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Original Article

Use of a Modified Fishbone Diagram to Analyze Diagnostic Errors in Emergency Physicians

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Introduction: Reilly et al. described a structured approach to the analysis of diagnostic errors by using a novel modified fishbone diagram. The application of this tool in emergency medicine had not previously been reported. The objective of this study is to use the modified fishbone diagram analysis method in examining the causes of common diagnostic errors committed by emergency physicians and the circumstances associating errors in cognitive processes.

Methods: Sixty-one cases of diagnostic errors involving ten board-certified emergency physicians (EPs) were identified through a peer review process. Using a qualitative study approach, in-depth semi structured interviews with EPs was conducted. All interview audiotapes were transcribed verbatim. Content analysis was performed on all textual data to identify the factors underlying errors using the modified fishbone diagram.

Results: In 61 cases, 165 diagnostic errors were identified (2.7 per case). The underlying contributions to errors fell into 7 categories: cognitive process (54/61, 89%), specific presentation (32/61, 52%), clinical data gathering (24/61, 39%), organization issues (12/61, 20%), affective factors (9/61, 15%), context of care (9/61, 15%), and communication (5/61, 8%). Of these cognitive errors were the most common. However, only six cases occurred in isolation (6/54, 11%), with the remaining 48 cases (48/54, 89%) occurring with other types of errors, the most common being specific presentation (28/54, 52%) and clinical data gathering (24/54, 44%).

Conclusions: The modified fishbone diagram is a useful tool to identify various categories of errors on diagnostic process in emergency department (ED). These findings provide a basis on which to build a framework for teaching EPs how to avoid misdiagnoses in the ED setting.

Key words: *cognitive error, diagnostic error, emergency medicine, fishbone diagram, patient safety*

Introduction

Patient safety is an important issue in medical care. Over the course of the last 20 years, the majority of hospitals have placed emphasis on improving hardware, constructing patient safety reporting and identification systems, and reducing medication errors. However, the impact of diagnostic errors by physicians on patient safety has not received the attention that it requires.[1] Statistics indicate that the ratio of patient injury caused by physician due to diagnostic errors is between 6.9% and 17%.[2] As such, this topic is worthy of attention. The likelihood of misdiagnoses by physicians range between 0.6% and 12% according to the department they serve in,[3] but may reach as high as 15% during emergencies.[4] Under emergencies,

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the cognitive processes of physicians are often affected by the situational context, such as treating numerous patients in a short amount of time, the inability of care takers to provide complete medical histories, or the loss of information when changing shifts.[5] These factors differ significantly from those of outpatient and inpatient situations, and therefore make it more likely for emergency physicians to commit errors.[5] As such, the examination of the effects of situational factors on the cognitive process is an important direction to pursue in reducing diagnostic errors.

The majority of experts accept the "dual process model" (fast and slow thinking) in describing the mental operations of physicians while making a diagnosis.[6] The initial presentation of illness is either recognized or not by the physician. If it is recognized, the fast, automatic processes engage, whereas if it is not, the slower, analytical processes of engage instead. An analysis of the cognitive processes of physicians based on this "dual process model" conducted by Norman et al. indicates that three major types of errors may occur, namely, cognitive skill errors, errors from poor attitude, errors attributable to knowledge gap.[7] Unfortunately, Norman et al. did not mention the external situational factors. Reilly et al. asserted that conventional root cause analysis is unable to completely identify the causes of diagnostic errors, and developed a modified fishbone diagram for use in assessing cases to systematically integrate physician cognitive processes and the external environment, thereby categorizing diagnostic errors into seven major types: cognitive process, specific presentation, clinical data gathering, organizational issues, affective factors, context of care, and communication errors, as shown in Fig. 1.[8] Their study indicated that this method can be applied to identify the causes of misdiagnosis for each case.[8] However, no studies used this method to analyze the diagnostic process in the emergency department (ED). The fishbone diagram is only an abstract concept. It is more important to provide concrete examples in order to stimulate learning motivation in medical students or residents especially in the chaotic emergency environment where medical errors frequently occur. Furthermore, the correlation between cognitive process and other causes of diagnostic errors is worthy of analysis.

The objective of this study is to use the modified fishbone diagram analysis method in identifying the causes of common diagnostic errors committed by emergency physicians and the circumstances associating the errors in cognitive processes. The results of this study can provide a basis for emergency medical education to improve patient safety.

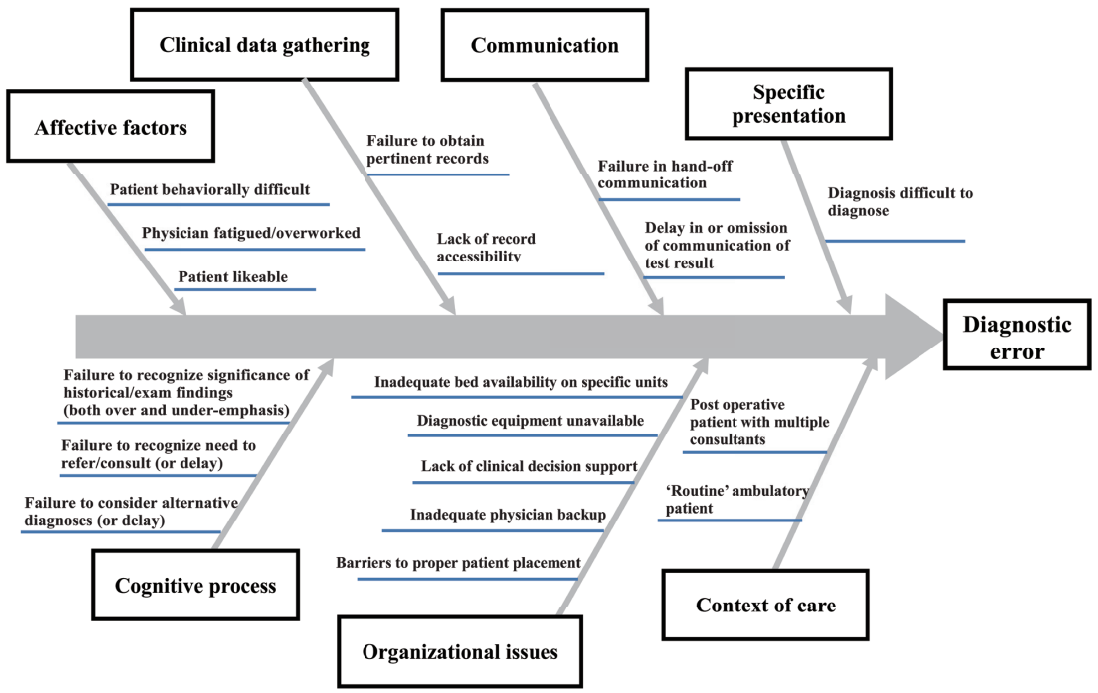

Fig. 1. Diagnostic error fishbone framework modified from Reilly's study.

Methods

A regional hospital in Taiwan was selected as the research site for this study and cases of diagnostic errors occurring between July 1, 2014 and June 30, 2015 were collected. In accordance with existing literature, three types of diagnostic errors were defined: delayed diagnoses (sufficient information was available earlier), wrong diagnoses (another diagnosis was made before the correct one), and missed diagnoses (no diagnosis was ever made).[6] The qualitative interview approach was specifically designed for use in this study and received approval from the institutional review board of the hospital. One of the authors of this study, Lin CS, was responsible for collecting cases of diagnostic errors, and cases corresponding to the aforementioned definitions of diagnostic errors were selected based on a review of inter-hospital transferring case diagnoses, emergency physician self-reports, and errors in inpatient discovered by attending physicians belonging to other departments.

The interviewees selected for this study were board-certified emergency physicians between 30 and 65 years old who committed diagnostic errors during the period of this study and were also willing to perform recorded interviews. Interviewees did not include medical students currently undergoing training for emergency medicine, post-graduated years (PGYs), or residents. Purposive sampling was conducted to select physicians most able to describe their cognitive process when diagnosing patients in order to obtain the richest content.[9] The number of interviewees was determined by the results of content analysis; sampling was conducted until the interview content did not generate new codes or themes.[9] The leading questions used in the interviews were designed to assist interviewees in recalling the diagnostic situation and process, followed by the provision of medical records of misdiagnosed patients to provide the interviewees with a more accurate basis for reflecting on the causes of the diagnostic error. The specific questions asked were as follows: (1) please describe the medical history and emergency treatment process for this case, including the chief complaint, current history, past history, physical examination, laboratory examination, preliminary diagnosis, and treatment of the diagnosis. (2) what was your diagnosis at the time? In retrospect, did you ever consider the final diagnosis over the course of the entire process? (3) why do you think the diagnostic error occurred? Why do you think that these are the causes? (4) based on the causes that you mentioned, what sort of improvements do you think can be made to the process, including the ED environment, support systems, your colleagues in the ED, and yourself in order to avoid the occurrence of diagnostic errors in the future?

The recorded interviews were transcribed, after which two researchers interpreted, coded, and organized the content according to the seven types of diagnostic error of the modified fishbone diagram, using grounded theory to develop theory which explains the process of diagnostic errors in ED.[9] When the two researchers held different opinions regarding the coding or were unable to classify cases into one of the seven types of diagnostic error, a discussion was conducted to achieve a consensus. The coding definitions and examples were documented for reference when analyzing new interview data.

Results

This study identified a total of 61 cases of misdiagnosis, with a total of 165 diagnostic errors (2.7 per case). The diagnostic distribution of diseases is as shown in Table 1, with the majority being non-traumatic cases (46/61, 75.4%). The ED of the hospital treats approximately 32,000 patients per year (excluding pediatric emergencies) with a total of 10 emergency physicians. Every physician was interviewed, of which one was female and the remainder were male. The average age of the physicians was 41.3 years (SD = 9.7), with an average of 10.2 years of experience in the ED (SD = 9.5).

The seven causes of diagnostic errors listed according to occurrence frequency and their respective proportions are as follows: cognitive process (54 /61, 89%), specific presentation (32/61, 52%), clinical data gathering (24/61, 39%), organizational issues (12/61, 20%), affective factors (9/61, 15%), context of care (9/61, 15%), and communication (5/61, 8%). These themes and interview data were shown in Table 2. Of these, cognitive process errors occurred most frequently. However, only six cases occurred in isolation (6/54, 11%); 48 cases (48/54, 89%) were concurrent with other types of errors. The most common concurrent errors were specific presentation (28/54, 52%) and clinical data gathering (24/54, 44%), as shown in Table 3. The seven types of diagnostic error are as described below.

Table 1. Diagnostic distribution of misdiagnosed cases

Category	Diagnosis	Number of cases	Notes
Trauma cases (15 cases)	Facial fractures	5	
	Rib fractures	1	
	Upper or lower extremity fractures	3	Femoral neck fracture (1 case), fibula fracture (2 cases)
	Scaphoid fractures	1	
	Foreign body in soft tissues	1	Small stone in the soft tissue of the knee
	Cervical trauma	2	One patient was intoxicated, the other patient suffered from mild symptoms
	Intra-abdominal hemorrhage	1	Multiple trauma
	Chest trauma	1	Pneumothorax caused by puncture wound (CXR normal)
Non-traumatic cases (46 cases)	General surgery	12	Gastric perforation (4 cases), appendicitis (5 cases),cecal diverticulitis (1 case), bile duct tumor (1 case), incarcerated hernia (1 case)
	Cardiovascular emergency	8	Acute myocardial infarction (5 cases), aortic esophageal fistula (1 case), aortic dissection (2 cases)
	Acute infection	8	Necrotizing fasciitis (3 cases), varicella (1 case), purulent arthritis (3 cases), sepsis (1 case)
	Gastrointestinal emergency	6	Biliary tract infection (2 cases), gastroesophageal reflux (1 case), overeating (1 case), liver tumor rupture (1 case), cirrhosis (1 case)
	Neurological emergency	3	Acute cerebrovascular disease (1 case), cerebral aneurysm (1 case), internal carotid artery dissection (1 case)
	ENT emergency	1	Peritonsillar abscess
	CO poisoning	1	AMI and CVA complications
	Hematologic malignancy	1	Leukemia
	Gynecological emergency	1	Teratoma
	Metabolic emergency	4	Diabetic ketoacidosis (1 case), pituitary apoplexy (1 case),subclinical hypothyroidism (1 case),thyroid storm (1 case)
	Thoracic emergency	1	Spontaneous pneumothorax

Table 2. Seven themes of diagnostic errors and interview data

1. Cognitive Process (54 /61, 89%) The following is an example of gastric perforation without peritonitis in which the "anchoring effect" error is present. The physician stated as follows: 74-year-old female. Walked into the emergency room at around 8 P.M. escorted by family members. No fever. Poor appetite over the course of the last four or five days. Some family members say that she took medicine inappropriately, while others say that she had not. Unclear information. Physical examination indicates abdominal bulging. Patient appears tired. Abdominal palpation results in pain, but peritonitis is absent. Blood leukocyte count of about 12000 (cells/μL), band 6%, CRP 37 (mg/L), blood sugar over 200 (mg/dl), BUN 57 (mg/dl), Cr 1.4 (mg/dl), and slight dehydration. At the time, I thought that if it was gastric perforation, the patient should be experiencing considerable abdominal pain. Palpation resulted in only mild pain. The patient claimed to have constipation and not having gone to the bathroom for several days. Scans indicated a significant amount of stool, so I prescribed two Dulcolax suppositories. At about 2 A.M., the patient said that she felt a lot better after passing stools and did not feel pain. Follow-up tests conducted at about 6 A.M. indicated that her WBC remained high, but the patient had no fever and exhibited no rebound tenderness. The information provided by family members was unclear. Although the CRP was high, the patient exhibited only mild discomfort. Should I perform a computed tomography (CT) ? Actually, I could have performed a CT when the CRP results came out. It took 24 hours to reach a diagnosis of gastric perforation.
2. Specific Presentation (32/61, 52%) The following case is an example of the early manifestations of appendicitis and subsequent misdiagnosis due to the case exceeding the experiences of the physician. The physician stated as follows: The reason why I regarded it as pelvic inflammatory disease (PID) was because the CT did not show significant swelling of the appendix. I did not have a clear understanding of the diagnostic capabilities of CT, as while CT can diagnose 98%-99% of appendicitis cases, 1% of cases may be overlooked. Half a day passed from when this case was first diagnosed as PID to when the patient underwent surgery. So the lesson of this case is that diagnoses of PID need to be tied to appendicitis. In addition, in situations when the appendix is not swollen but fecaliths are present, physicians should be alert to the possibility of early appendicitis.
3. Clinical Data Gathering (24/61, 39%) One physician stated as follows: An 83-year-old elderly man living independently attempted charcoal-burning suicide. At time of arrival, his GCS was 9, blood pressure was normal, and electrocardiogram (ECG) showed sinus tachycardia. Hematological testing found CO-Hgb at 36% and a Troponin I value of 9 (ng/ml). A detailed physical examination was not conducted at the time, and the case was treated as a case of carbon monoxide poisoning complicated by a myocardial infarction. However, when another physician arrived to assist in transferring the patient, a more detailed physical examination indicated that the patient exhibited right limb weakness, while the CT did not exhibit intracranial hemorrhage (ICH). The patient suffered from two severe complications: Non-ST-Elevation Myocardial Infarction (NSTEMI) and an ischemic stroke.
4. Organizational Issues (12/61, 20%) One physician stated as follows: 64-year-oldmale. Emergency Medical Technicians (EMTs) transported the patient to the emergency room. The chief complaint was that the patient was unable to walk or sit up. The patient lived alone. The patient exhibited a fever in the observation room. His white blood cells (WBC) was 2790 (cells/μL), segment was 49.1%, and monocyte was 13.6%. After the patient was transferred to a different hospital, it was found that his pro blast was above 20%. The subsequent diagnosis was leukemia. Evidently, the laboratory workflow had problems; it was not routine in the laboratory to conduct blood smears; WBC differential counts were only conducted using machines. Technical personnel only conducted manual counting if the machine prompted a need for it. Subsequent investigation revealed that the manual counting triggering point for our hospital differed from that of other hospitals. Our standards were higher, so the status of this patient did not trigger manual counting.

Table 2. Seven themes of diagnostic errors and interview data (continued)

5. Affective Factors (9/61, 15%) The following case is one in which the attending physician had been assigned to consecutive night shifts, followed by encounters with family member of patients repeatedly inquiring about patient conditions, thus causing the physician to commit an error when arranging for testing. The physician stated the following: There were a lot of people! I did not have time to deal with the patient for a while, but the family members came one after another to ask about his condition. I explained the patient's condition once, but then the family members came after a few hours to ask again. I could not deal with it after the third time… Firstly, there were a lot of patients and I was really too busy to take more time out to explain the patient's condition. Secondly, some family members understood what I was saying, while others did not. I did think of the possibility that the Hb dropped due to a hepatoma rupture, but the family members were too annoying. Actually, an echo could have been performed at 6-7 A.M, but I was angry!
6. Context of Care (9/61, 15%) One physician stated the following: This dialysis patient was transferred from the emergency department to an orthopedic clinic and then transferred back to the emergency department from the orthopedic clinic. The patient was examined by a total of six physicians over the course of the process. While many physicians provided their opinions, the diagnosis was delayed because of the lack of integration. The emergency physician did not notice that the band count and meta ratio were both very high. CT was not performed until the patient was hospitalized and exhibited low blood pressure. It was necrotizing fasciitis.
7. Communication (5/61, 8%) The following case describes the misdiagnosis process of a patient with a cervical spine fracture in which the incoming physician was lulled into a false sense of security due to the lack of communication regarding the cause of the injury when changing shifts. The physician stated the following: When the patient arrived at the emergency room he said that his neck and upper body hurt. The patient had a fever of 38 °C and had accidentally fell down and hit his head that morning. It was flu season, and there were many patients with fevers and body aches. The initial diagnosis by the first physician was a upper respiratory tract infection (URI). I did not ask if the patient had experienced any trauma injuries when I came. Later on, a nurse came to tell me that the condition of the patient was strange and that only his upper body was sore. There were actually several symptoms that indicated that it was not a URI.

Cognitive Process

Cognitive errors refer to diagnostic errors caused by the influence of the external environment or deviations in cognitive logic during the diagnostic process.[8] The most common cognitive error is the "anchoring effect," which is the presence of a certain diagnosis in the mind of a physician leading to the overlooking of inconsistent clinical manifestations and failure to alter the existing diagnosis. Other errors include "premature closure," or the situation in which a physician has made a correct diagnosis, but fails to reach a second existing diagnosis for the patient. The cognitive error of "blind obedience" is also relatively common; when emergency physicians receive a consultation, they often adopt the opinions of the referring physician without determining whether or not the diagnosis is reasonable. Cognitive errors often occur as a result of insufficient disease knowledge, particularly when disease manifestations are atypical.

Specific Presentation

This type of diagnostic error is a result of the rare occurrence of a disease or atypical manifestation of a disease and subsequent inability of a physician to recognize the disease as it does not exist in the physician's memory.

Clinical Data Gathering

Clinical data gathering refers to errors committed in the process of data collection, such as the omission of inquiry about medical history, conducting a physical examination, and arranging for blood or ultrasound testing.

Organizational Issues

Organizational issues refer to the diagnostic errors caused by software and hardware problems present in the external working environment, such as hospital policies, standard operating procedures, or malfunctioning equipment.

Table 3. The common concurrent situations associated with cognitive error

Situations	Number (Percentage)
Specific Presentation	28 (28/54; 52%)
Incorrect interpretation of radiology study	11
Atypical presentation	11
Lack of knowledge of disease	6
Clinical Data Gathering	24 (24/54; 44%)
Failure to perform focused physical examination	14
Incomplete history taking	7
Failure to arrange electrocardiogram (ECG) or abdominal echo studies	2
Combination of history taking and physical examination	1
Context of Care	9 (9/54; 17%)
Delay in consultation	3
Medical care deviations from standard procedures	3
Failure to provide appropriate follow up mechanism	2
Forgetting to read X-ray films	1
Affective Factors	6 (6/54; 11%)
Intoxicated patient or mental illness	3
Physician work stress	2
Patient told a lie	1
Communication	5 (5/54; 9%)
Patient handoff	3
Communication with radiologist or other specialist	2
Organization Issues	5 (5/54; 9%)
Inadequate physician backup	3
Hematology test results exceeding dangerous values but was not reported	1
CT machine malfunction	1

Affective Factors

Affective factors refer to emotional problems on the part of physicians that affect their diagnostic decisions. Causes of poor emotional responses include overwork, night shift pressures, or intoxicated patients.

Context of Care

Context of care errors refer to diagnostic errors caused by deviations from standard operating procedures for consultation, clinical visit arrangements, or medical treatment during the care taking process.

Communication

Communication problems are caused by handovers when physicians pass on information between shifts or when emergency physicians communicate with other departments.

Discussion

The results of this study found that the seven causes of emergency diagnostic errors verified the fishbone diagram analysis method as a viable framework inclusive of misdiagnosis causes occurring in the ED. Although the framework was developed according to the circumstances and situations faced by a U.S. medical center, this study used it to analyze misdiagnosed cases in a Taiwanese regional hospital. This method allowed us to discover problems from different perspectives when analyzing diagnostic errors, thus avoiding solely emphasizing knowledge or cognitive errors; the method allowed for the consideration of personal af-

fective, institutional, and procedural issues. As such, it is recommended that this analytical framework can be used in discussions regarding emergency room mortalities in the belief that it will improve the quality of discussion. To the best of our knowledge, this is the first study to use the modified fishbone diagram to analyze the emergency physician's diagnostic process. In addition, the significance of each medical error is discussed along with actual cases. These examples are useful for medical educators in preparing for teaching materials as well as stimulating leaning motivation.

The educational approach for reducing diagnostic errors remain a controversial area. To use debiasing strategies or not to use that is the question.[10,11] Our study showed that cognitive errors occurred alongside specific presentation and clinical data gathering errors 52% and 44% of the time, respectively. The importance of this finding is its implication for educational training. Tversky and Kahneman proposed that "cognitive biases" originated from quick intuitive thinking.[10] Based on this theory, medical education has emphasized debiasing strategies, such as "slow down" techniques, over the course of the last ten years.[11] These debiasing strategies are largely mainstream, with numerous relevant literature for reference. However, Norman et al. believe that the prevention of diagnostic errors should begin by addressing knowledge and memory.[11] Learners who have memorized comprehensive illness scripts are able to recall corresponding scripts from their memory when faced with clinical situations to develop correct diagnoses. The inferences made by Norman et al. currently lack a sizeable body of supporting research.[11,12] The results of this study support the arguments of Norman et al., as it was found that the majority of cognitive biases and errors existed concurrently with insufficient physician knowledge of different disease manifestations. As such, while including debiasing strategies in training physicians to avoid diagnostic errors remains important, broader and more in-depth case training is necessary; neither can be neglected. Another aspect of educational training is the emphasis on the importance of physical examination and medical history collection, as the lack of complete information leads to cognitive process errors. Although this principle is simple, it is a common error committed by emergency physicians under time pressures to make diagnoses. Future research should focus on resolving this issue.

This study had three limitations. Firstly, the results of this study were obtained through qualitative interviews of emergency physicians serving in a regional hospital; the generalizability of the findings of this study to hospitals of different levels and physicians of other departments will require future studies to engage in more diverse sampling to achieve more comprehensive results. Although the modified fishbone diagram analysis method was developed by a U.S. medical center, because it has not been applied in different cultures, future studies evaluating its feasibility are necessary. Secondly, the method of case collection didn't include patients discharged from the hospital on physician's order. While these missing cases are likely to exist, in consideration of limited human resources and funding, follow up on each case was not possible. As such, it is recommended that future researchers follow up the discharged cases via telephone to obtain more complete results. Thirdly, the chosen definition of "diagnostic error" differs from that included in *Improving Diagnoses in Health Care* published by the Institute of Medicine in late 2015. The new definition of diagnostic error is the failure to: 1. establish an accurate and timely explanation of patient's health problems or 2. communicate that explanation to the patient.[13] This definition emphasizes patient involvement and the prioritization of physician-patient communication. As this study was conducted between 2014 and 2015, the new definition had yet to be published; the chosen definition took into account only the accuracy of the final diagnosis and did not consider whether patients received a prompt and comprehensible explanation. As such, different research results may be reached because of the different definition; future researchers can improve upon the method to obtain more valuable results.

Although this study exhibited certain limitations, its results demonstrate that the Western modified fishbone diagram analysis method is capable of discovering comprehensive causes of diagnostic errors when applied to a Taiwanese hospital ED. The results of this study support the arguments of Norman et al. that educational training should not overemphasize debiasing techniques, but should rather use a broad range of cases to assist physicians in comprehending the various manifestations of illnesses in order to reach correct diagnoses.

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