Quantitative Evaluation of the Diagnostic Thinking Process in Medical Students
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OBJECTIVE: To explore the diagnostic thinking process of medical students.

SUBJECTS AND METHODS: Two hundred twenty-four medical students were presented with 3 clinical scenarios corresponding to high, low, and intermediate pre-test probability of coronary artery disease. Estimates of test characteristics of the exercise stress test, and pre-test and post-test probability for each scenario were elicited from the students (intuitive estimates) and from the literature (reference estimates). Post-test probabilities were calculated using Bayes' theorem based upon the intuitive estimates (Bayesian estimates of post-test probability) and upon the reference estimates (reference estimates of post-test probability). The differences between the reference estimates and the intuitive estimates, and between Bayesian estimates and the intuitive estimates were used for assessing knowledge of test characteristics, and ability of estimating pre-test and post-test probability of disease.

RESULTS: Medical students could not rule out disease in low or intermediate pre-test probability settings, mainly because of poor pre-test estimates of disease probability. They were also easily confused by test results that differed from their anticipated results, probably because of their inaptitude in applying Bayes' theorem to real clinical situations. These diagnostic thinking patterns account for medical students or novice physicians repeating unnecessary examinations.

CONCLUSIONS: Medical students' diagnostic ability may be enhanced by the following educational strategies: 1) emphasizing the importance of ruling out disease in clinical practice, 2) training in the estimation of pre-test disease probability based upon history and physical examination, and 3) incorporation of the Bayesian probabilistic thinking and its application to real clinical situations.

KEY WORDS: diagnostic thinking process; test characteristics; pre-test probability; post-test probability; Bayes' theorem.


Evaluating the thought process of clinical diagnosis is difficult because of the methodological difficulty in studying complex cognitive skills including clinical reasoning and judgment. Sackett et al. described 4 types of diagnostic thinking styles—pattern recognition, multiple-branching method, method of exhaustion, and hypothetico-deductive method—based upon results in cognitive psychology theory. He emphasized the usefulness of the hypothetico-deductive method for clinical diagnosis in the primary care setting. This method is based on Bayes' theorem and naturally lends itself to integration in quantitative decision analysis. The diagnostic behavior of seasoned physicians seems to fit the hypothetico-deductive method. Experienced physicians usually focus their attention quite narrowly to provide only a few specific diagnostic hypotheses. They then evaluate new clinical data in the light of these hypotheses, adjust for the likelihood of each hypothesis, reject some as implausible, and introduce a new hypothesis. This process of sequential revision is interrupted when the likelihood of one diagnosis becomes high enough to warrant action (i.e., a special test or an urgent therapy) or low enough to abandon further consideration of the disease.

Little is known, however, regarding how to evaluate a physician's diagnostic thinking process and how to improve a novice physician's diagnostic expertise efficiently. Quite often we encounter cases in which medical students or novice residents have difficulty in differentiating diagnosis and repeat inadequate laboratory or imaging tests. Accordingly, we planned this study to clarify the following: 1) how closely medical students follow the hypothetico-deductive method in diagnostic thinking process; and 2) the nature of the problems they face in their diagnostic process. We analyzed their diagnostic abilities in terms of 3 elements of the hypothetico-deductive method, knowledge of test characteristics (sensitivity and specificity), ability to estimate pre-test disease probability from clinical history, and ability to estimate post-test probability from pre-test probability and test characteristics.

METHODS

Target Population and Data Collection

We surveyed fifth-year medical students between September 1999 and May 2000 at 3 medical schools in Japan. The total number of years in medical school in Japan is universally 6. The curricula generally consist of 1 to 2 years of liberal arts education, 1 to 2 years of basic medical science courses, and 2 to 3 years of clinical science courses and clinical rotations. The curricula of the these medical schools are similar and include 2 or 3 sessions of primer courses on clinical epidemiology that cover basic principles of epidemiology, design of clinical
Table 1. Hypothetical Clinical Scenarios

| Case scenario 1 (typical anginal pain, reference estimate of pre-test probability is 90%) |
| A 55-year-old man presented to your office with 4-week history of substernal, pressure-like chest pain. The chest pain is induced by exertion such as climbing stairs and relieved by a 3- to 5-minute rest. It sometimes radiates to the throat, left shoulder, down the arm. |
| Case scenario 2 (atypical anginal pain, reference estimate of pre-test probability is 46%) |
| A 45-year-old man without past medical history and coronary risk factors presented with 3-week history of stabbing chest pain in the retrosternal area. The patient reported that the pain was usually stabbing-like but sometimes pressure-like and developed during both rest and exercise. On physical examination, there is vague tenderness on costochondral joints. |
| Case scenario 3 (non-anginal chest pain, reference estimate of pre-test probability is 5%) |
| A 30-year-old man without a significant medical problem and coronary risk factors presented with 6-week history of squeezing pain in the lower retrosternal area to upper abdomen. The pain develops after meals, especially when he is lying down after late dinner. |

trials, and the concepts of frequency, risk, and probability. The curricula also include an introduction to Bayes' theorem and the use of the probabilistic perspective in clinical diagnosis.

Subject students were surveyed before starting clinical rotation (medical school B and C) or within 2 weeks after starting rotation (medical school A), so that the medical students had no actual experience of clinical work at the time of this study. The students had completed at least 1 session of Bayes' theorem.

We presented hypothetical scenarios of chest pain patients to the students and asked them to answer questions. Each student was asked to provide answers independently to the best of his or her ability, based on the scenarios along with their own knowledge and experience. Clinical scenarios of typical anginal pain, atypical anginal pain, and non-anginal chest pain were provided. The corresponding pre-test probabilities of coronary artery disease were calculated as 90%, 46%, and 5%, respectively, from the data of Diamond et al. (Table 1).3,4

The questionnaire consisted of 3 sections: 1) test characteristics questions, 2) pre-test and post-test probability questions, and 3) decision questions (Table 2). The test characteristics questions were asked before presenting the clinical scenarios. Then, the pre-test and post-test probability questions were posed for each scenario, followed by the decision questions regarding typical anginal chest pain with a negative exercise stress test (EST) result (Case scenario 1), or atypical chest pain with a positive EST result (Case scenario 3). Students were expected to provide a dichotomized answer for closed-ended questions and to provide a single numerical value for open-ended questions.

Table 2. Questionnaire

1) Test characteristics questions
1. Do you understand clearly the idea of sensitivity, specificity, or pre-test and post-test probability? Yes or No?
2. What is the sensitivity of the exercise stress test (EST)? Or what proportion of those patients with significant coronary artery disease (CAD) will show more than 1 mm of horizontal or downward ST-segment depression with EST? Significant CAD is defined as the presence of at least 75% of luminal narrowing of 1 or more major coronary vessels.
3. What is the specificity of EST? Or what proportion of those patients without significant CAD will not show more than 1 mm of horizontal or downward ST-segment depression with EST?
2) Pre-test and post-test probability questions
1. What is the probability that this patient has significant CAD?
2. What is the probability that this patient has significant CAD if EST shows more than 1 mm of horizontal or downward ST-segment depression?
3. What is the probability that this patient has significant CAD if EST is negative?
3) Decision questions
1. For case scenario 1 (typical anginal pain) Should this patient be treated with beta-antagonists or nitrates when the EST is negative? Yes or No?
2. For case scenario 2 (atypical anginal pain) Should this patient be treated with beta-antagonists or nitrates when the EST is positive? Yes or No?