The Importance of Early Problem Representation during Case Presentations

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Case discussion have remained the primary way that clinical faculty assess both how much a medical student or house officer knows and how well that knowledge is applied in making a diagnosis. Exactly how these discussions help to sort out successful and unsuccessful diagnosticians, however, has been a subject of much controversy. The work of Elstein et al. initially directed attention to the process of clinical reasoning. While the concepts of data acquisition, hypothesis generation, and hypothesis evaluation were commonly discussed by them and others, Elstein et al. concluded that "differences between experts and weaker problem solvers are more to be found in the repertory of their experiences, organized in long-term memory, than in differences in the planning and problem-solving heuristics employed." This led other investigators to examine the roles of knowledge retrieval and organization in diagnostic problem solving (e.g., Feltovich's logical competitor sets,[2] Patel and Groen's production rules,[3] Norman et al.'s instances,[4] Bordage and Zack's prototypes,[5] and Lemieux and Bordage's semantic networks[6-8]). Up to now, researchers have found that successful clinicians have better sets of diagnostic hypotheses, but they have been unable to explain this phenomenon in a way that sheds light on the nature of the mental processes that produce better diagnostic hypotheses.

Bordage and colleagues[9] have developed and validated a method to assess knowledge structures based on semantic analyses of clinician's discourses. Semantic analysis offers a unique appraisal of case presentations by assessing how well clinicians ascribe meaning to the presenting symptoms and clinical findings. For instance, a student might transform a patient's "painful, swollen, right knee that began two nights ago with attacks two and nine years ago" into a conceptualization or representation of the problem such as "an acute, recurrent attack of abrupt, nocturnal, and extremely severe pain in a single, large joint." The underlined words are called semantic qualifiers (SQs), that is, terms (adjectives or adverbs) that represent the student's conceptualization or abstraction of the clinical findings. Semantic qualifiers reflect the meaning that the clinician assigns to the clinical data. Semantic analysis systematically searches for these semantic qualifiers and their use in comparing and contrasting potential diagnoses throughout a case presentation. Clinicians who use SQs to sort out diagnoses are more successful in making accurate diagnoses than are those who simply stick to the raw symptoms and signs (see Bordage's discussion of elaborated or compiled discourses compared with reduced or dispersed ones[9,10]). Taken together, a clinician's transformations or SQs reveal his or her *representation* of the chief complaint and present illness.

Problem representation has been shown in cognitive psychology to play a crucial role in solving problems (e.g., in algebra education[11]). In medicine, problem representation would constitute an intermediate step between data acquisition and hypothesis generation whereby the representation helps the clinician to understand the problem and to direct his or her knowledge retrieval toward relevant diagnostic groups or diagnoses. We hypothesized, based on the notion of problem representation, that successful diagnosticians (those with correct diagnoses) would have more thorough, more relevant, and earlier problem representations, as evidenced by semantic transformations, and would be able to simultaneously compare and contrast several diagnoses during their case presentations. A case study was conducted to explore and test these hypotheses.

Methods

Subjects and standardized patient. Nineteen third-year medical students and four expert rheumatologists examined a standardized patient with a chief complaint of pain and swelling in a knee of two days' duration that had begun in the middle of the night. The students were the entire cohort in a medicine clerkship at a university hospital; it was the last clerkship of their third year. The rheumatologists were university-based clinical faculty selected because of their recognized clinical expertise. The subjects interviewed and examined one of two standardized patients trained to portray the case; the students were tested over a five-day period and the rheumatologists over two days. The patient's history, physical examination, and laboratory tests were taken from a real patient with recurrent, acute, gouty arthritis. The subjects were asked to present the case in terms of two stimulus questions: What diagnosis did you come up with? What made you arrive at that diagnosis? The attending physician asked clarification questions during the presentation as necessary. The case presentations were recorded and transcribed.

Semantic analysis. Four trained coders (two physicians, an occupational therapist, and a medical educator) used a standard procedure[9] to (1) divide each presentation into arguments representing a distinct line of reasoning (i.e., a section of text containing a leading topic and all statements or phrases that are related to it), (2) note the diagnoses expressed within each argument, and (3) identify instances when discrete data from the clinical presentation (e.g., "the knee pain woke me up") were transformed into a semantic qualifier (e.g., "acute" knee pain). The coders have been shown to be reliable in their judgments.[9]

The SQs associated with six basic semantic attributes of the chief complaint and present illness were noted: (1) onset: sudden, acute, abrupt, or rapid; (2) site: mono, large, local, unilateral, focal, or proximal joint; (3) course: episodic, remote, recurrence, previous, or irregular; (4) severity: intense or extreme; (5) context: while at rest or nocturnally; and (6) patient characteristics: male or older.

Generally, these attributes encompass the basic definition of any chief complaint or present illness (e.g., Bates[12, p.14]). The list above was thought by the researchers to represent the conceptualization or problem representation that was most relevant to a differential diagnosis of an acute monoarthritis. A single point was assigned per attribute whenever one or more SQs associated with that attribute was mentioned in an argument. This allowed for the designation of a basic semantic attribute score for each argument that could range from 0 to 6. All gout arguments were examined.

Statistical analysis. The subjects were divided into two groups: the 16 who made the correct diagnosis and the seven who did not. The following parameters were calculated for each subject and then each group: the mean basic semantic attribute score for the arguments containing gout (a measure of relevance of the semantic transformations), the mean number of distinct (non-repeated) SQs in gout arguments (a measure of thoroughness of semantic transformations), and the mean number of diagnoses expressed in gout arguments (level of competitiveness among diagnoses). The parameters were also calculated for each subject's first gout argument (to assess the clinicians' early representation of the problem). In addition, a maximum basic semantic attribute score in any single gout argument as

well as a cumulative basic semantic attribute score for all gout arguments (combined measures of thoroughness and relevance) were noted for each subject, and group means were calculated. Differences in group means were evaluated using Mann–Whitney U tests.

Results

Two of the seven subjects who arrived at incorrect diagnoses did not have any argument that contained gout; they were excluded from the analyses. Those who made the correct diagnosis used three times as many basic semantic attributes (2.1 vs 0.6), indicating that their representations of the problem were more relevant than were the representations of those who made incorrect diagnoses. Similarly, they used twice as many distinct semantic qualifiers in representing the patient's clinical findings (6.5 vs 3.1). This indicated that the successful diagnosticians had more thorough problem representations than did their counterparts. Those who made the correct diagnosis mentioned twice as many diagnoses in their gout arguments than did those who made incorrect diagnoses (2.9 vs 1.5). This indicated that the successful diagnosticians were comparing and contrasting simultaneously among more possible diagnoses than were their counterparts. These differences were both clinically and statistically significant (all p-values $< .01$). The differences in basic semantic attributes persisted when the analysis was restricted to the first gout argument, confirming that those making the correct diagnosis constructed relevant problem representations early in their presentations (see Table 1).

Discussion

The differences between the successful and unsuccessful diagnosticians were striking both clinically and statistically. The successful diagnosticians had more thorough and relevant problem representations than did the unsuccessful ones and did more simultaneous comparing and contrasting of diagnoses. The differences might suggest that those who made incorrect diagnoses had lesser funds of knowledge. This is likely to be true in the two cases where gout was never mentioned during the case presentation. However, gout was mentioned by the other five who made incorrect diagnoses, indicating some prior knowledge of or experience with this diagnosis. While differences in knowledge or experience base might explain some of the difference between the successful and the unsuccessful diagnosticians, the difference in their abilities to compare and contrast among several diagnoses simultaneously by using relevant representations of the clinical problem is more striking and could lead to interesting educational implications.

The study of problem representation has not been explored in medical education. To date, most researchers investigating diagnostic problem solving have concentrated on documenting that successful and experienced diagnosticians make better diagnostic hypotheses and that their knowledge is greater and better organized, but few research findings have led to specific educational strategies for enhancing diagnostic skills. For instance, the strategy to improve clinical problem solving discussed by Kassirer and Kopelman[13] encourages early hypothesis generation and evaluation. Although there are several teaching principles that guide students in improving their hypothesis evaluation, there is no explicit method for teaching students how to generate good hypotheses, except perhaps by memorizing lists of differential diagnoses associated with specific chief complaints, a not very successful strategy.[10] Concentrating on problem representation, however, may allow students to better access their funds of knowledge of pathology and pathophysiology gained in the preclinical years of their medical education. Problem representation, as exemplified by the ability to transform clinical data into sets of relevant semantic qualifiers, allows the diagnostician to link a patient's signs and symptoms (e.g., acute, monoarthritis) with relevant pathophysiology (e.g., infectious vs crystal mechanism) and diseases (e.g., septic arthritis vs gout). The problem representation gives a sense of the big picture (acute, mono) that can trigger retrieval of relevant diagnoses organized in memory (septic arthritis vs gout), as suggested by Elstein et al. 20 years ago: "Although differences in the content of the memory store apparently distinguish stronger from weaker problem-solving performance, this does not imply that medical problem solving is dependent solely upon mastery of passively recalled content. Knowledge must be *retrieved* and *organized*" [emphasis ours].[1]

The crucial role of "problem representation" in problem solving has been shown in educational psychology and in mathematics education in particular (for example, Brenner et al.[11]). The process of solving a problem was analyzed according to several phases, the first of which is problem representation in which the problem solver constructs a mental representation of the situation, followed by solution planning, execution, and monitoring. Several formats can be used to represent problems, including words (such as SQs), graphs, diagrams, tables, equations, and pictures. Brenner and colleagues[11] hypothesized that many students were being asked to solve problems before they had really built representations of the problem in their minds, before they really understood the situation. They showed that instruction using several formats for problem representation improved students' problem-representation skills and resolution of problems.

Problem representation in medicine can be viewed in terms of

Table 1. Results for Parameters of Semantic Analysis of Clinicians' Correct and Incorrect Final Diagnoses in a Case of Acute Gouty Arthritis

	Correct Diagnosis ($n = 16$)	Incorrect Diagnosis ($n = 5$)*	p-value (Mann–Whitney U Test)
	Mean (SD)	Mean (SD)	
Overall case presentation			
Average basic semantic attribute score (out of 6) in gout arguments	2.1 (1.1)	0.6 (.69)	.008
Cumulative basic semantic attribute score for all gout arguments	3.8 (1.3)	1.6 (2.1)	.04
Number of distinct semantic qualifiers per gout argument	6.5 (3.9)	3.1 (1.7)	.05
Number of diagnoses per gout argument	2.9 (1.3)	1.5 (.44)	.008
Basic semantic attribute score in best gout argument	3.4 (1.1)	1.2 (1.3)	.006
First gout argument			
Basic semantic attribute score for first gout argument	2.7 (1.4)	.60 (.90)	.01
Number of distinct semantic qualifiers in first gout argument	8.8 (5.8)	3.4 (2.9)	.08
Number of diagnoses in first gout argument	2.6 (1.6)	1.4 (.55)	.08

*Seven of the subjects arrived at incorrect diagnoses; two of them did not have any argument that contained gout, and these two were excluded from the analysis.

abstractions, as sets of semantic qualifiers that portray or represent a situation, for example, "an older man with a gradual onset of bilateral motor and sensitive deficits in the hands" as opposed to "a young man with a sudden onset of a unilateral motor deficit in the right arm."[9] The SQs serve as abstract verbal representations of the problem that can be linked to other kinds of representations that are useful in retrieving knowledge from memory, such as visual representations of the pathophysiology or pathology (e.g., seeing in the mind's eye an inflamed joint with its various structures). The abstract transformations associated with problem representation might also correspond to greater diagnostic depth and accuracy, as reflected by semantically elaborated or compiled discourses rather than reduced or dispersed ones.[10]

The findings from this case study and the theoretical framework that underpins this work suggest that educational strategies that attempt to integrate problem-representation activities (acute, monoarthritis) with clinical knowledge (infectious–crystals) are likely to improve the diagnostic skills of trainees (making an accurate diagnosis of gout in this case). The irony is that in many medical schools, courses in physical diagnosis (which could promote abstract representations of a patients' problem) and in pathophysiology (which could promote abstract or visual representations of diseases) are typically taught concurrently but with little or no integration for the students.

The present findings suggest that high-quality problem representations are evident early in case presentations. Those who are successful diagnosticians use relevant semantic qualifiers at the beginning of the presentation. They use them not only as a way to describe patient characteristics, but also as a means of accessing and of comparing and contrasting relevant diagnoses (e.g., acute, monoarthritis vs acute, polyarthritis related to septic arthritis, gout, or rheumatoid arthritis). These preliminary findings have important implications for theory building and instruction in medical education that are captured in the following three questions. How pervasive is the process of problem representation within a clinician and across medical domains (generic skills vs case specificity)? Can problem representation skills be taught to medical students (as was the case with algebra students)? And, will the use of problem representations enhance learning and diagnostic accuracy?

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