiagnosed as cured?

Basis: inference Source: declarative knowledge, experience, case

Relevant data: cure rates for schizophrenia, occurrence rates of symptomless schizophrenia, recurrence rates of schizophrenia

Answer type: declarative = cure rates for condition/frequency of symptoms; procedural = diagnostic criteria; criteria for declaring a cure

Goal: confirm diagnosis Strategy 2: confirm cause-and-effect hypothesis

Cause-and-effect hypothesis: estrogens cause psychotic symptoms to disappear

Certainty: probable

Decision factors: patient who [had been previously diagnosed] as [schizophrenic], who was [now pregnant] [diagnosed] as [cured] [because of a lack of symptoms]

Stated need: [reports of estrogen as antipsychotic drug]

Assumption 1: Pregnancy causes increased estrogen.
Certainty: confirmed Basis: declarative knowledge

Assumption 2: Antipsychotic drugs control symptoms of schizophrenia.
Certainty: confirmed Basis: declarative knowledge

Query 1: Is estrogen an antipsychotic drug?
Basis: inference Source: declarative knowledge, case

Relevant data: reports of antipsychotic effect of estrogen Answer type: declarative = effects of estrogen; procedural = none

APPENDIX B

Prediagnostic assessment frame

In this information-gathering context, decision processes are few and relatively simple. The emphasis is on general, declarative information.

<table>
<thead>
<tr>
<th>Slot</th>
<th>Facet</th>
<th>Examples of values</th>
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<tbody>
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<td>Condition</td>
<td>Status</td>
<td>past, chronic</td>
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<tr>
<td></td>
<td>Features</td>
<td>cause, treatment options</td>
</tr>
<tr>
<td></td>
<td>Relationships</td>
<td>co-occurrence, cause-and-effect</td>
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<tr>
<td>Prognosis</td>
<td></td>
<td>cure</td>
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<tr>
<td>Evidence</td>
<td>Source</td>
<td>test</td>
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<td>Treatment</td>
<td>Mechanism</td>
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<td></td>
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<td>Processes</td>
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<td>find facts</td>
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<tr>
<td></td>
<td>Confirm</td>
<td>match to other examples, opinions</td>
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<tr>
<td></td>
<td>Predict</td>
<td>propose probable outcome</td>
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APPENDIX C

Diagnosis frame

Decision processes are broken into subprocesses that employ information from the other slots. An asterisk indicates the possibility of more than one occurrence of a given slot or facet within the frame.

<table>
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<th>Examples of values</th>
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<td>Treatment</td>
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<tr>
<td>Diagnosis</td>
<td>Certainty</td>
<td>confirmed, probable, unlikely</td>
</tr>
<tr>
<td></td>
<td>Epidemiology*</td>
<td>occurrence, distribution</td>
</tr>
<tr>
<td>Evidence*</td>
<td>Source</td>
<td>patient, observation, test</td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td>material, fluid</td>
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<tr>
<td></td>
<td>Measure</td>
<td>numeric value, image</td>
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<tr>
<td></td>
<td>Decision</td>
<td>diagnostic, suggestive</td>
</tr>
<tr>
<td></td>
<td>weight</td>
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</tr>
<tr>
<td></td>
<td>Relationship</td>
<td>compatible, conflicting</td>
</tr>
<tr>
<td></td>
<td>Interpretation</td>
<td>normal</td>
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</table>

APPENDIX D

Treatment choice frame

Treatment decision processes demand more procedural information. The nature of knowledge required for the treatment slots is more procedural than that required for diagnostic slots in the diagnosis frame. An asterisk indicates the possibility of more than one occurrence of a given slot or facet within the frame.

<table>
<thead>
<tr>
<th>Slot</th>
<th>Facet</th>
<th>Examples of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition*</td>
<td>Name</td>
<td>neutropenia</td>
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<tr>
<td>Diagnosis</td>
<td>Certainty</td>
<td>probably, confirmed</td>
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<td></td>
<td>Status</td>
<td>new, existing, future</td>
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<tr>
<td></td>
<td>Features*</td>
<td>body changes, prognosis</td>
</tr>
<tr>
<td>Treatment*</td>
<td>Type</td>
<td>surgery</td>
</tr>
<tr>
<td></td>
<td>Action</td>
<td>removal, suppression</td>
</tr>
<tr>
<td></td>
<td>Outcome</td>
<td>mortality/morbidity rate</td>
</tr>
<tr>
<td></td>
<td>Relationship</td>
<td>cause-and-effect, supplement, alternative</td>
</tr>
<tr>
<td>Procedure</td>
<td>Features*</td>
<td>steps of technique, dosage</td>
</tr>
<tr>
<td></td>
<td>Application*</td>
<td>mechanisms, side effects</td>
</tr>
<tr>
<td></td>
<td>Usage</td>
<td>condition it treats</td>
</tr>
<tr>
<td></td>
<td>Implementa-tion</td>
<td>preferred, experimental, novel</td>
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<td></td>
<td>Complicators*</td>
<td>partial excision, implant</td>
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<td>Patient</td>
<td>Special feature*</td>
<td>other treatments, conditions</td>
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<td></td>
<td>Treatment</td>
<td>unsuccessful</td>
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<tr>
<td></td>
<td>history</td>
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<td>Outcome*</td>
<td>Prognosis</td>
<td>recovery rate</td>
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<td></td>
<td>Context</td>
<td>quality of life</td>
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<tr>
<td></td>
<td>Certainty</td>
<td>probable, unlikely</td>
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<td>Processes</td>
<td>Identify</td>
<td>find facts, values</td>
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<tr>
<td></td>
<td>Confirm</td>
<td>establish acceptable level of certainty</td>
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<tr>
<td></td>
<td>Verify</td>
<td>determine correctness</td>
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<tr>
<td></td>
<td>Compare</td>
<td>match to similar case or standard</td>
</tr>
<tr>
<td>Slot</td>
<td>Facet</td>
<td>Examples of values</td>
</tr>
<tr>
<td>--------</td>
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<td>-------------------------------------</td>
</tr>
<tr>
<td>Condition</td>
<td>Diagnostic clue</td>
<td>value of test evidence</td>
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<tr>
<td></td>
<td>Features</td>
<td>cause, symptoms</td>
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<tr>
<td></td>
<td>Evidence</td>
<td>tests, observation</td>
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<tr>
<td></td>
<td>Sources</td>
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</tr>
<tr>
<td></td>
<td>Relationship</td>
<td>co-occurrence, cause-and-effect</td>
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<td>Prevention</td>
<td>technique</td>
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<tr>
<td>Substance</td>
<td>Source</td>
<td>thorn, environment</td>
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<td></td>
<td>Effect</td>
<td>symptom, body change</td>
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<td>Toxicity</td>
<td>levels, standards</td>
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<tr>
<td>Treatment</td>
<td>Usage</td>
<td>novel, established</td>
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<td></td>
<td>Procedure</td>
<td>steps, application</td>
</tr>
<tr>
<td>Relation-</td>
<td>Nature</td>
<td>co-occurrence, cause-and-effect</td>
</tr>
</tbody>
</table>

**APPENDIX E**

**Learning frame**

Learning activities result from information gathering and decision processes of clinical practice. They provide background information for future decision making. Their outcome may be declarative or procedural knowledge.

<table>
<thead>
<tr>
<th>Clinical problem solving</th>
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</thead>
<tbody>
<tr>
<td>Justify</td>
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<tr>
<td>Compare</td>
</tr>
<tr>
<td>Explain</td>
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<tr>
<td>Choose</td>
</tr>
<tr>
<td>Eliminate</td>
</tr>
<tr>
<td>Weigh</td>
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<tr>
<td>Compare</td>
</tr>
<tr>
<td>Predict</td>
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<td>Predict</td>
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</table>

**APPENDIX F**

**Declarative and procedural information expected in published literature**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Information expected</th>
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<tbody>
<tr>
<td>Conditions</td>
<td>Symptom associations, causes, links to other conditions, prognosis, incidence, distribution by patient characteristic, symptom co-occurrence</td>
</tr>
<tr>
<td>Substances</td>
<td>Acceptable levels, hazard levels</td>
</tr>
<tr>
<td>Tests</td>
<td>Value interpretation, error rates, specificity rates</td>
</tr>
<tr>
<td>Treatments</td>
<td>Side effects and their frequency, mechanism of action, use by patient characteristic, expected and unexpected outcomes, guidelines for long-term application</td>
</tr>
<tr>
<td>Patients</td>
<td>Relevant demographic characteristics, relevant factors of disease history, treatment outcomes</td>
</tr>
<tr>
<td>Decision factors</td>
<td>Cause-and-effect relationships, co-occurrence, strength of association, choices, comparison of outcomes for two approaches, weights, normal range, interactions, implications</td>
</tr>
<tr>
<td>Confirmation</td>
<td>Consensus support, current practice</td>
</tr>
</tbody>
</table>