review article

What every teacher needs to know about clinical reasoning

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CONTEXT One of the core tasks assigned to clinical teachers is to enable students to sort through a cluster of features presented by a patient and accurately assign a diagnostic label, with the development of an appropriate treatment strategy being the end goal. Over the last 30 years there has been considerable debate within the health sciences education literature regarding the model that best describes how expert clinicians generate diagnostic decisions.

PURPOSE The purpose of this essay is to provide a review of the research literature on clinical reasoning for frontline clinical teachers. The strengths and weaknesses of different approaches to clinical reasoning will be examined using one of the core divides between various models (that of analytic (i.e. conscious/controlled) versus non-analytic (i.e. unconscious/automatic) reasoning strategies) as an orienting framework.

DISCUSSION Recent work suggests that clinical teachers should stress the importance of both forms of reasoning, thereby enabling students to marshal reasoning processes in a flexible and context-specific manner. Specific implications are drawn from this overview for clinical teachers.

KEYWORDS education, medical, undergraduate/ *methods; clinical competence/ *education; decision making; teaching/ methods; review literature.

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INTRODUCTION

> A 43-year-old woman is brought to the Emergency Room by her husband at 0200 in the morning because of acute shortness of breath. The dyspnea had occurred suddenly at 1100 pm and had awoken the patient from sleep. She had felt nauseated and vomited a small amount of bile. She complained of retrosternal chest pain that was worse on deep breathing. For several days she had coughed up small amounts of blood. For 4 days she had felt unwell and had had a sore throat and sinus congestion that resolved. She complained of having experienced fever and chills on several occasions in the past few days. The previous night she had woken with chest tightness, but this had settled after a short while. Her past history included bronchitis.[1]

What is the most likely diagnosis? Analogous to determining 'whodunit' when reading a mystery story, the diagnostic challenge involves considering each piece of available information and determining the most plausible explanation for the illustrated pattern. Doing so is not a straightforward task. It often entails careful observation, appropriate elicitation of historical information, accurate performance of physical manoeuvres, the generation of hypotheses, appreciation of the relationship between each piece of data and each hypothesis, and attempting to confirm/disconfirm hypotheses through the appropriate ordering of diagnostic tests. Unlike the reader of a mystery story, the clinician is often faced with the added task of determining if, when and how various pieces of information will be collected.

The challenge facing clinical teachers is perhaps even greater. Not only must clinical teachers be capable of performing all the tasks listed above, but they must also find a way to convey their knowledge and

Overview

What is already known on this subject

Traditional models of clinical decision making provide insufficient descriptions of the way in which clinicians reason; non-analytic processes (e.g. pattern recognition) play a major role, but can result in biases at all levels of expertise.

What this paper adds

This paper orients clinical teachers to the need to teach students multiple reasoning strategies. It attempts to re-conceptualise the construct of expertise to that of an amorphous entity that might best be defined as flexibility regarding the ways by which solutions to clinical problems can be derived.

Suggestions for further research

Further study of the optimal way in which various reasoning strategies can be conveyed to medical trainees, contextual factors influencing the co-ordination of analytic and non-analytic processes, and the nature of the flexibility displayed by experts is required.

reasoning strategies to novice diagnosticians to nurture each pupil's own expertise. Over the last half century it has become clear that the ability to do so is related to, but distinct from, expertise within the content area to be taught.[2] The maintenance of clinical teaching expertise requires, in part, an understanding of strategies expert clinicians use, often unconsciously, to reason through diagnostic case presentations like that which opened this article.[3] Adding to the clinical teacher's challenge is the fact that the psychological mechanisms underlying such reasoning tendencies are not always available to introspection.[4]

This article was written to provide a review of the literature on clinical reasoning for frontline clinical teachers. In doing so, few details will be provided regarding the research methods that led to each conclusion – references will be provided for those who are interested. Rather, the focus will be placed on current understanding of the way in which clinicians solve diagnostic challenges and the implications arising from this understanding. Discussion will focus on instructional techniques for maximising the probability that students will become successful medical problem solvers and on strategies for accurately assessing whether or not students have in fact developed the required competencies. To begin, we will undertake a more careful examination of how one might solve the diagnostic problem that opened this article.

WHAT IS THE MOST LIKELY DIAGNOSIS (AND HOW IS IT DERIVED)?

One need not look very far to recognise that medical educators have traditionally focused on what are known as 'analytic' models of clinical reasoning; models that presume a careful analysis of the relation between signs and symptoms and diagnoses are the hallmark of clinical expertise. For example, *Harrison's Principles of Internal Medicine* presents shortness of breath as an indication of both pneumonia and pulmonary thromboembolism (PTE). In the above case, the additional features of sore throat, nausea and vomiting further suggest pneumonia,[5] whereas the additional feature of coughing up blood suggests PTE.[6] The implication, in both cases, is that the characteristic features are plainly evident and that diagnostic reasoning involves understanding the relationship between the features detected and the underlying disorders. Generation of a differential list of relevant diagnoses and application of an appropriate diagnostic algorithm then allows each diagnosis to be weighted in terms of its relative probability.[6]

Clinical reasoning models that incorporate Bayes' theorem or regression analyses best represent this form of reasoning.[7,8] Briefly, these models assume that physicians are aware of the a priori probability with which a particular diagnosis may present and the conditional probability associating each piece of evidence (e.g. signs, symptoms and diagnostic tests) with the diagnosis. The mathematical model computes a post-test assessment of the likelihood of each diagnosis under consideration. This process, illustrated in Fig. 1, continues to be promoted by individuals close to the evidence-based medicine movement.[9,10] While some have argued that the forward flow of information illustrated in Fig. 1 (i.e. reasoning from the evidence to diagnoses) best captures the essence of 'expert' clinical reasoning,[11,12] the posterior probabilities presented could just as easily be used to

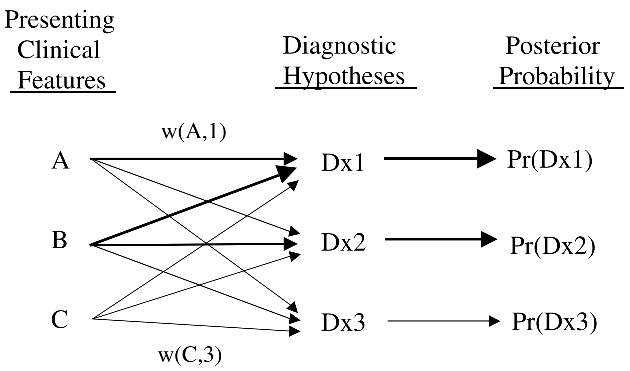

Figure 1 Analytic processes in clinical reasoning. Unique diagnoses are indicated by numbers, clinical features by letters. Each feature maintains a unique relationship (i.e. weight) with each diagnosis. The magnitude of the weights is indicated by the size of the arrow. Two (e.g. weight of the relationship between feature A and diagnosis 1) are labelled. The result of combining base rates and feature-based weights is assignment of a conditional probability (Pr) to each diagnostic hypothesis that takes into account the cluster of features observed.

feed back onto the collection and analysis of additional data and the model would remain an analytic processing model as long as the notion of careful analysis is maintained.

In fact, analytic processes have been used in many ways across different models of expertise.[13–15] At the heart of each approach, however, is the fundamental belief that causal rules linking features (e.g. signs and symptoms) to categories (e.g. diagnoses) can be extracted from the world and that the development of expertise in clinical reasoning consists of the development and elaboration of rules that become more and more attuned to reality. This view of clinical reasoning suggests that the educator's task is to facilitate the development of such rules. As an example, Elieson and Papa have shown the pedagogical benefit of providing students with diagnostic aids that explicitly describe the probabilistic relationships between features and symptoms.[16] One need not maintain such an extreme view of the usefulness of explicit probabilities, however, to incorporate the import of analytical reasoning strategies into one's clinical teaching – intuitive theories of the value of analytical reasoning are espoused every time a clinical teacher admonishes a student to 'be objective' and 'carefully consider all the evidence available before generating diagnostic hypotheses'.

There is, however, another way to solve the problem described above – one that has received increasing amounts of attention over the past 15 years. As an illustration, attempt to diagnose the following case:

> A 43-year-old woman is brought to the Emergency Room by her husband at 02 : 00 in the morning because of acute shortness of breath. The dyspnea had occurred suddenly at 11 : 00 pm and had awoken the patient from sleep. She had felt nauseated and vomited a small amount of bile. She complained of retrosternal chest pain that was worse on deep breathing. For several days she had coughed up small amounts of blood. For 4 days she had felt unwell and had had a sore throat and sinus congestion that resolved. She complained of having experienced fever and chills on several occasions in the past few days. The previous night she had woken with chest tightness, but this had settled after a short while. Her past history included bronchitis.[1]

Even clinically naïve readers will recognise that a plausible differential diagnosis for this case includes pneumonia and pulmonary thromboembolism. Why? Because this case has been encountered before (at the beginning of this article). When asked, 'What is 120 divided by 10?', most of us can quickly and effortlessly respond '12.' Clinicians are similarly often in such a position that they need not 'reason' at all. Referred to as pattern recognition in some circles, the more general form of 'non-analytic reasoning', illustrated in Fig. 2, essentially amounts to comparing

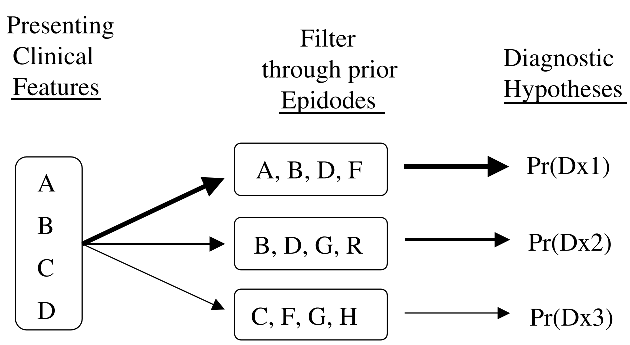

Figure 2 Non-analytic processes in clinical reasoning. Unique diagnoses are indicated by numbers, clinical features by letters. Each patient (represented by the rounded rectangles) presents with a cluster of features. This cluster is compared (unconsciously) to examples that have been encountered in the past, resulting in a probability being assigned to each hypothesis. The strength of the match between the current patient and past experiences is variable, as indicated by the size of the arrows.

the current case to those that have been encountered in the past and using these past experiences to make judgements regarding the probability that any particular case belongs within a particular diagnostic category.[17,18] The example provided here is extreme in that all features were presented in exactly the same way both times the case was encountered, but, as Fig. 2 shows, it is not necessary for all features to correspond in order for a potential 'match' to be identified.

This form of 'reasoning' is hypothesised to occur with sufficient automaticity to make it often take place without conscious awareness. Despite the tendency we as humans have to offer explanations for our actions, in reality the sources of our behaviour and decisions are often unknown to us.[4] Although this fact makes it impossible to assume that the responses we get are valid when we simply ask clinicians if/when they use pattern recognition, the evidence that clinicians use non-analytic processes in reaching diagnostic decisions is indisputable.[19] For example, in a series of studies Brooks *et al.* showed that diagnostic accuracy is higher for dermatological cases that are similar to cases seen before relative to cases that are perceptually quite distinct.[20] Furthermore, Hatala *et al.* reported that even diagnostically irrelevant features of a case (e.g. being a banker) have an impact on the diagnosis of subsequently presented cases in which the irrelevant piece of information is similar.[21]

It has been argued that the ability to use non-analytic bases of clinical decision making increases with expertise and, as a result, the use of pattern recognition should not be advocated among medical students for fear of 'potentially grim consequences'.[22 (p 699)] At the extreme, it must be the case that absolute novices have no past experience on which to rely and, hence, are unable to utilise similarity-based reasoning strategies. In reality, however, it has been shown that the strategy employed by even the most junior medical students is qualitatively indistinguishable from that employed by experienced doctors – both groups generate hypotheses very quickly, presumably based in part on non-analytic reference to past experiences.[23] More experienced clinicians are more likely to generate the correct response, however, as would be expected given that they have a larger database to refer to. More directly, whenever the advantage of teaching students to reason in an analytic manner has been explicitly compared to the influence of teaching students to trust in their non-analytic judgements, diagnostic accuracy has been at least as good if not better in the group trained to use non-analytic reasoning, even among relative novices.[22,32] Non-analytic bases of judgement are not inferior to more analytic forms of reasoning and clinical teachers should inform their students that similarity to past instances can serve as a useful guide. The potential for 'grim consequences' is a specious argument, given that the final responsibility for clinical care typically remains with the clinical teacher, not with novice trainees.

THE UNION OF ANALYTIC AND NON-ANALYTIC REASONING STRATEGIES

That being said, it does appear to be true that excessive reliance on non-analytic approaches to clinical reasoning can be a source of diagnostic error. First impressions, while useful, are often incorrect, even among experienced clinicians.[24] Contextual factors, such as receipt of a diagnostic suggestion, have been shown to decrease both the likelihood that features consistent with alternative diagnoses will be identified[25] and the relative weight assigned to features consistent with alternative diagnoses that are identified.[26] Eva has provided evidence that these biases derive from excessive reliance on non-analytic processing; simple instruction to explicitly list the evidence present in a case (i.e. an instruction that can be anticipated to promote more analytic processing) was found to be sufficient to eliminate this type of bias.[27] A critical factor, however, was that the analytic processing should be carried out in close temporal relation to performing the actual task of diagnostic judgement.

Where does this leave the clinical teacher? First, it must be recognised that these two forms of processing are not mutually exclusive. It is highly probable that both forms of processing contribute to the final decisions reached in all cases (for both novices and experts). The impact of similarity, in some cases, will be to prompt an analytic consideration of the current case that is analogous to analyses that were performed on a similar case in the past. As a result, the optimal form of clinical reasoning should be considered an additive model in which both analytic and non-analytic processes play a role. One such model is illustrated in Fig. 3. In this model, the clinician forms a mental representation of the case upon presentation of a patient and this mental representation leads to hypothesis testing, which in most cases will take the form of history taking, physical examination and the ordering of diagnostic tests. Importantly, the direction of

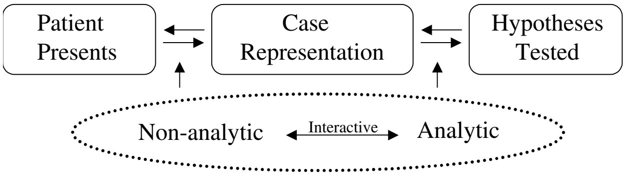

Figure 3 A combined model of clinical reasoning. The analytic and non-analytic models from Figs 1 and 2 are combined in this model. Each type of processing is believed to interact with both the mental representation of the case being presented and the hypotheses that are raised, but to different degrees depending on the context.

reasoning is illustrated to proceed in both directions; results from hypothesis testing will influence the mental representation maintained by the clinician and the mental representation may have an influence on the way a patient's problems are perceived. The bi-directional flow can be expected to occur in both novices and experts.[28] In addition, it should be noted that while non-analytic processing is expected to dominate during the initial phases of considering a new case and analytic processing is expected to play a dominant role in hypothesis testing, these two forms of reasoning should be viewed as being very interactive; rather than lying along a continuum, they are instead complementary contributors to the overall accuracy of the clinical reasoning process, each influencing the other.[29–31]

Recent work provides practical support for this model.[32] When teaching absolute novices (undergraduate psychology students) to diagnose electrocardiograms (ECGs), one group of participants were instructed during practice and test phases to trust feelings of similarity (a non-analytic basis of clinical reasoning), but to avoid 'jumping the gun' by explicitly considering the specific features present on the ECG (an analytic strategy). This group showed higher diagnostic accuracy than two other groups in which participants received either the non-analytic instruction or the analytic instruction alone. The diagnostic performances of the latter two groups were equivalent. This result replicates and extends past work where combined instruction resulted in greater diagnostic accuracy than did purely analytic instruction.[33] In both studies it appeared clear that students who were instructed to use purely analytic techniques found themselves awash in a virtual torrent of clinical features, making it difficult to reconcile the observed pattern with a single diagnostic entity. Furthermore, other work suggests that failure to perform an analytic confirmation results in premature closure and diagnostic errors, even among highly experienced clinicians.[24] To avoid either of these situations, clinical teachers should promote both forms of reasoning in combination. Further consideration of the implications of this view will be outlined after a brief note on the stability of specific diagnostic strategies.

THE 'STATE' OF THE UNION

From the above description of clinical reasoning it is easy to infer the need for clinical teachers to nurture students to become 'good problem solvers' or 'good co-ordinators of analytic and non-analytic processing'. Such views of the diagnostic process are outdated and inaccurate, because of the robust finding that the successful solution of a particular clinical problem does not accurately predict the successful solution of another clinical problem, even within an area of specialisation.[34,35] Reasoning ability is not a 'trait' that can be assigned to an individual. Undoubtedly some individuals are better diagnosticians than others, but clinical teachers must recognise that the context within which a problem is being addressed (i.e. the 'state') has a major impact on the accuracy of the decisions reached and the optimal balance between potential reasoning 'strategies.' 'Context' includes both situational factors (for example the clinical setting and cases that have been present recently) and personal factors (for example the experience of the clinician and current thought and opinion).

Despite attempts to offer students a uniform curriculum, no two students ever have exactly the same experiences. Different students see different cases, reflect upon different aspects of a given case, and derive different insights from such reflections. Each of these differences will have an impact upon the way an individual student approaches a given case (i.e. specific situational factors will influence the 'reasoning strategy' adopted). This state-based conception of clinical practice is perhaps the most fundamental reason for ensuring that students are provided with multiple strategies that might enable them to work through a clinical problem. In some cases a heavy dose of pattern recognition is most likely to yield the correct solution. In others, a more complete history, or application of a diagnostic algorithm, or consideration of the basic science underlying the pathophysiology might be required. The more tools one has in one's workshop, the more likely it is that one of the tools will successfully enable completion of the task at hand.

With this in mind, it becomes unlikely that any single construct will ever fully define the term 'expert' in a domain as broad as clinical reasoning. By way of analogy, consider the development of reading expertise. In performing a component skills analysis of reading ability, Levy and Hinchley administered a series of 11 reading tests and found that while poor readers were on average worse than good readers, any individual reader had some strengths and some weaknesses.[36] In fact, 56% of the good readers exhibited performance deficits on one or more tests and 58% of the poor readers showed superior skill on one or more tests. It is likely, therefore, that expertise in clinical reasoning should be considered an amorphous entity that enables competent clinicians to compensate for case-specific weaknesses. It allows one to adapt to the demands of the situation, flexibly (albeit often unconsciously) utilising the full armament available.

IMPLICATIONS FOR CLINICAL TEACHERS

In summary, a great deal of debate has taken place within the medical education literature pertaining to the structure of medical expertise. In the late 1970s, Elstein *et al.* presented the hypothetico-deductive model of clinical reasoning – namely, that when faced with a new case, doctors generate a set of hypotheses that they later use to test against the data presented.[37] Since that time numerous frameworks of knowledge representation have been developed, but research performed in the last 15 years has called into question whether or not any particular framework will prove correct.[38] More recently still, evidence has begun to accumulate that suggests a more comprehensive approach to clinical teaching, an approach that includes recognition of the benefits of both analytic and non-analytic approaches to clinical reasoning and that can enable students to take advantage of the best of both worlds.[32] Further awareness of the prevalence of context specificity has highlighted the need to provide students with an array of strategies that might better position them to flexibly adapt as the situation demands. The remaining paragraphs of this article will outline some of the implications that arise from this present understanding in an effort to facilitate reflection on current pedagogical techniques and stimulate the development of new approaches.

First and foremost this review highlights the importance of teaching around examples. The earlier students begin to accumulate a mental database of cases, the sooner they will develop a firm foundation on which to allow non-analytic processes to contribute. This idea is not new to medical educators – it is a fundamental principle of good pedagogy. What is relatively new, however, is the recognition that a few complex and elaborate examples are likely to be suboptimal as effective teaching tools. Context specificity and the need to build up an adequate database from which to reason by way of analogy demand that many examples be seen, that students be enabled to actively engage in the problem solving process, and that the examples provide an accurate representation of the range of ways in which specific conditions present.[34] This latter criterion has become increasingly important to consider as the evolution of the health system in many parts of the world has lessened the probability that students will randomly encounter a large number of some medical conditions during their clinic-based learning experiences. As a result, greater awareness and creativity on the part of clinical teachers and curriculum planners is required to ensure that students receive adequate exposure to pedagogically useful cases.

Second, clinical teachers should recognise that the traditional 2-stage approach to clinical teaching, dating back at least as far as Flexner,[39] in which students are expected to master the basic biomedical sciences before proceeding to consideration of clinical problems, may be inappropriate. There is evidence to suggest that an understanding of basic science mechanisms can assist diagnosticians in generating accurate hypotheses and therefore should remain part of medical training.[40,41] It must be recognised, however, that this strategy provides *a* way of reaching the correct diagnosis, not *the* way. Similarly, simply working on a ward and interacting with a series of patients without additional focus on the underlying principles of the cases may do students a disservice by weakening one of the avenues by which they might be able to derive solutions to future cases.

Third, practice with cases should proceed in a way that mimics the eventual use of the resulting knowledge. Clinicians rarely encounter a novel case in which the diagnosis is known. Working through textbook cases in which one already knows the diagnosis as a result of the chapter topic (or the topic of the lecture) does not enable the student to determine whether or not they would be able to recognise the case if it were to show up on the ward. If the patient presentation and case representation outlined in Fig. 3 are fully entwined with a particular diagnosis, practice with the critical hypothesis testing phase is lost. In support of this statement, many investigators have shown that 'mixed practice' in which students see cases of multiple categories mixed together (as opposed to blocked practice in which students work through a block of cases from one diagnostic category before proceeding to the next block of cases from a different diagnostic category) is pedagogically optimal.[42,43]

Furthermore, clinical teachers should not rely on students to make meaningful comparisons across problems spontaneously. Students are much more likely to successfully reason by way of analogy when they have been explicitly instructed to attempt to identify similarities in the underlying concepts of superficially distinct problems.[44] As such, principles inherent in novel examples should be related back to those inherent in past examples whenever possible. Adding to the benefit of such an educational strategy is the by-product of the provision of better information to the clinical teacher regarding where students may be experiencing difficulties. It is well known that experts have difficulty predicting the errors that others make.[45] Providing students with an opportunity to reveal idiosyncratic mistakes enables clinical teachers to focus teaching efforts in a direction that is most likely to benefit individual students.

Finally, the flexibility inherent in clinical reasoning and the prevalence of context specificity has very real implications for clinical teachers' evaluation of trainees. One should not assume that because a student has provided an accurate diagnosis and/or management plan, he or she fully understands the physiological mechanisms underlying the process. Similarly, even if the student can explain the underlying physiological mechanisms, one should not assume that he or she would provide an accurate diagnosis upon encountering the next case. In domains that are afflicted by context specificity (i.e. all domains), a 'multiple biopsy' approach to evaluation is required to accurately assess a student's performance. While no one would dream of assessing knowledge with a single multiple-choice question, recognition of the need to broadly sample when assessing other characteristics of expertise has been less forthcoming. In hindsight it has become clear that context specificity is a major contributor to the poor psychometric qualities of evaluation exercises like the triple jump, patient management problems and long essay and oral examinations.[46] The more time required to perform an evaluation task, the less opportunity there is to have students complete the task multiple times. To ensure information that reliably indicates student ability level is collected, clinical teachers should continue to utilise tools such as the objective structured clinical examination, clinical reasoning exercise and multiple-choice tests.[47]

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