

Medicine Beyond Machines: The Art of Thinking in the Age of AI

Isabella B. B. Ferreira, Rodrigo C. Menezes, Luis Cláudio L. Correia, Bruno B. Andrade

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Table of Contents

Original Manuscript.....	4
---------------------------------	----------

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Abstract

The widespread adoption of Large Language Models (LLMs) is reshaping clinical decision-making by influencing not only data interpretation but also the cognitive structure of medical reasoning. While these tools enhance diagnostic capacity and streamline workflows, misuse may diminish critical, contextual, and humanized thinking, reducing physicians to passive validators of algorithmic outputs. This article explores the evolution of medical cognition and proposes strategies for integrating AI in ways that preserve cognitive autonomy, such as structuring information, reducing bias, and strengthening metacognition. We argue that AI should serve as a "cognitive stethoscope", a tool that refines reasoning without compromising its essence.

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Medicine Beyond Machines: The Art of Thinking in the Age of AI

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ABSTRACT

The widespread adoption of Large Language Models (LLMs) is reshaping clinical decision-making by influencing not only data interpretation but also the cognitive structure of medical reasoning. While these tools enhance diagnostic capacity and streamline workflows, misuse may diminish critical, contextual, and humanized thinking, reducing physicians to passive validators of algorithmic outputs. This article explores the evolution of medical cognition and proposes strategies for integrating AI in ways that preserve cognitive autonomy, such as structuring information, reducing bias, and strengthening metacognition. We argue that AI should serve as a "cognitive stethoscope", a tool that refines reasoning without compromising its essence.

INTRODUCTION

Before the advent of antibiotics, anesthetics, or sophisticated examinations, medicine was built on the pillars of care and curiosity. Over time, this innate curiosity became intertwined with innovation, using it as a tool for continuous improvement. Technology has since expanded human capabilities far

beyond biological limits, reconfiguring the way we diagnose, treat, and even think.

Now, we stand at the threshold of another technological leap: the incorporation of artificial intelligence (AI) into clinical practice, particularly through Large Language Models (LLMs) [1]. These tools go beyond providing information; they analyze patterns, interpret data, and suggest diagnoses and therapeutic approaches, fundamentally reshaping the relationship between physicians and technology.

However, this advancement raises a fundamental question: to what extent does AI enhance medical cognition, and to what extent might it undermine it? On one hand, it enables the rapid analysis of vast amounts of complex data, also identifying patterns previously indiscernible to human perception. On the other, over-reliance on these systems risks reducing physicians to mere validators of algorithmic outputs. Medicine is more than a game of probabilities. While AI serves as a powerful predictive tool, clinical decision-making is a far more complex and multidimensional exercise. It is an art that relies on judgment, inference, and human perception, aspects that algorithms have yet to fully replicate.

In this article, we explore the evolution of medical cognition, examining what distinguishes human thought from AI's role in clinical practice. Our goal is to provide insights that guide physicians and medical students in integrating AI without compromising independent, critical, and humanized thinking. The challenge is not to resist technology but to harness it as a tool for deeper and more thoughtful medical reasoning.

SCIENTIFIC REVOLUTION AND THE TRANSFORMATION OF MEDICAL THINKING

Medicine was once upheld by experimentation, traditions, beliefs, and individual observations. Diseases were attributed to miasmas or humoral imbalances, with treatments based more on assumptions than evidence [2]. Then, science began to unveil the invisible. In the 19th century, John Snow mapped London's cholera outbreaks, tracing the source to a contaminated water pump. Through an astute and sophisticated approach, his work demonstrated that patterns hidden in chaos could guide medical reasoning, laying the foundation of modern epidemiology [3].

With the discovery of germs, medicine shifted from speculation to identifying specific etiological agents. For example, tuberculosis was no longer seen as a "tragic fate" but as a disease caused by *Mycobacterium tuberculosis* [4,5]. This shift from speculation to specificity marked a new era, as advancements in medicine have continuously expanded our perception and understanding of disease and the human body. Tools like the stethoscope, laboratory tests and imaging technologies sharpened our senses, allowing clinicians to sharply detect internal bodily sounds, decode biochemical signals, and enabled us to overcome the insurmountable, visualizing internal organs and tissues without the need for surgical intervention.

Innovative technologies began to be assessed with scientific rigor: comparing interventions or exposures, controlling variables, and measuring outcomes. Intuition gave way to evidence, to randomized clinical trials, and systematic reviews, transforming patient care from trial and error to a practice grounded in probabilities and objective results. This shift led to milestones such as the dramatic reduction in mortality among patients with acquired immunodeficiency syndrome, whose

five-year mortality once ranged between 80% and 90%, but with the introduction of antiretroviral therapy, life expectancy for these patients has approached that of the general population [6].

Medicine has also become more difficult. Past decisions were straightforward, whether to administer insulin, drain an abscess, or amputate a gangrenous limb. Today, physicians navigate nuanced trade-offs, balancing marginal effects and long-term outcomes. Whereas they once relied solely on history-taking, observation, and subjective associations, they now process an overwhelming volume of sounds, images, reports, and probabilities, a task demanding critical judgment and scientific expertise. Meanwhile, the pace of change has accelerated dramatically. While new information took an average of 17 years to be integrated into textbooks and guidelines in the early 2000s, discoveries are now rapidly adopted into practice [7]. Yet this transformation poses a new challenge: managing the exponential growth of medical knowledge that now unfolds faster than the human capacity for absorption.

THE ANATOMY OF MEDICAL THINKING: FROM GUT FEELINGS TO ORGANIC NEURAL NETWORKS

Unlike a purely logical or algorithmic process, clinical reasoning is dynamic, shaped by perception and inference. It develops in layers, each influenced by internal factors, such as knowledge, bias, and emotion, and external ones, including context, time, and access to resources. Even before a patient speaks their first word, the clinical gaze captures a range of unstructured information, such as how the patient enters the room or their posture when sitting. This initial perception exists at the intersection of intuition and technique, where every detail, no matter how subtle, becomes a potential piece in the diagnostic puzzle.

During anamnesis, the physician–patient dialogue is structured, with each question serving a distinct purpose [8]. Guided by emerging hypotheses, the physician tailors the interview in real time, asking precise questions without leading the patient and adjusting expectations as new information arises. This process goes beyond cataloging symptoms; it involves understanding how the patient perceives their condition within the narrative of their life.

Medicine is not a science of isolated facts but of context. Illness and suffering are shaped by both internal and external forces, so understanding a patient's life history, environment, cultural background, work dynamics, and socioeconomic conditions is essential. Moreover, human behavior is driven by complex, non-binary motivations, meaning a patient's report may not fully reflect their experience. Some may exaggerate out of fear of dismissal, while others downplay or conceal symptoms due to shame or anxiety, or even modify their narrative for secondary gains. Consequently, the physician must critically interpret not just what is said, but also how it is said and what is left unsaid, as every detail can shift the course of clinical reasoning.

After data collection, the delicate process of synthesis begins, balancing two extremes: overly broad reasoning that opens endless possibilities, leading to irrelevant hypotheses, unnecessary tests, and unwarranted interventions, and an overly narrow focus that risks dismissing critical diagnoses. The physician must walk this fine line, carefully weighing what to prioritize and what to set aside. Recognizing uncertainty is essential, as biology is seldom exact. The medical mind operates within layers of probability and judgment, constantly reassessing hypotheses as new information emerges, considering both the plausibility of each possibility and the potential impact of diagnostic errors. Beyond the application of algorithms, medicine is the art of recognizing patterns, interpreting narratives, and managing uncertainty to construct a logical thought process that adapts to the real

patient.

Refining clinical reasoning requires metacognition, a fundamental yet sometimes neglected process. The physician must actively monitor their own thinking, constantly questioning whether bias is unduly influencing decisions, prematurely discarding hypotheses, or succumbing to external pressures. This critical self-reflection safeguards against systematic errors and strengthens decision-making over time. Recognizing cognitive biases is essential: anchoring bias traps thinking in the first fitting diagnosis, availability bias overemphasizes recently encountered or common diseases, and confirmation bias leads clinicians to seek evidence that merely supports their initial hypothesis, all inherent to human thought. However, biases thrive in the absence of structured cognitive models.

External pressures also shape decision-making. Time constraints often favor speed over accuracy, cognitive overload and exhaustion impairs analytical depth, and clinical settings impose different cognitive demands. Emergency rooms prioritize rapid stabilization, while outpatient clinics allow for more deliberation. Yet, decision-making extends beyond rigid algorithms; it is a process of negotiation, where physicians propose, explain, and adapt, and patients, exercising autonomy, share their perspectives, limitations, and desires. The result is a plan that balances evidence with individual context.

Therefore, the greatest challenge to medical reasoning is not AI, but the stagnation of cognitive training. Physicians are trained in protocols and guidelines, which dictates "what to do", but receive little formal training in structured cognitive models that guide "how to think." Medicine has long relied on heuristics and experience, yet decision-making under uncertainty demands more: structured frameworks for interpreting risk, managing trade-offs, and adapting reasoning beyond rote memorization.

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON MEDICAL THINKING: COGNITIVE EXPANSION OR REDUCTION?

Artificial intelligence has been part of medical practice for decades, particularly through specialized systems designed to optimize diagnoses and improve the efficiency of physicians and researchers. Machine and deep learning algorithms analyze vast clinical, genomic, and epidemiological data to reveal hidden patterns and correlations. In radiology, AI improves diagnostic accuracy by detecting subtle anomalies that may elude even experienced clinicians, while AI-driven surveillance tracks disease outbreaks in real time. Its applications continue to expand, as AI surpasses human capabilities in pattern recognition, memory retrieval, and probability calculations using sophisticated multivariable models.

However, a turning point emerged with the widespread adoption of Large Language Models. Unlike earlier predictive algorithms that operated within rigid, pre-defined parameters, LLMs generate responses that mimic human reasoning, answering open-ended questions, analyzing clinical cases, and even suggesting diagnoses and treatments [9]. This evolution redefines the physician-technology relationship, but as these models shift from data-driven support to directly influencing patient treatment decisions, their use demands careful scrutiny [10]. AI does not "think" in the way humans do. It recognizes patterns, calculates probabilities, and predicts the most statistically probable outcome based on prior data. While this can resemble clinical reasoning, it lacks causal inference; it does not ask "why" something happens [11]. This distinction is fundamental in medicine, as a model may suggest a treatment based on past associations, but it does not grasp the underlying mechanisms or contextual trade-offs involved in patient care.

Unlike human thought, which is creative and capable of challenging assumptions and formulating novel hypotheses, LLMs cannot reassess their own assumptions or correct embedded biases. When training datasets contain distortions due to historical disparities, underrepresentation, or flawed methodologies, LLMs simply amplify these inaccuracies, presenting biased outputs as statistical truth. This is especially concerning in clinical decision-making, where reliance on flawed AI insights may exacerbate disparities, propagate medical inaccuracies, and compromise patient safety, further deepening global health inequities due to the underrepresentation of underserved regions in scientific data [12].

Clinical reasoning is not limited to a retrospective analysis of past data; it is a dynamic, adaptive process that integrates real-time observations, hypothesis testing, and situational judgment. This adaptability becomes particularly crucial in emerging clinical scenarios, resource-limited settings, or regions with unique sociocultural determinants of health. Doctors and scientists continually reassess and adjust their theories and decisions in response to new discoveries or real-world constraints. In contrast, LLMs generate responses based on pre-existing data within their training sets [13]. As a result, AI models trained on generalized datasets may produce recommendations that fail to account for specific patient populations, local epidemiological variations, or contextual barriers such as limited access to medications, diagnostic tools, and specialized care.

Another limitation of AI is its inability to assimilate unrecorded or deliberately adjusted elements, as clinical reasoning extends beyond explicit data; it relies on interpreting subtle cues that often go unregistered in formal records [14]. Moreover, AI often presents responses with an unwarranted level of confidence, creating an illusion of precision [15]. In contrast, experienced physicians recognize that uncertainty is intrinsic to clinical reasoning, continuously refining hypotheses as new

information emerges, and remain cautious about trusting algorithmic outputs when underlying data may be insufficient or unreflective of the patient's true condition.

Overestimating the role of AI, by delegating cognitive autonomy to it, means giving up functions that have long been exclusive to clinical reasoning, thereby weakening medical practice. Conversely, when used rationally, with a reflective and integrative approach, AI can serve as a catalyst for cognitive expansion, enhancing medical thinking by strengthening analytical and adaptive capabilities.

THE COGNITIVE STETHOSCOPE: HOW TO HEAR ACROSS AI'S PATTERNS

The integration of LLMs into medical practice is inevitable, but their impact will depend on how physicians choose to engage with them. The real danger is not just that AI can make mistakes, but that physicians may stop thinking critically, failing to question, refine, or override its suggestions when necessary, becoming passive validators rather than active decision-makers. However, when properly utilized, AI can strengthen medical reasoning, serving as a strategic tool to organize thought processes, reduce biases, and validate hypotheses, while preserving human judgment (Table 1).

AI contributes to clinical reasoning in distinct yet complementary ways. It can rapidly analyze vast datasets to highlight potential diagnoses, suggest additional differential diagnoses, and flag atypical findings that might be overlooked. Physicians, in turn, assess these AI-generated insights in clinical context, determining which hypotheses warrant further investigation based on severity, likelihood, and the patient's individual circumstances. AI can also quantify probabilities and model potential

outcomes, but physicians must interpret these results, weighing risk-benefit trade-offs, ethical considerations, and practical feasibility before proceeding with diagnostic tests or treatments.

Beyond diagnostics, AI enhances post-decision safety checks, flagging potential drug interactions, contraindications, and unintended side effects that might require patient monitoring. It can remind physicians of common adverse effects, such as postural hypotension after antihypertensive therapy, prompting proactive follow-up. However, the ultimate responsibility remains with the physician, who must integrate these insights with clinical intuition, patient preferences, and real-world complexities.

Additionally, AI streamlines administrative burdens, allowing physicians to focus more fully on the doctor-patient relationship. Once a case is documented, AI can assist with charting, generating reports, completing notification forms, and managing referrals, reducing the bureaucratic workload that often detracts from patient care. With AI handling routine tasks without compromising clinical autonomy, physicians can dedicate more time to listening, understanding, and engaging meaningfully with their patients.

Far from replacing the human element, AI can be an ally in restoring the focus on what has always been essential in medicine: the connection between physician and patient. The real opportunity does not lie in delegating decision-making to AI, but in integrating it strategically as a tool for critical reflection. Doubt must remain central to the physician-AI interaction, as the physician of the future will not be the one who merely consults AI for answers, but the one who knows when to trust it, when to challenge it, and, most importantly, when to think beyond it.

CONCLUSION

Throughout history, each technological advancement has transformed how physicians think and make decisions. However, no previous innovation has had the potential to reshape medical cognition as profoundly as artificial intelligence. Unlike traditional tools that solely gather information, AI structures clinical reasoning and influences decisions. This makes it both one of the most promising innovations in medicine and one of the greatest challenges to physicians' cognitive autonomy.

Medicine goes beyond a probabilistic exercise. It is a science intertwined with the art of care, perception, inference, critical judgment, and the flexibility to navigate uncertainty. In today's landscape, the use of AI in clinical practice demands active oversight and discernment, ensuring that it does not become a shortcut for clinical reasoning, but rather a tool to strengthen it. To be prepared for this new era, physicians must be aware of their critical capacity and their intrinsic value—the ability to recognize what an algorithm cannot predict: the unique complexity of another human being.

AUTHOR CONTRIBUTIONS

All authors wrote, made edits to and reviewed the manuscript, and approved the final version of the manuscript for submission.

DECLARATION OF INTERESTS

The authors declare no conflicts of interest.

REFERENCES

1. Clusmann J, Kolbinger FR, Muti HS, et al. The future landscape of large language models in medicine. *Commun Med*. 2023;3(1):1-8. doi:10.1038/s43856-023-00370-1
2. Hope B. The Greatest Benefit to Mankind: A Medical History of Humanity From Antiquity to the Present. *BMJ*. 1998;316(7132):713.

3. Tulchinsky TH. John Snow, Cholera, the Broad Street Pump; Waterborne Diseases Then and Now. *Case Studies in Public Health*. Published online 2018:77-99. doi:10.1016/B978-0-12-804571-8.00017-2
4. Waller J. The Discovery of the Germ: Twenty Years That Transformed the Way We Think About Disease. In: ; 2003. Accessed February 19, 2025. <https://www.semanticscholar.org/paper/The-Discovery-of-the-Germ%3A-Twenty-Years-That-the-We-Waller/f831069b55ebabfb122227a422763541f45deb76>
5. Barberis I, Bragazzi NL, Galluzzo L, Martini M. The history of tuberculosis: from the first historical records to the isolation of Koch's bacillus. *Journal of Preventive Medicine and Hygiene*. 2017;Vol 58:E8-E12 Pages. doi:10.15167/2421-4248/JPMH2017.58.1.728
6. Palella FJ, Delaney KM, Moorman AC, et al. Declining morbidity and mortality among patients with advanced human immunodeficiency virus infection. HIV Outpatient Study Investigators. *N Engl J Med*. 1998;338(13):853-860. doi:10.1056/NEJM199803263381301
7. Morris ZS, Wooding S, Grant J. The answer is 17 years, what is the question: understanding time lags in translational research. *J R Soc Med*. 2011;104(12):510-520. doi:10.1258/jrsm.2011.110180
8. Duffy FD. Dialogue: The Core Clinical Skill. *Ann Intern Med*. 1998;128(2):139-141. doi:10.7326/0003-4819-128-2-199801150-00011
9. Cascella M, Semeraro F, Montomoli J, Bellini V, Piazza O, Bignami E. The Breakthrough of Large Language Models Release for Medical Applications: 1-Year Timeline and Perspectives. *J Med Syst*. 2024;48(1):22. doi:10.1007/s10916-024-02045-3
10. Goh E, Gallo R, Hom J, et al. Large Language Model Influence on Diagnostic Reasoning: A Randomized Clinical Trial. *JAMA Netw Open*. 2024;7(10):e2440969. doi:10.1001/jamanetworkopen.2024.40969
11. Pearl J, Mackenzie D. *The Book of Why: The New Science of Cause and Effect*. First trade paperback edition. Basic Books; 2020.
12. Zack T, Lehman E, Suzgun M, et al. Assessing the potential of GPT-4 to perpetuate racial and gender biases in health care: a model evaluation study. *Lancet Digit Health*. 2024;6(1):e12-e22. doi:10.1016/S2589-7500(23)00225-X
13. Gao Y, Myers S, Chen S, et al. Uncertainty estimation in diagnosis generation from large language models: next-word probability is not pre-test probability. *JAMIA Open*. 2025;8(1):ooae154. doi:10.1093/jamiaopen/ooae154
14. Giordano C, Brennan M, Mohamed B, Rashidi P, Modave F, Tighe P. Accessing Artificial Intelligence for Clinical Decision-Making. *Front Digit Health*. 2021;3:645232. doi:10.3389/fdgth.2021.645232
15. Zhou K, Hwang JD, Ren X, Sap M. Relying on the Unreliable: The Impact of Language Models' Reluctance to Express Uncertainty. Published online 2024. doi:10.48550/ARXIV.2401.06730

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Table 1: Pitfalls and Successes in Physicians uses of AI for Clinical Reasoning

Aspect	Pitfalls	Successes
Initial Assessment	Ignores clinical cognitive skills, such as perception and inference	Enhances data gathering by structuring patient information efficiently.
Hypothesis Formation	Over-reliance on AI-generated differential diagnoses, potentially overlooking emergent situations or specific sociocultural context	Offers broad differential diagnosis lists, reducing cognitive fixation on a single hypothesis.
Decision-Making	Passive acceptance of AI recommendations without critical evaluation.	Supports evidence-based decision-making by providing up-to-date guidelines and treatment options.
Error Handling	Propagate biases from training data, leading to false confidence in incorrect conclusions.	Identifies inconsistencies, flags potential errors, and reduces biases.
Patient Engagement	Risk of depersonalization by automating interactions with patients or overuse during consultation	Automates administrative tasks, allowing more time for meaningful patient interactions.
Longitudinal Patient Management	Functions episodically, making decisions based on isolated encounters.	Tracks longitudinal health data, identifying patterns over time that might escape human observation.
Clinical Teaching & Medical Training	Overuse may hinder medical trainees from developing critical thinking and diagnostic intuition.	Functions as an adaptive learning tool, offering case-based scenarios, interactive feedback, and personalized study recommendations.
Ethical Decision-Making	Difficulty in aligning AI-driven recommendations with patient values, cultural considerations, and complex ethical dilemmas.	Summarizes ethical frameworks, guidelines, and case precedents to aid in ethical deliberation.
AI in Emergency & High-Stakes Situations	May slow or misguide decisions in novel or rapidly evolving emergencies due to lack of data.	AI-driven alerts and decision-support systems can enhance rapid response in critical care and emergency medicine.

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