



## Diagnostic Errors in Clinical Reasoning: A Comprehensive Literature Review on Cognitive Processes, Causes, and Error Reduction Strategies

Klinik Akıl Yürütmede Tanı Hataları: Bilişsel Süreçler, Nedenler ve Hata Azaltma Stratejilerine İlişkin Kapsamlı Bir Literatür İncelemesi

Neşe Pekcan<sup>1</sup>, Özlem Coşkun<sup>2</sup>

<sup>1</sup>Education Specialist, Ministry of National Education, Ankara, Türkiye

<sup>2</sup>Department of Medical Education, Gazi University Faculty of Medicine, Ankara, Türkiye

### ABSTRACT

Diagnostic decision-making in complex and uncertain clinical settings relies heavily on diagnostic thinking as a core component of clinical reasoning. As healthcare complexity increases, understanding how physicians and medical students reason is essential for ensuring patient safety and quality of care. This review explores the evolution of diagnostic models from early hypothetico-deductive frameworks to contemporary knowledge-based and dual-process perspectives. A narrative synthesis was conducted by drawing on the literature from major biomedical and educational databases, including PubMed, Web of Science, and Scopus. The review focused on conceptual and empirical discussions regarding cognitive processes, diagnostic errors, and error-reduction strategies in clinical practice. Diagnostic errors, which often arise from incomplete data collection or misinterpretation of findings, significantly contribute to patient harm and increased healthcare costs. Notably, interpretation errors are resistant to improvement through clinical experience alone, emphasizing the role of cognitive biases and underdeveloped mental representations (illness scripts). Contextual factors, such as time pressure and physician density, further influence diagnostic accuracy. Reducing diagnostic errors requires targeted educational efforts to enhance pattern recognition, metacognitive awareness, and the systematic use of debiasing strategies. Integrating artificial intelligence as a supportive tool and adopting constructive terminology, such as "missed diagnostic opportunities," may foster a more reflective and safe diagnostic environment.

### ÖZ

Karmaşık ve belirsizlik içeren klinik ortamlarda tanısız karar verme süreçleri, klinik akıl yürütmenin temel bileşenlerinden biri olan tanısız düşünmeye büyük ölçüde dayanmaktadır. Sağlık hizmetlerinin giderek daha karmaşık hâle gelmesiyle birlikte, hekimlerin ve tıp öğrencilerinin nasıl akıl yürüttüklerinin anlaşılması, hasta güvenliğinin ve bakım kalitesinin sağlanması açısından kritik önem taşımaktadır. Bu derleme, tanısız modellere ilişkin yaklaşımların erken dönem varsayımsal-tümdengelimli (hipotetiko-dedüktif) çerçevelerden, günümüzde öne çıkan bilgi temelli ve ikili süreç (dual-process) perspektiflerine uzanan gelişimini incelemektedir. Bu çalışma, PubMed, Web of Science ve Scopus başta olmak üzere temel biyomedikal ve eğitim veri tabanlarında yer alan literatüre dayalı olarak gerçekleştirilen anlatsal bir sentez niteliğindedir. Derleme kapsamında, klinik uygulamada bilişsel süreçler, tanı hataları ve hata azaltma stratejilerine ilişkin kavramsal ve ampirik tartışmalara odaklanılmıştır. Çoğu zaman eksik veri toplama ya da bulguların yanlış yorumlanmasından kaynaklanan tanı hataları, hasta zararına ve sağlık hizmeti maliyetlerinin artmasına önemli ölçüde katkıda bulunmaktadır. Özellikle yorumlama hatalarının, yalnızca klinik deneyim yoluyla iyileştirilmesinin zor olduğu görülmektedir. Bu durum, bilişsel yanlılıkların ve yeterince gelişmemiş zihinsel temsillerin (hastalık şemaları/illness scripts) tanısız süreçlerdeki rolünü vurgulamaktadır. Ayrıca zaman baskısı ve hekim yoğunluğu gibi bağlamsal faktörlerin de tanısız doğruluğu etkilediği belirlenmiştir. Tanı hatalarının azaltılması; örüntü tanıma becerilerinin geliştirilmesi, üstbilişsel farkındalığın artırılması ve yanlılık azaltma (debiasing) stratejilerinin sistematik

**Cite this article as:** Pekcan N, Coşkun Ö. Diagnostic errors in clinical reasoning: a comprehensive literature review on cognitive processes, causes, and error reduction strategies. Gazi Med J. [Epub Ahead of Print].

**Address for Correspondence/Yazışma Adresi:** Neşe Pekcan, Ministry of National Education, Ankara, Türkiye  
Ministry of National Education, Ankara, Türkiye

**E-mail / E-posta:** [npeccann@gmail.com](mailto:npeccann@gmail.com)

**ORCID ID:** [orcid.org/0000-0001-9687-9504](http://orcid.org/0000-0001-9687-9504)

**Received/Geliş Tarihi:** 14.08.2025

**Accepted/Kabul Tarihi:** 13.01.2026

**Epub:** 09.03.2026



Copyright 2026 The Author(s). Published by Galenos Publishing House on behalf of Gazi University Faculty of Medicine. Licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 (CC BY-NC-ND) International License.

<sup>1</sup>Telif Hakkı 2026 Yazar(lar). Gazi Üniversitesi Tıp Fakültesi adına Galenos Yayınevi tarafından yayımlanmaktadır. Creative Commons Atf-GayriTicari-Türetilemez 4.0 (CC BY-NC-ND) Uluslararası Lisansı ile lisanslanmaktadır.

## ABSTRACT

**Keywords:** Diagnostic thinking, clinical reasoning, diagnostic error, cognitive bias, metacognition

## ÖZ

biçimde kullanılması gibi hedefe yönelik eğitimsel yaklaşımları gerektirmektedir. Ayrıca, yapay zekânın destekleyici bir araç olarak entegrasyonu ve “tanı fırsatının kaçırılması” (missed diagnostic opportunities) gibi daha yapıcı terminolojilerin benimsenmesi, daha yansıtıcı ve güvenli bir tanı ortamının oluşmasına katkı sağlayabilir.

**Anahtar Sözcükler:** Tanısal düşünme, klinik akıl yürütme, tanısal hata, bilişsel hatalar, metabiliş

---

## INTRODUCTION

The decision-making process in healthcare often involves complex situations characterized by uncertainty and time pressure. Although treatment-related decisions can also be complex, clinicians typically face the highest degree of uncertainty during the diagnostic phase (1). The diagnostic process encompasses a range of cognitive skills, such as analytical thinking, non-analytical pattern recognition, metacognitive monitoring, and the use of knowledge structures. In this respect, diagnostic thinking is positioned as an integral component of clinical reasoning (2). In recent years, the thought processes of physicians and medical students have become a subject of interest. The development of these processes will enable more accurate and efficient healthcare. To understand and foster the development of diagnostic thinking, it is necessary to examine the cognitive processes of physicians and medical students.

Research on medical thinking processes began in the 1980s. One of the earliest approaches in this field was the hypothetico-deductive diagnostic model developed by Elstein et al. (3). Subsequent research moved toward knowledge-based models, focusing on how medical information is structured and retrieved from memory (4-8). The hypothetico-deductive model is an iterative process comprising the stages of cue acquisition, hypothesis generation, data interpretation, and hypothesis testing (3). In contrast, the knowledge-based model focuses on how medical knowledge is organized in memory and how it is accessed; its core components include the recognition of meaningful information, the structuring of clinical knowledge, and the access to stored knowledge frameworks (9).

In summary, as cognitive psychology has advanced, various strategies have been employed to conceptualize medical thinking processes. These processes have been examined in terms of the ways the mind operates, the retrieval of knowledge, pattern recognition, and metacognition. This narrative review aims to synthesize the current understanding of diagnostic thinking processes, examine the cognitive origins of diagnostic errors, and discuss evidence-based strategies to mitigate such errors in clinical practice.

### **Diagnostic Thinking**

Diagnostic thinking is regarded as one of the most critical cognitive skills of physicians, and the enhancement of this process constitutes a primary objective in improving patient safety. Contemporary frameworks for understanding the diagnostic process often employ Dual Process Theory, which categorizes clinical reasoning into two cognitive modes: intuitive (System 1) and analytical (System 2) reasoning. While earlier models focused on hypothetico-deductive methods, this dual-process perspective provides a robust lens

for examining how clinicians balance heuristic-based speed with deliberate logic (2). The intuitive approach relies largely on the clinician’s experience and is characterized by inductive reasoning. Experienced physicians often recognize patient information within general patterns (gestalt) and make rapid, largely unconscious decisions. These decisions are frequently made under conditions of time pressure, incomplete information, and uncertainty. In intuitive processes, mental shortcuts such as “thin slicing”, which rely on instinctive first impressions, are commonly employed. However, these rapid decisions have limitations, as they are often made without access to the full range of data.

In contrast, analytical reasoning is grounded in a more systematic and logical process. When decision-makers have access to more information and resources, they follow a deliberate, step-by-step process to reduce uncertainty. This approach is more closely aligned with normative reasoning and rationality. Most robust clinical decisions are made under conditions in which analytical processes are active. In recent years, these two approaches have been conceptualized within the psychology literature as dual-process theory. System 1 produces rapid, automatic, and context-sensitive decisions, whereas System 2 is engaged in situations requiring slower, deliberate, and logical analysis. Physicians often draw on both systems simultaneously when making diagnoses. Clinical decisions are influenced not only by patient data but also by contextual factors such as environmental conditions, workload, resource limitations, and prior experiences (2,10).

Croskerry (2) argues that System 1 and System 2 are not entirely independent structures but operate along a cognitive continuum, allowing transitions between them. These transitions can influence the accuracy and efficiency of decisions. When conflict arises between the two systems, activating System 2 to review and challenge a System 1 intuitive judgment may provide a safer approach for the patient. Royce et al. (11) note that System 1 relies on pattern recognition and heuristic shortcuts for rapid decision-making, whereas System 2 is more likely to be engaged in the presence of unfamiliar problems or contradictory evidence, operating in a slower and more analytical manner. *Dual-process theory* suggests that these two systems interact dynamically. While System 1 often generates rapid, intuitive responses, System 2 can be engaged to critically analyze the situation, monitor the outputs of System 1, or take over the reasoning process when high levels of complexity or novelty are encountered (2,12) Norman and Eva (13) contend that when experts deliberately become more analytical, their likelihood of making errors can increase. Their research indicates that training aimed at reducing cognitive biases is often ineffective due to limited

transferability, whereas interventions supporting both intuitive and analytical reasoning can yield small but consistent improvements in accuracy.

Coughlan et al. (14) argue that improving medical decision-making requires physicians to recognize their own thinking patterns and to learn strategies for avoiding cognitive errors. They emphasize that such training should incorporate metacognitive awareness and epistemological understanding. Metacognition involves monitoring and regulating one's own thought processes and consciously engaging in problem-solving, particularly via System 2. Reflection within this process enables decisions to be evaluated more analytically (11).

According to foundational cognitive models, the diagnostic process is structured around several key elements: accurate data collection (gathering high-quality information during history-taking and physical examination), identification of meaningful information (selecting relevant cues), information integration (combining disparate data within a clinical context), and interpretation (evaluating findings against diagnostic hypotheses) (15). Emphasizing the content-specific nature of diagnosis highlights the context sensitivity of diagnostic thinking: recognizing the role of content in identifying errors increases the need for probabilistic or hypothetical reasoning. This aspect parallels the processes of trial-and-error and probabilistic hypothesis generation seen in physiotherapy (16). While these thinking strategies are well-represented in the literature, they warrant further discussion. In particular, the integration of metacognitive concepts into diagnostic thinking processes may enhance awareness among physicians and medical students. Thinking errors arising from these processes are addressed in the subsequent section of this study.

### **Diagnostic Thinking Errors**

Diagnosis plays a central role in patient care, providing meaning to the disease and shaping treatment decisions. The term diagnostic error is used as an umbrella concept, describing a broad spectrum of unintentional errors, including delays in diagnosis, misdiagnoses, and missed diagnoses. However, the terminology used in this field varies considerably among authors (1). Diagnostic errors most often arise from insufficient knowledge, inaccurate data collection, and flawed integration or interpretation of data. While clinical experience can mitigate knowledge gaps and reduce data collection errors, errors in data interpretation do not improve to the same extent. These findings (17,19) suggest that interpretive skill is related not only to the breadth of knowledge but also to the quality of clinical reasoning. Moreover, experience alone does not guarantee expertise, as the ability to recognize key clinical features does not necessarily prevent faulty inferences (17).

Research indicates that the majority of diagnostic errors occur during physician–patient encounters, particularly in core stages such as history-taking, physical examination, selection of diagnostic tests, and interpretation of test results. This underscores the multifaceted nature of errors in the diagnostic process. Clinical competence requires the integrated development of effective communication, examination skills, data analysis and synthesis, and reasoning abilities. Nonetheless, even the most experienced physicians occasionally commit diagnostic errors (1).

Although diagnostic errors are difficult to measure, studies have demonstrated their association with suboptimal patient outcomes,

and unnecessary healthcare costs (1). Errors in diagnosis are most often linked to clinical reasoning and generally result from inadequate knowledge, poor data collection, or errors in data integration and interpretation. While knowledge deficits and data collection errors may diminish with clinical experience, interpretive errors tend not to improve proportionally. This suggests that diagnostic reasoning is related not only to the amount of knowledge but also to the way in which information is processed. Interpretation skills, in particular, are considered competencies independent of experience (17). For this reason, it is important to approach diagnostic thinking as a holistic process and to remain aware of the principles of psychological functioning; otherwise, incorrect decisions, misdiagnoses, and diminished quality of care are likely to occur (20).

For example, according to the comprehensive analysis by Berner and Graber (21), error rates are very low (less than 5%) in “perceptual” specialties such as radiology and pathology, whereas in high-intensity settings such as emergency departments, the rate rises to 10–15%. In the United States, diagnostic errors are estimated to contribute to approximately 40,000–80,000 hospital deaths annually, with the combined number of deaths and disabilities related to these errors ranging from 80,000 to 160,000 (22). The actual figures may be even higher. While the most serious errors often occur in emergency departments, the overall burden is largely borne by primary care. Certain groups—such as women, ethnic minorities, and younger patients—are at greater risk of diagnostic errors (1). Therefore, these high-risk populations and contexts should be prioritized in both error-reduction strategies and clinical education.

Diagnostic errors can arise not only from individual cognitive processes but also from systemic failures. Examples of process errors include overlooking vital signs, failing to order necessary tests, or delaying communication of laboratory results (23). In addition, mislabeling of symptoms with an incorrect diagnosis (e.g., interpreting pyelonephritis as musculoskeletal pain) or the absence of any diagnosis are examples of diagnostic labeling errors (24). Process and labeling errors can occur independently or together, and pose threats to patient safety. Overuse of diagnostic labels and overdiagnosis are also considered diagnostic errors. For example, in musculoskeletal disorders, pathoanatomic diagnoses are frequently overused, leading to increased imaging, surgical referrals, overtreatment, and patient dissatisfaction (25). Numerous studies have demonstrated that the results of diagnostic tests are not necessarily associated with patient outcomes (26,29).

### **How Can Diagnostic Errors Be Reduced?**

The most fundamental way to prevent diagnostic errors is to increase awareness of one's own thinking processes. This requires individuals to critically examine their own mental functioning and develop metacognitive awareness—the ability to “think about thinking.” In diagnostic decision-making, it is particularly important to avoid becoming overly anchored to the initial diagnostic hypothesis. Clinicians should be aware that first impressions can be misleading and that premature closure may lead to diagnostic errors. Therefore, the validity of the initial hypothesis should be continuously questioned, and alternative diagnoses should be actively considered.

Adopting a systematic approach to diagnostic reasoning also contributes to error reduction. Strategies such as hypothetical-deductive reasoning and pattern recognition can support the structured operation of cognitive processes; however, these strategies should be applied flexibly, tailored to the specific context and patient. At this point, cognitive flexibility emerges as a critical skill that enhances diagnostic accuracy. The ability to recognize both automatic and analytical reasoning processes—and consciously transition between them—helps mitigate diagnostic biases.

To reduce the influence of cognitive biases in clinical decision-making, individuals should base their decisions not only on their own knowledge and intuition, but also on objective data, diagnostic test results, and established clinical guidelines. In particular, accurate interpretation of diagnostic test sensitivity, specificity, and predictive values helps avoid false-positive or false-negative conclusions. It has also been noted that patients with the same diagnosis may present with different phenotypic subgroups—a process known as phenotyping (26,30). Variables such as pain sensitivity, psychological status, body mass index, and muscle strength can influence patient outcomes. Recognizing these differences allows for targeted treatments and more accurate prognoses (26).

In undergraduate medical education, it is also essential to train students in ways that reduce the likelihood of future diagnostic errors. Evidence suggests that medical students' diagnostic thinking skills are often underdeveloped and insufficiently addressed in formal education (31,32). Instructional strategies such as problem-based learning, team-based learning, and case-based learning aim to cultivate skills specific to diagnostic thinking, such as processing information rather than memorizing it, formulating hypotheses, and evaluating alternatives (33). Consequently, these approaches should be integrated into the curriculum.

Diagnostic thinking skills of medical students and residents can be monitored using the Diagnostic Thinking Inventory (DTI) (9,31). Personalized learning strategies can then be developed based on whether the learner relies more on analytical or non-analytical reasoning processes. For learners with low DTI scores, interventions aimed at fostering cognitive flexibility can be designed. Exposure to diverse clinical cases can help students develop adaptable thinking skills. High cognitive-demand environments—such as hospital settings—can be strategically utilized to foster the development of diagnostic thinking (34,35). Systematic instruction in critical thinking skills can also improve diagnostic accuracy, while metacognitive training—teaching individuals to think about their thinking—can increase awareness of diagnostic errors (36).

Finally, efforts to improve diagnostic thinking should be supported not only at the individual level but also through teamwork, a feedback culture, and structured educational programs. Collaborative case analysis fosters alternative perspectives and raises awareness of potential biases (37,38). Receiving feedback enables individuals to recognize their own thinking errors and avoid repeating them in the future. In educational settings, an approach should be adopted in which thinking processes are explicitly articulated and inquiry-based learning methods are encouraged.

In summary, avoiding diagnostic thinking errors requires more than technical knowledge alone; it necessitates understanding the underlying cognitive processes, continuously reviewing these

processes, and fostering supportive learning environments. This represents a fundamental mental discipline that strengthens clinical safety and decision-making accuracy over the long term.

## DISCUSSION

In medical settings, decision-makers frequently operate under less-than-ideal conditions such as time pressure, distraction, fatigue, sleep deprivation, and resource constraints. Clinical decisions are often made rapidly and intuitively under the influence of factors such as cognitive load, environmental stimuli, and limited resources. This environment compels healthcare providers to develop strategies for maintaining patient care efficiency amidst a dynamic and unpredictable workload (2).

The diagnostic process is not limited to interpreting test results; it encompasses multidimensional tasks such as analytical reasoning, contextual evaluation, and consideration of phenotypic diversity. This approach requires linking the diagnostic process not only to measures such as accuracy or test sensitivity but also to the patient's overall management. For this reason, higher-order thinking skills are critical in clinical decision-making. Moving beyond rote-based approaches, clinicians need structured thinking models for differential diagnosis and patient-centered care (13,26).

Research on malpractice and diagnostic errors highlights the importance of advanced clinical reasoning skills and the necessity of educational strategies focused on critical thinking (11,39). Recommended educational interventions aim to develop metacognitive strategies, increase awareness of cognitive biases, and provide techniques to mitigate these biases (11,13). Furthermore, identifying phases of the diagnostic process where errors are most concentrated and creating targeted educational content for these phases have the potential to reduce error rates.

An analysis of the causes of diagnostic errors reveals that the diagnostic process is shaped not only by individual knowledge but also by contextual factors such as early specialization (which may narrow diagnostic focus) and environmental differences (35). The quality of clinical experience is thus inextricably linked to the context in which it occurs. A critical contextual factor is time pressure, which often stems from high patient volumes. For example, although the number of physicians per 1,000 inhabitants in Turkey has recently increased to 2.2 (40), this figure remains below the OECD average, which may lead to increased workloads and shorter consultation times. Indeed, Monteiro et al. (41) demonstrated that reduced thinking time significantly lowers diagnostic accuracy, particularly when clinicians cannot engage in reflective reasoning. Consequently, an educational process that provides sufficient time and experiential learning opportunities is essential to facilitate more accurate diagnoses (42).

In the clinical diagnostic process, intuitive thinking and cognitive biases significantly affect decision quality. While intuitive approaches can be functional for urgent decisions, they often lead to systematic reasoning errors. Cognitive biases, defined as deviations from rational judgment, are frequently associated with these heuristic shortcuts (14). However, educational strategies that solely focus on identifying biases have proven ineffective to date. This underscores the need to integrate memory-based strategies into training programs (11).

To develop effective mental representations in the diagnostic process, it is important to deliberately expose students to rare or atypical cases. Natural clinical distributions are insufficient for building such representations. Therefore, simulation-based learning techniques and principles of deliberate practice should be integrated early in medical training.

Modern medical education is shifting away from purely knowledge-transmission approaches toward models that emphasize problem-solving and critical thinking. However, for this transformation to be sustained and effective, curricula must include structures that promote analytical thinking and provide strategies for metacognitive awareness. Prioritizing the interpretation and integration of clinical knowledge will support the development of graduates' reasoning skills.

The diagnostic thinking process transcends simple hypothesis generation and testing; it fundamentally relies on knowledge structure, pattern recognition, and rapid information retrieval. While pattern recognition is a hallmark of clinical expertise, over-reliance on this intuitive process without analytical verification can lead to cognitive pitfalls such as premature closure (44). Furthermore, weak, fragmented, or incomplete mental representations—often referred to as underdeveloped illness scripts—render clinicians more susceptible to biases (45). Consequently, medical education must go beyond factual knowledge to systematically teach metacognitive skills and debiasing strategies to safeguard the diagnostic process.

Artificial intelligence (AI)-supported systems hold significant potential for reducing diagnostic errors. However, AI should be positioned as an advisory tool rather than as a replacement for physicians (14,43). AI remains limited in performing cognitive processes, such as analyzing the temporal evolution of symptoms, evaluating contextual information, and prioritizing differential diagnoses. Moreover, overreliance on AI could hinder the development of critical thinking skills and reduce transparency in the diagnostic process. The most effective approach is for the human physician to make the final decision, with AI serving to support the process.

Evaluating the level of diagnostic thinking could be considered a quality management and accreditation metric in healthcare services (45). Assessment activities conducted throughout physicians' training play a critical role in identifying reasoning errors. Additionally, raising awareness of the reliability of the literature and facilitating access to reliable information can help reduce diagnostic errors.

Finally, Royce et al. (11) argue that replacing terms such as “diagnostic error” with more constructive and flexible expressions (e.g., “missed diagnostic opportunity”), or replacing “differential diagnosis” with “diagnostic hypothesis,” may make errors easier to acknowledge and discuss. Reframing the language used in diagnostic reasoning could, in turn, contribute to transforming these processes.

## CONCLUSION

Diagnostic errors remain a significant threat to patient safety and healthcare quality worldwide. As demonstrated in the literature, these errors arise not only from knowledge deficits but primarily from flaws in cognitive processing, contextual pressures, and underdeveloped illness scripts. Clinical experience alone does not guarantee improved diagnostic accuracy, particularly in relation to

interpretive errors. Therefore, structured educational interventions that promote metacognitive awareness, cognitive flexibility, and deliberate practice are essential. In addition, system-level strategies, collaborative diagnostic practices, and supportive integration of artificial intelligence may further enhance diagnostic reliability. Ultimately, improving diagnostic thinking requires a comprehensive approach that integrates cognitive science, medical education, and healthcare system reform.

## Footnotes

### Authorship Contributions

Concept: N.P., Ö.C., Design: N.P., Ö.C., Data Collection or Processing: N.P., Ö.C., Analysis or Interpretation: N.P., Ö.C., Literature Search: N.P., Ö.C., Writing: N.P., Ö.C.,

**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study received no financial support.

## REFERENCES

1. Benishek LE, Weaver SJ, Newman Toker DE. The cognitive psychology of diagnostic errors. *Sci Am Neurol*. 2015; 1-21.
2. Croskerry P. A universal model of diagnostic reasoning. *Acad Med*. 2009; 84: 1022-8.
3. Elstein AS, Shulman LS, Sprafka SA. *Medical problem solving: An analysis of clinical reasoning*. Cambridge, MA: Harvard University Press; 1978.
4. Gale J, Marsden P. *Medical diagnosis: From student to clinician*. Oxford: Oxford University Press; 1983.
5. Bordage G, Zacks R. The structure of medical knowledge in the memories of medical students and general practitioners: categories and prototypes. *Med Educ*. 1984; 18: 406-16.
6. Bordage G, Lemieux M. Semantic structures and diagnostic thinking of experts and novices. *Acad Med*. 1991; 66: 570-2.
7. Patel VL, Groen GJ. Knowledge based solution strategies in medical reasoning. *Cogn Sci*. 1986; 10: 91-116.
8. Norman GR. Problem-solving skills, solving problems and problem-based learning. *Med Educ*. 1988; 22: 279-86.
9. Bordage G, Grant J, Marsden P. Quantitative assessment of diagnostic ability. *Med Educ*. 1990; 24: 413-25.
10. Graber ML, Ruz D, Jones ML, Farm-Franks D, Jones B, Cyr Gluck J, et al. The new diagnostic team. *Diagnosis (Berl)*. 2017; 4: 225-38.
11. Royce CS, Hayes MM, Schwartzstein RM. Teaching critical thinking: A case for instruction in cognitive biases to reduce diagnostic errors and improve patient safety. *Acad Med*. 2019; 94: 187-94.
12. Evans JSB. Dual-processing accounts of reasoning, judgment, and social cognition. *Annu Rev Psychol*. 2008; 59: 255-78.
13. Norman GR, Eva KW. Diagnostic error and clinical reasoning. *Med Educ*. 2010; 44: 94-100.
14. Coughlan JJ, Mullins CF, Kiernan TJ. Diagnosing, fast and slow. *Postgrad Med J*. 2021; 97: 103-109.
15. Bordage G. Elaborated knowledge: a key to successful diagnostic thinking. *Acad Med*. 1994; 69: 883-5.
16. Leuders T, Loibl K, Sommerhoff D, Herppich S, Praetorius AK. Toward an overarching framework for systematizing research perspectives on diagnostic thinking and practice. *Educ Psychol Rev*. 2022; 34: 591-611.

17. Groves M, O'Rourke P, Alexander H. Clinical reasoning: the relative contribution of identification, interpretation and hypothesis errors to misdiagnosis. *Med Teach*. 2003; 25: 621-5.
18. Eva KW. What every teacher needs to know about clinical reasoning. *Med Educ*. 2005; 39: 98-106.
19. Schmidt HG, Rikers RM. How expertise develops in medicine: Knowledge encapsulation and illness script formation. *Med Educ*. 2007; 41: 1133-9.
20. Ivanovich C, Fedorovich AA. The importance of researching general components of diagnostic thinking in modern psychology. *J Psychol Clin Psychiatry*. 2018; 9: 270-1.
21. Berner ES, Graber ML. Overconfidence as a cause of diagnostic error in medicine. *Am J Med*. 2008; 121: S2-23.
22. Newman-Toker DE, McDonald KM, Schaffer AC. Charting the course: Improving the diagnosis of healthcare quality. *J Gen Intern Med*. 2014; 29: 1579-81.
23. National Academies of Sciences, Engineering, and Medicine. Improving diagnosis in health care. Balogh EP, Miller BT, Ball JR, editors. Washington (DC): National Academies Press (US); 2015. doi: 10.17226/21794. Available from: <https://nap.nationalacademies.org/catalog/21794/improving-diagnosis-in-health-care>
24. Zwaan L, Thijs A, Wagner C, van der Wal G, Timmermans DR. Design of a retrospective patient record review study of diagnostic error in the internal medicine setting. *BMC Health Serv Res*. 2010;10:331. doi: 10.1186/1472-6963-10-331. Available from: <https://bmchealthservres.biomedcentral.com/articles/10.1186/1472-6963-10-331>
25. Foster NE, Anema JR, Cherkin D, Chou R, Cohen SP, Gross DP, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. *Lancet*. 2018; 391: 2368-83.
26. Cook CE, Décarry S. Higher order thinking about differential diagnosis. *Braz J Phys Ther*. 2020; 24: 1-7.
27. Chou R, Fu R, Carrino JA, Deyo RA. Imaging strategies for low-back pain: Systematic review and meta-analysis. *Lancet*. 2009; 373: 463-72.
28. Jarvik JG, Hollingworth W, Martin B, Emerson SS, Gray DT, Overman S, et al. Rapid magnetic resonance imaging vs. radiographs for patients with low back pain: a randomized controlled trial. *JAMA*. 2003; 289: 2810-8.
29. Lurie JD. Review: routine spinal imaging for low back pain does not improve outcomes. *Evid Based Med*. 2003;8(6):191. Available from: <https://ebm.bmj.com/content/8/6/191>
30. O'Sullivan PB, Caneiro JP, Kiernan M, Lin I. Unraveling the complexity of low back pain. *J Orthop Sports Phys Ther*. 2016; 46: 932-7.
31. Picho K, Maggio LA. The diagnostic thinking inventory: A systematic review of its development and use in medical education. *Acad Med*. 2020;95(12):1930-9. Available from: [https://journals.lww.com/academicmedicine/fulltext/2020/12000/the\\_diagnostic\\_thinking\\_inventory\\_\\_a\\_systematic.38.aspx](https://journals.lww.com/academicmedicine/fulltext/2020/12000/the_diagnostic_thinking_inventory__a_systematic.38.aspx)
32. Schmidt HG, Norman GR, Boshuizen HP. A cognitive perspective on medical expertise: theory and implication. *Acad Med*. 1990; 65: 611-21.
33. Owlia F, Keshmiri F, Kazemipoor M, Rashidi Maybodi F. Assessment of clinical reasoning and diagnostic thinking among dental students. *Int J Dent*. 2022;2022:1085326.
34. Durning SJ, Costanzo ME, Beckman TJ, Artino AR Jr, Roy MJ, Cleary TJ, et al. Functional neuroimaging correlates of thinking flexibility and knowledge structure in memory: exploring the relationships between clinical reasoning and diagnostic thinking. *Med Teach*. 2016; 38: 570-7.
35. Grageda ME, Rotor E. Diagnostic thinking skills of Filipino physical therapists. *Physiotherapy*. 2015;101(Suppl 1):eS480.
36. Lunney M. Use of critical thinking in the diagnostic process. *Int J Nurs Terminol Classif*. 2010; 21: 82-8.
37. Graber ML, Kissam S, Payne VL, et al. Cognitive interventions to reduce diagnostic error: A narrative review. *BMJ Qual Saf*. 2012; 21: 535-45.
38. Mamede S, Schmidt HG, Penaforte JC. Effect of vicarious experience, group discussion, and reflection on students' diagnostic accuracy. *Med Educ*. 2014; 48: 259-73.
39. Saber Tehrani AS, Lee H, Mathews SC, Shore A, Makary MA, Pronovost PJ, et al. 25-Year summary of US malpractice claims for diagnostic errors 1986-2010: an analysis from the National Practitioner Data Bank. *BMJ Qual Saf*. 2013; 22: 672-80.
40. OECD. Health at a glance 2023: OECD indicators. Paris: OECD Publishing; 2023. Available from: [https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2023\\_7a7afb35-en](https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2023_7a7afb35-en)
41. Monteiro SD, Sherbino J, Patel A, Mazzetti I, Norman GR, Howey E. Reflecting on diagnostic errors: Taking a second look is not enough. *J Gen Intern Med*. 2015; 30: 1270-4.
42. Monteiro SM, Norman G. Diagnostic reasoning: Where we've been, where we're going. *Teach Learn Med*. 2013;25 Suppl 1:S26-32. Available from: <https://www.tandfonline.com/doi/full/10.1080/10401334.2013.842911>
43. Harada T, Shimizu T, Kaji Y, Suyama Y, Matsumoto T, Kosaka C, et al. A Perspective from a case conference on comparing the diagnostic process: human diagnostic thinking vs. artificial intelligence (AI) decision support tools. *Int J Environ Res Public Health*. 2020; 17: 6110.
44. Croskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. *Acad Med*. 2003; 78: 775-80.
45. Hamzeh H, Madi M. Using the diagnostic thinking inventory in musculoskeletal physiotherapy: A validity and reliability study. *Physiother Res Int*. 2021; 26: e1895.