
Problem Knowledge Couplers: reengineering evidence-based medicine through interdisciplinary development, decision support, and research*

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The rapid growth of medical knowledge is creating a demand for new ways of providing information in support of evidence-based medical practice. Problem Knowledge Couplers are a clinical decision support software tool that offer a new approach to this growing problem. Couplers are developed through a collaboration among clinicians, informaticians, and librarians. They recognize that functionality must be predicated upon combining unique patient information, gleaned through relevant structured question sets, with the appropriate knowledge found in the world's peer-reviewed medical literature. Two pilot studies indicate that couplers can meet the gold standards of decision making within both a primary care and a specialty practice. Issues remain about how to best integrate Problem Knowledge Couplers into clinical practice and whether large-scale outcomes research will support the findings of pilot studies. However, Problem Knowledge Couplers represent a promising approach that might portend a new model for health care delivery in the next millennium.

Evidence-based medicine has become the standard for quality medical practice. Efficient and effective access to this evidence, in the form of knowledge-based information, has traditionally fallen under the purview of librarians. However, time constraints have pushed the development of other forms of evidence, including clinical decision support software programs, which are derived from knowledge-based information combined with specific medical findings and weighted by probabilities to generate suggestions for diagnosis or management [1].

Current clinical decision support software programs vary both in content and in logic algorithms that generate diagnostic and management options. All such programs are based on extant accepted medical knowledge, although the sources of the knowledge range from annual reviews to a detailed analysis of quality-filtered medical journal literature. Bayesian logic is used in most such programs to define probabilities, however one clinical decision support software

program, Problem Knowledge Couplers [2], uses combinatorial logic to list all diagnostic or management options based on facts contained in the knowledgebase rather than options filtered and ranked according to probability within a specific patient population.

Problem Knowledge Couplers are developed around common presenting problems and the hundreds of potential causes of each. Each coupler is comprised of questions designed to elicit responses from the patient that, when linked to the facts contained in the knowledge net, enable the generation of a list of potential diagnostic or management options based on their relevance to the published literature.

Problem Knowledge Couplers are unique in the world of clinical decision support software systems for a number of reasons. As mentioned above, they use combinatorial rather than Bayesian logic. The knowledge net, which encompasses the evidence driving the decision support, is composed of facts gleaned from a wide array of critically analyzed medical monographs and journal literature rather than annual composites of new medical knowledge. Even the guiding principle sets the system apart in its belief that patients, with all of their unique attributes ascertained through struc-

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tured question sets, need to guide the decision-making process, based not on how likely the diagnostic or management option is relative to other similar patients but on how likely that option is relative to the unique patient based on the world's published medical knowledge.

DEVELOPMENT OF PROBLEM KNOWLEDGE COUPLERS

Problem Knowledge Couplers are created and continually refined through the work of an interdisciplinary team composed of clinicians, informaticians, and librarians. Each member of the team has a unique and vital role in the development process, and is guided by the vision of Lawrence Weed, M.D., professor emeritus, Department of Medicine, University of Vermont, and president, PKC Corporation. Dr. Weed created the problem-oriented medical record, and Problem Knowledge Couplers were an outgrowth of his early work in the development of an electronic medical record and decision support software.

Problem Knowledge Couplers are built on the premise that no single clinician can remember all of the numerous possible causes of any symptom and that clinicians tend to focus on the one or few medical problems that fall within their recent experiences rather than the hundreds that may or may not be pertinent to the patient with the problem. The couplers, therefore, take the recall variable out of the equation of diagnostic or management problem solving, and give clinicians a set of possible solutions based on the patient responses to the questions linked to the facts in the knowledge net. From this set of solutions, clinicians are then able to rule out the impossible, review the improbable, and select the most logical solution to the medical problem as determined by the patient and the knowledgebase with little or no reliance on personal biases.

To construct such a set of tools requires several unique sets of skills. Obviously, informaticians must design the computer architecture to ensure that the program achieves its goals. In addition to performing complex tasks in linking the questions to the knowledge net, it also must be constructed in such a way as to take advantage of the best of current and emerging technologies and to ensure that the tools are both useful and usable for their intended audiences.

The content falls under the purview of the clinicians and the librarians. For the creation of a single Problem Knowledge Coupler, an enormous amount of literature in the form of evidence must be amassed. Information already contained in the knowledge net must be reviewed and analyzed for applicability to the new problem. If factoids (pieces of information contained in any concept within the medical literature) are found to be relevant, then they have to be linked to specific ques-

tions within the new coupler. However, linking to existing concepts within the knowledge net is only the beginning.

The management or diagnostic problem for which the coupler is being developed must be thoroughly researched. Librarians, as part of the interdisciplinary team, develop complex search strategies to determine even the most obscure findings related to any medical problem. Positive findings, linked to evidence in the literature through the coupling process, could mean that some remote diagnosis is made although under normal circumstances it would never have been considered. This linking is the power and the process of the tools.

Following the compiling of the evidence, the enhancing of the knowledge net to support the facts related to the new medical problem, and the writing of the appropriate questions and their linkages to the factoids in the knowledge net, subject specialty clinicians review the new coupler for accuracy and completeness. Many modifications to any Problem Knowledge Coupler are made prior to its addition to the set, and each coupler is continually reviewed and revised based on comments from clinicians using the couplers in practice.

One of the major problems with any clinical decision support software program is ensuring that its knowledgebase is current. This problem is somewhat easier for those systems that use the Annual Review series or the Yearbook series to update their knowledgebases. However, the currency problem for Problem Knowledge Couplers, which includes information from hundreds of medical books and journals, is immense. To mitigate this problem, librarians are again a valuable part of the team, continually reviewing journal and monographic literature and suggesting modifications and additions to extant couplers to ensure that they can offer the best in decision support.

DECISION SUPPORT AND PROBLEM KNOWLEDGE COUPLERS

Lack of information when it is needed in medical practice is a major cause of stress among physicians, nurse practitioners, physicians assistants, and other health care providers. The root cause of uncertainty, or ambiguity, in medical practice is the medical information explosion and the impossibility for health care providers to amass all of the information necessary to ensure efficient and effective quality medical care for every patient. While most patients in seeing primary care clinicians present with medical problems for which diagnostic and therapeutic medical decision making is based on common practice, a small but significant number of patients have medical problems that fall outside the norm. Similarly, patients seeing specialists occasionally present with medical problems that are

confounded by conditions not usually encountered by the specialty practice. These patient problems are major stressors, the cause of feelings of ambiguity among providers, and the source of an identified need for a decision support tool.

In her seminal treatise, Fox studied medical students and defined three kinds of uncertainty related to the acquisition of medical knowledge: personal uncertainty about the subject matter, sense of uncertainty about the accuracy or completeness of information presented, and uncertainty arising from the inability to distinguish between the two [3]. Light expanded on Fox's knowledge-based uncertainty to add uncertainties regarding diagnosis, treatment, and patient responses [4]. Gorman and Helfand looked at what factors contributed to physicians' knowledge seeking and determined that knowing that such knowledge existed, knowing that the patient problem was acute, and knowing that the patient expected the clinician to know the answer were primary precipitants in acquiring needed information [5].

Gerrity, DeVellis, and Earp suggested that the rapid growth of technology and scientific knowledge has in part been responsible for a growing ambiguity in the medical profession. To ascertain effective reactions to uncertainty and whether feelings of ambiguity result in stress, two Physicians' Reactions to Uncertainty Scales were developed, comprised of a thirteen-item Stress from Uncertainty Scale and a nine-item Reluctance to Disclose Uncertainty to Others Scale. The researchers found that stress arose primarily from a fear of failure and personal inadequacy although most health care providers have developed defense mechanisms ranging from denial to rituals in dealing with ambiguity in health care decision making [6]. Geller, Tambor, Chase, and Holtzman, in order to define practices regarding genetic testing as a correlate for ambiguity tolerance, developed a new eighteen-item Tolerance for Ambiguity scale and found that tolerance for ambiguity increased with the length of time in practice [7].

Eddy looked at the role of uncertainty as a factor in practice variations. As in earlier works, Eddy noted that uncertainty arose from the recognition of an infinite variety and combination of signs, the symptoms and observer variations in diagnostic processes, the availability of numerous management options compounded by the efficacy of each based on who performs treatment, the variables surrounding measurement of outcomes and individual variations in responses to procedures, and the determination of the best medical decision in terms of the individual preferences of the patient. Eddy concluded that uncertainty in medical practice could never be eliminated. However, he suggested that the profession needed to begin to manage ambiguity to lessen its potential negative impact on patient care. To do this, collection and eval-

uation of the patient's medical information needed to be based on evidence and logic within the context of medical decision making [8].

Librarians have long been a primary support in assisting clinicians with information problems. They are able to negotiate an information problem, to formulate and run complex searches for needed information, to quality filter the bibliographic outputs, and to provide rapid retrieval services to ensure that the health care provider has access to information at the point of medical decision making. Clinical medical librarian programs are excellent examples of teamwork to improve patient care through rapid access to specifically relevant information in support of clinical decision making. However, not every hospital has a clinical medical librarian program and it would be virtually impossible to assign to every clinician across the country a librarian, who would be on call when an information problem arises.

Accepting that ambiguity of medical practice is a constant and that human intervention in the form of a clinical medical librarian on call twenty-four hours a day, five days a week, is impossible, then a computer tool may provide a viable alternative. This tool needs to combine the best precepts of evidence-based medicine—as gleaned from an extensive knowledge net, preferably supported by highly skilled medical librarians—with the findings of the unique patient to identify causes and suggest diagnostic and management options in support of clinical decision making. Such a tool can be used to mitigate the normal stress caused by the ambiguity or uncertainty of practice. In addition, if this tool empowers the physician to resolve ambiguous questions for patient care in a timely manner, then it can have a demonstrable impact on the outcomes of patient care.

Problem Knowledge Couplers attempt to address uncertainty in medical decision making caused by a rapidly expanding medical knowledgebase and the sociology of current medical practice in which clinicians are expected to know not only the common medical problems but also the uncommon ones. However, the acceptance of such a tool requires a major paradigm shift in the health care environment.

Most clinicians will readily admit that they do not have all the answers. However, clinicians are less comfortable admitting that a computer program may offer suggestions that they would not have considered for common presenting complaints. In addition, to use such tools properly, reengineering current practices becomes necessary. Couplers, and all current clinical decision support software programs, require more time than is normally allotted to the routine office visit. However, to be used effectively, all questions must be answered and the programs must be used routinely with every patient visit. Such use would require that other members of the health care team take an active

role in the patient visit by triaging every patient and providing findings to the clinician to make the final decision in concert with the patient.

Because changing routine office practice is not a viable option for most clinicians unless they are committed to reorganizing the way they practice medicine permanently, use of clinical decision support software in general and Problem Knowledge Couplers in particular is not widespread. However, one other reason has had a major impact on the lack of use. Very little research has been done that demonstrates the advantages of using such systems. In a 1994 article comparing four clinical decision support software programs, the authors found that the programs gave a large amount of irrelevant information and incorrect diagnoses [9]. The findings of this study, which did not look at Problem Knowledge Couplers, suggested that, in 1994, clinical decision support software needed improvement and that more research needed to be done to prove its efficacy.

RESEARCH AND PROBLEM KNOWLEDGE COUPLERS

Problem Knowledge Couplers are the result of an interdisciplinary collaboration among clinicians, informaticians, and librarians. Examples of partnerships between librarians and clinicians in information acquisition in support of health care delivery are available in virtually every hospital and academic medical center. However, there are few published works that list librarians among the authorship groups as viable members of the research teams, and librarians are not the only health care professionals routinely excluded from research protocols.

Bland and Ruffin identified twelve characteristics of a productive research environment. These characteristics included clear goals, emphasis on research, distinctive organizational culture, positive group climate, assertive participative governance, decentralization, frequent communication, accessible human resources, appropriate size and diversity of the research group, appropriate rewards, focus on recruitment, and leadership with research expertise [10]. Their findings indicated that differences among members of research teams in both discipline and levels of terminal degrees often promoted creative problem solving and greater productivity. However, most analysis of interdisciplinary research team performance was found almost exclusively in the nursing literature [11–14].

Use of clinical decision support software in medical practice offers a research problem that lends itself to an interdisciplinary team approach. Little research has been done on Problem Knowledge Couplers. They have been extremely valuable in the educational process of undergraduate medical students, where they have been used to support basic curricular concepts

(e.g., providing structure for a history and physical or supporting information as a basis for medical practice in the core clerkships). They have also provided a foundation for more advanced decision support in acting internships and senior selectives [15–16]. However, they have not been evaluated using a formal research methodology, even in the form of a pilot project.

The premise of coupler development is that no single practitioner can store and recall all facts necessary to always make appropriate clinical decisions across the broad spectrum of medical knowledge and complicated by the complexities within each medical problem. This premise is particularly true in primary care where providers cannot concentrate on the medical knowledge pertinent to a narrowly defined area of medical practice but must rely on a more global understanding of all medical problems. Couplers, therefore, offer a tool that can support practitioners during times of uncertainty or ambiguity.

To test this hypothesis, a multicomponent research project, in the form of two pilot studies on the use of clinical decision support tools to lessen ambiguity in both primary and specialty care, was designed to determine whether Problem Knowledge Couplers were reliable tools for common diagnostic problems and could affect decision making. The research team was led by a librarian and a Ph.D. nurse researcher with a nurse informatician who was a specialist in Problem Knowledge Coupler use.

METHODOLOGY

The descriptive pilot studies involved a general primary care practice and one that specialized in the care of the chronically ill, specifically, those afflicted with chronic obstructive pulmonary disease (COPD). The health care providers participating in the study from the first site included two family practice physicians and one nurse practitioner in a rural primary care setting. One pulmonologist in rural practice participated in the second pilot.

Because of the differences in the practices, each of the pilot studies was designed slightly differently to meet the specific practice needs of both the health care providers and the specific patient populations. The clinicians at the primary care site were asked to take a much more active role in the analysis of the impact of couplers on their medical decision making at the time the patient was being seen. The pulmonologist participated in the project retrospectively through discussions about findings from couplers in comparison to the chart reviews.

Family practice site

Prior to the beginning of the study, the three participants were given instruction on the use and potential

efficacy of the Problem Knowledge Couplers and an overview of the study design. In order to limit the Hawthorne effect (a change in practice due to observation of that practice), the coupler pilot study was structured in such a way as to minimize the primary care practitioners' involvement with the couplers. To accomplish this minimization, patients who scheduled routine visits for medical problems were asked if they would like to participate in a study evaluating the use of the a clinical decision support tool. If they responded in the affirmative, they were asked to plan on remaining in the office following the appointment with the primary care provider to answer coupler questions. Patients scheduled for annual physicals were excluded. No patient was compensated for participation.

During a random week, the two nurse researchers trained in coupler use collected patient data for the pilot study. Patients arriving at the office who indicated a willingness to participate in the study were asked to sign a consent form. Following their visit with their primary care provider, they were shown into a room with one of the nurse researchers who explained the coupler process. Because many of the questions rely on history or physical data, the nurse had access to the patient's medical record and entered all relevant clinical data if it was available.

There were over seventy couplers and the choice of the coupler used was based on the presenting chief complaint. The coupler sets enabled the questions to be answered in three ways: yes, no, and unknown. The couplers also allowed for the addition of comments next to individual questions. All questions that could be answered by the patients were entered into the coupler. Any physical findings or laboratory data noted in the medical record were also entered. However, if the coupler asked for information that the patient was not able to answer or was not contained in the patient record, even if such information might be a physical finding observed by the nurse researcher, it was omitted, with the inclusion of a comment if appropriate.

All data collected were saved and findings as well as information obtained by the "coupling" process were printed and stored in the individual patient's medical record. When the office was closed, both during the two-hour lunch break and following the last patient seen at the end of the day, records were reviewed to determine if any medical data had not been collected that might have helped with the diagnostic or management problem and if the coupling process revealed findings that could affect a change in diagnosis or management. If appropriate, patients were scheduled for follow-up appointments.

Rural chronic disease site

Although the primary activities of the second practice site revolved around the management of rural chronic

disease, the physician was a board certified pulmonologist, and because of this specialty and the limitations of his practice, the second pilot did not focus on defining his ambiguity in decision making. Instead, the research looked at whether the couplers could be validated against his professional judgement and whether they would suggest management or diagnostic options not previously considered, which might impact his delivery of patient care and thus lessen ambiguity, inherent and yet unrecognized, in his practice.

The pulmonologist was asked to select five patients who had been seen within the past six months, all of whom had presented with signs of asthma or severe breathing difficulties. He was also asked to base his selection on patients on whom he had detailed medical histories, to mitigate the effect of undocumented findings in the patients' charts. Following the selection of the patients, the librarian and one of the nurse researchers did a detailed analysis of each patient's chart and selected couplers against which the findings could be run. The procedure involved going through each of the question sets in the specifically relevant couplers and using the charts as a baseline source of information that would provide the relevant answers to the questions.

FINDINGS

The purpose of the research was two-fold. First, it needed to determine whether or not the use of Problem Knowledge Couplers in primary care or specialty care practice could provide a basis for clinical decision support as validated against the diagnostic performance standards of the health care providers using the tools. This research question became the focus of the two pilot studies.

The second question involved whether the use of couplers had the potential to mitigate the feelings and effects of ambiguity in practice and, if substantiated, whether couplers would be considered for use by the participants. This second question was answered by discussions with the health care provider participants in both pilot studies and an analysis of the coupler findings against the diagnostic and management options of those involved in the study.

Family practice site

Local and unforeseen environmental problems (Town Meeting Day in Vermont, a blizzard causing the office to be closed, and a substantial number of patient appointment cancellations on the days it was open) resulted in data collection on six patients during a two-day period. Because this was a pilot study to determine whether the couplers would support decision making in a primary care setting and meet the gold

Table 1
Analysis of findings from family practice site

Patient/chief complaint coupler used		Chart findings	Coupler findings (Other pertinent findings, nonrelated findings)
PT 1/two-week strep infection			
URI complaints	Muscle, joint pain; fatigue; swollen lymph nodes		Muscle, joint pain; fatigue; swollen lymph nodes (<i>dizziness; watery eyes, snoring, headache; also smoking; easy bruising</i>)
Probable diagnosis:	Tonsillitis		Tonsillitis
PT 2/severe cough			
URI complaints	Weight loss; pale; nasal congestion; hacking cough; vomiting with abdominal pain		Weight loss; pale; nasal congestion; hacking cough; vomiting with abdominal pain (<i>whooping sound during cough; also exposure to rodents (Hanta virus?); Vincent's angina; and many others</i>)
Probable diagnosis:	Pertussis		Pertussis
PT 3/sore throat & cough			
URI complaints	Ineffective cough; nasal congestion & discharge; sore throat; hoarseness		Ineffective cough; nasal congestion & discharge; sore throat; hoarseness (<i>neck pain; itchy eyes; also headache; heart disease; unexplained weight loss</i>)
Probable diagnosis:	Viral pharyngitis		Viral pharyngitis
PT 4/itching, watery eyes & nasal congestion			
URI complaints	Itching, watery eyes; nasal congestion; chronic hoarseness		Itching, watery eyes; nasal congestion; chronic hoarseness (<i>swollen lymph nodes; sore throat; habitual throat clearing</i>)
Probable diagnoses:	Viral pharyngitis or acute laryngitis		Viral pharyngitis or acute laryngitis
PT 5/itching, watery eyes & nasal congestion			
URI complaints	Itching, watery eyes; nasal congestion		Itching, watery eyes; nasal congestion (<i>snoring; obstructive apnea; sore throat; habitual throat clearing; productive cough lasting more than 3 months; also headache; weakness or fatigue; unexplained weight loss; wakes gasping for air; smoker</i>)
Probable diagnoses:	Viral pharyngitis or acute laryngitis		Viral pharyngitis or acute laryngitis
PT 6/burning upon urination			
Dysuria—women	Pain when urinating; positive culture for candida		Pain when urinating; positive culture for candida (<i>tenesmus; external and internal sensations of dysuria; abrupt onset of symptoms; also lower abdominal pain; diet high in refined sugar</i>)
Probable diagnosis:	Urinary tract infection		Urinary tract infection

standard established by the primary care providers, the sample was considered sufficient.

Of the six patients, all were female, five presenting with a chief medical complaint of upper respiratory distress—the most common seasonal complaint in Vermont for the time of year—and one with burning upon urination. The patients were all Caucasian and ranged in age from sixteen to sixty-five. While having males in the sample would be more descriptive of the patient population, the lack of minorities was representative both of the practice and the state in which the entire minority population is less than 5%.

Two couplers were used in the pilot evaluation, the upper respiratory infection (URI) complaints coupler and the dysuria in women coupler. The printouts of the findings from the couplers were compared to the findings noted in the medical records to ascertain common findings in both and to determine which findings were present in one but not the other. The primary options for diagnosis in the couplers were then compared to the medical records against the respective provider's primary diagnosis to look for concordance. A detailed analysis of the findings is found in Table 1.

The use of the couplers at the family practice site

indicated that there were a number of findings either not revealed in the initial history and physical or not recorded in the medical records that could have had an impact on the ability of the providers to make a clinical decision. This information, in itself, would have lessened ambiguity in more complex cases. However, there was 100% concordance in the diagnosis of the providers and the coupler primary options in routine cases seen in the rural primary care office. The coupler use did, however, also reveal risk factors unrelated to the presenting problem, which were caught early and followed for the pertinent study participants.

The family practice site coupler pilot study required that the patient be seen by both the clinician and the nurse researcher, who frequently repeated questions asked during the initial encounter. There is a recognition that routine coupler use requires more time than would ordinarily be allocated to a single patient visit and would be impractical to attempt to integrate into primary care offices without a complete reengineering of the medical practice.

However, because of the concordance of the diagnoses and the comprehensiveness of the findings, this pilot has demonstrated the effectiveness of the couplers for routine clinical decision support and has

Table 2
Analysis of findings from rural chronic disease site

Patient/chief complaint coupler used		Chart findings	Coupler findings (Other pertinent findings, nonrelated findings)
PT 1/breathing difficulty; chest pain; productive cough			
History coupler	Progressive or severe breathing difficulty; chest pain; productive cough with yellow sputum; breathlessness; recommended IgE or sputum tests (Note: not recommended by coupler, potentially problematic if initial presentation of disease)	Progressive or severe breathing difficulty; chest pain; productive cough with yellow sputum; breathlessness (constant stuffy nose; also need to update immunizations)	
Known diagnosis:	Allergic bronchopulmonary aspergillosis	Allergic bronchopulmonary aspergillosis	
PT 2/extreme breathing difficulty becoming more pronounced			
History coupler	Progressive or severe breathing difficulty; history of childhood pertussis; yellow nasal discharge; pus filled or bloody sputum	Progressive or severe breathing difficulty; history of childhood pertussis; yellow nasal discharge; pus filled or bloody sputum (chest pain or discomfort; breathlessness in spells; also need to update immunizations; evaluate for hyperlipedemia)	
Known diagnosis:	Bronchiectasis	Pending results of lung function tests	
PT 3/continuous dry cough, lethargy, and severe breathing difficulty			
History coupler	Dry cough that will not stop; lethargy; breathlessness	Dry cough that will not stop; lethargy; breathlessness (exposure to farm and organic dust; recommendation for lung function tests; also recommendation for TSH & FT4 assays to rule out hypothyroidism)	
Known diagnosis:	Sarcoidosis	Sarcoidosis	
PT 4/evaluation of lung cancer lung cancer workup			
Coupler	Known diagnosis of lung cancer; abnormal liver consistency; prominent hilum; recommended sputum analysis; lung function tests (PFTs) and CT scan recommended	Suspected diagnosis of lung cancer; abnormal liver consistency; prominent hilum; recommended sputum analysis (PFTs not recommended because of suspected metastases; biopsy indicated because of small adrenal mass with normal mediastinum, contraindicated because of cough)	
Known diagnosis:	Lung cancer	Lung cancer	
PT 5/suspected lung cancer lung cancer workup			
Coupler	Suspected diagnosis of lung cancer; sputum cytology; X-ray of chest—prominent hilum; PFTs	Sputum cytology recommended because of low cost; X-ray of chest—prominent hilum (PFTs, but marginal in surgical candidate)	
Probable diagnosis:	Lung cancer	Lung cancer	

shown their usefulness in identifying risk factors or underlying indicators of emerging medical problems that could lead to more effective practice management, particularly in a managed care environment.

Rural chronic disease site

The second pilot study involved chart reviews of five patients with diagnosed or suspected chronic obstructive pulmonary disease (COPD) who presented with an acute episode of either cough or asthmatic symptoms. For the purpose of this study, asthma was defined by the couplers as a disease marked by recurrent attacks of paroxysmal dyspnea, wheezing, cough, and a sense of constriction due to spasmodic contraction of the bronchi. COPD generally refers to the class of diseases that inhibit breathing and obstruct the lung, such as chronic bronchitis and emphysema. These diseases are often characterized by asthmatic symptoms.

Of the couplers available, those with management components as well as diagnostic components were chosen because four of the five patients had already been diagnosed with the primary cause of their COPD. Because there was no specific COPD coupler, three of the patients presenting with asthmatic symptoms were evaluated using the generic history coupler. Two patients, one with diagnosed and the second with sus-

pected lung cancer, were evaluated using the lung cancer workup coupler. A detailed analysis of findings is found in Table 2.

The findings from the rural chronic disease site were slightly more difficult to analyze than those from the primary care site, both because of the methods used and because of the choice of a quasi-primary care provider as a study participant. Running the couplers against the findings obtained in the chart reviews showed that all patients, in accordance with the orders of their pulmonologist, had received standard treatment for their acute conditions, and that the same diagnostic tests and primary management options had been recommended by the coupler used. The respective couplers did, however, also provide substantive information supporting recommendations that could have been shared with the patient at the point of decision making.

No new findings relating to patient pulmonary problems were discovered using the couplers. While the coupler and the pulmonologist agreed on both diagnostic tests and management options, there was some question as to whether any new information was added in the area of the specialty. However, two of the five patients were not up-to-date on their immunizations and one patient, based on the coupler recom-

mentation for a TSH test, was subsequently found to have hypothyroidism.

AMBIGUITY AND COUPLER USE

In summarizing the findings of the coupler comparisons and the discussions with the health care providers participating in the study, some interesting trends began to emerge. Those at the family practice site demonstrated an average level of stress relative to ambiguity in practice and an extremely high tolerance for ambiguity. In each of the six cases analyzed using couplers, the family practitioners arrived at the same diagnostic conclusions as the couplers, some less obvious than others, but they also recognized that they missed some signs and symptoms, which could have been predictors of more serious conditions that needed to be ruled out.

There was a general consensus among the clinicians at the practice sites that coupler use with the patient would lessen uncertainty in many conditions. However, there were serious questions about how to integrate couplers into the current practice. Ideally, the family practitioners said that they would like to be able to use it as an aid for questions of ambiguity after work, however, that practice would inhibit the benefit derived from having the patient answer questions that had not been asked.

In terms of the COPD practice, the pulmonologist and the couplers had complete concordance in the diagnostic and management options relative to each patient. The question of meeting the gold standard was answered. However, the pulmonologist saw little value for the couplers in assisting his decision making regarding COPD. This finding paralleled the findings of all of the ambiguity scales and subscales, which indicated that specialists experienced less ambiguity because of their greater ability to assimilate and apply information regarding their specialties.

The pulmonologist suggested that the greatest potential for coupler use in his practice was vested in the ability of couplers to identify problems outside of his area of specialization, or those problems that caused ambiguity because of the way they manifested themselves in patients with chronic disease. He also reflected that this ambiguity was a significant problem in his practice because many patients in rural areas preferred to use the specialists managing their chronic illnesses as their primary care providers.

CONCLUSIONS

The confluence of the rapid growth of medical knowledge and the demands of the contemporary health care practice environment, particularly in an era of managed care and information literate health care consumers, has created a growing need for rapid access

to knowledge-based information and a mandate for evidence-based medical practice. Clinical decision support software offers some promise in solving this problem, however any such tool must first be proven to meet acceptable standards of care established by the potential users. Secondly, these tools must offer additional attributes that will enhance the knowledgebase of the health care providers leading to improved care delivery.

Problem Knowledge Couplers are such a set of tools. They are the product of a collaboration among clinicians, informaticians, and librarians. They use the very best precepts of evidence-based medicine by building links between unique patient attributes and a wide array of quality filtered and critically analyzed monographic and journal literature to generate diagnostic and management options. Couplers, built on the work of librarians, enable access to literature for clinical problem solving when it is impractical for a librarian to be present.

Collaborative research between librarians and clinicians in the form of two pilot studies has demonstrated that couplers have met the acceptable standards of care based on the gold standard of the clinicians involved in the research. While the coupler use did not change decision making about the diagnosis and management of the cases studied, the couplers did offer alternatives for diagnostic decision making that would not have been considered by the family practice group in one of the pilots and detailed explanations of management options in the COPD practice that would have helped the patient to make an informed decision about choices of care in the second pilot. The couplers also identified tangential medical problems that would not have been found in routine office visits but could have led to more serious conditions if left untreated. Four of the patients received additional care as the result of the use of couplers in these pilot studies.

In terms of specific use by the different types of practices, the primary care site indicated that it would like to use couplers for those unique cases in which the specific diagnostic or management option was elusive. The pulmonologist indicated that he saw little benefit in using the couplers for his COPD patients who presented with respiratory symptoms, but that he did see value in those patients with complex chronic illness, such as a diabetic COPD patient or one who developed heart disease.

While the health care providers involved in both pilot studies felt that couplers offer a means to mitigate most ambiguity in their practices effectively, the major identified problem is how best to use the couplers within the current workflow. For couplers to achieve maximum effectiveness, they need to be used with the patient prior to being seen by the caregiver, and not following the initial examination. This timing has sig-

nificant implications for small practices in terms of human resources and space requirements.

Problem Knowledge Couplers offer a unique way to manage ambiguity in primary or specialty care caused by the growth of medical knowledge, if health care providers are willing to accept a new model of health care delivery. More studies with larger cohorts need to be done to validate coupler use in both primary and specialty care practice settings and to determine the most effective practice model in which to incorporate them. However, because of their interdisciplinary development, provision of decision support, and ability to enable positive clinical outcomes, Problem Knowledge Couplers hold the potential for reengineering evidence-based medicine in the next millennium.

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