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RESEARCH ARTICLE

The Logical-Methodological Potential Of Avicenna In The Era Of Digital Technologies: Rethinking "The Canon Of Medicine"

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Abstract

This paper is devoted to the study of the logical-methodological potential of the medical system of Abu Ali ibn Sina (Avicenna, 980–1037) and his fundamental work "The Canon of Medicine" in the context of the modern digital transformation of medicine. The purpose of the study is to identify the structural and functional homology between Avicenna's logical methods — syllogistics, deductive-inductive argumentation, taxonomic classification, causal analysis — and the principles of constructing modern algorithmic systems, including artificial intelligence (AI), decision support systems, and methods of big data analysis in medicine.

KEYWORDS

Ibn Sina, Avicenna, "The Canon of Medicine," logic in medicine, syllogistics, algorithmic thinking, artificial intelligence in medicine, digital healthcare, history of medicine, philosophy of medicine.

INTRODUCTION

The digital transformation of modern medicine represents one of the most significant epistemological shifts in the history of medical knowledge. The application of methods of machine learning, neural networks, clinical decision support systems, and genomic data analysis poses a fundamental question for the philosophy of medicine: is the algorithmization of medical thinking a radically new phenomenon, or does it reproduce logical structures that were already implicitly present in classical medical theory?

This paper argues that Avicenna's "The Canon of Medicine" — the most systematized medical treatise of the pre-industrial era — contains a developed logical-methodological architecture that is structurally homologous to the principles of constructing modern diagnostic algorithms. This makes it possible to consider Avicenna not merely as an outstanding medieval physician, but as a methodologist of medical knowledge who anticipated the formal requirements for algorithmically organized clinical reasoning.

The relevance of the study is determined by two circumstances. First, the rapid introduction of AI into clinical practice creates a need for a historical-philosophical understanding of the foundations of medical rationality. Second, despite the abundance of works on the history of Avicennian medicine, its logical-structural aspect in comparison with digital technologies remains practically unexplored. The present paper is intended to fill this gap.

The research problem is formulated as follows: to what extent do the logical principles underlying "The Canon of Medicine" correspond to the formal characteristics of algorithmic systems of clinical decision-making, and what does this correspondence say about the nature of medical knowledge as such?

The study of Avicenna's logic has a long tradition in European and Arab-Islamic philosophy. The classical works of J. Rescher and D. Gutas laid the foundations for the critical analysis of Avicennian syllogistics in its relation to the Aristotelian tradition. A. I. Sabra showed that Avicenna substantially modified Aristotelian logic, giving it a greater operational orientation as applied to medical argumentation. The works of L. E. Goodman and M. E. Marmura reveal the epistemological foundations of Avicennian natural philosophy.

In the field of the history of medicine, N. G. Siraisi's study devoted to the reception of the "Canon" in medieval Europe remains fundamental. Modern works in the philosophy of medicine — above all those of K. W. M. Fulford and T. Schramme — raise the question of the nature of clinical reasoning as a special form of logical activity.

In parallel, an extensive literature on AI and clinical decision-making systems has developed: from the pioneering MYCIN system to modern architectures based on transformer language models. However, no systematic comparison of Avicennian medical logic with the principles of constructing these systems has been presented in the existing literature. The present paper fills this gap by proposing an original comparative-methodological framework.

The theoretical basis of the study is structuralism as applied to the history of science, I. Lakatos's concept of "research programmes," as well as the ontology of medical knowledge of C. Boorse and I. Kagal, which distinguishes between the descriptive and normative components of clinical judgment.

"The Canon of Medicine" opens with a fundamentally important methodological statement: medicine is a science (ilm) that cognizes the states of the human body from the standpoint of health and disease; it is a science, not a craft. This distinction has far-reaching epistemological consequences. By insisting on the scientific status of medicine, Avicenna thereby requires medical knowledge to satisfy the criteria of apodictic demonstrability, that is, to be derived with necessity from reliable principles.

The structure of the "Canon" reflects this attitude. The first book lays the theoretical foundations: the doctrine of natures (tabā'i), elements (uṣūl), temperaments (mizāj), organs, and vital forces. The second book is devoted to materia medica — the systematic classification of medicinal substances according to their properties and application. The third and fourth books cover pathology from head to toe (a capite ad calcem), and the fifth covers compound medicinal preparations. This architecture is not accidental: it reproduces the structure of Aristotle's "Posterior Analytics" — from general principles through middle terms to particular conclusions.

It is fundamentally important that Avicenna builds medical taxonomy on the basis of essential features rather than superficial observations. The classification of diseases in the "Canon" is organized according to the principle of dichotomous division (divisio per dichotomiam): each concept is consistently divided into species according to a single differentiating feature. This method, going back to Platonic diairesis and Aristotle's theory of definition, represents a direct logical predecessor of tree-like classification structures in modern medical ontologies: ICD-11, SNOMED CT.

Avicenna's diagnostic methodology is based on strict syllogistics. In the first book of the "Canon," he formulates a general principle: "Signs are what is found in the body and indicates its state; they may be manifest or hidden, constant or variable." This provision structures diagnosis as an inference from effect to cause: the physician observes symptoms, the minor premise, correlates them with the classification of diseases, the major premise, and arrives at a diagnosis, the conclusion.

A specific example from the first book of the "Canon" is illustrative: the diagnosis of fever. "If we see that the patient experiences heat, thirst, and a rapid pulse, and if we know that the combination of these signs necessarily accompanies inflammatory fever (humma warami), then we conclude that this patient suffers from inflammatory fever." The formal scheme here fully corresponds to the first figure of the Aristotelian syllogism, Barbara: if S is M, and M is P, then S is P.

It is methodologically significant that Avicenna systematically introduces the concept of sufficient reason for diagnostic judgment. He distinguishes between "pathognomonic" signs, specific only to a given disease, and "general" signs, occurring in several diseases, which corresponds to the modern distinction between the specificity and sensitivity of a diagnostic test — key metrics of modern evidence-based medicine.

The doctrine of causality occupies a central place in the methodology of the "Canon." Avicenna applies the Aristotelian doctrine of four causes — material (sabab māddī), formal (sabab ṣūrī), efficient (sabab fā'il), and final (sabab ghā'ī) —

to the structure of medical explanation. In application to diagnosis, this means that a full medical explanation of a disease must describe its substrate, the affected organ or humoral substrate, its form, the specific nature of the disorder, its producing cause, the external or internal influence that disturbed the balance, and its telos, deviation from the norm of health as the target state of the organism.

This multilevel causal scheme is not merely a philosophical tribute to tradition. In the third book of the "Canon," devoted to diseases of specific organs, Avicenna consistently applies it to each pathological condition: for example, in describing ophthalmia, inflammation of the eyes, he distinguishes the material cause, excess hot moisture, the efficient cause, external irritation or overstrain, and the formal cause, disturbance of the transparency of the membranes. Such a structure of reasoning corresponds to the principle of multifactorial etiology underlying modern clinical protocols of differential diagnosis.

Also noteworthy is the chapter of the "Canon" devoted to the study of the pulse. Avicenna describes dozens of pulse varieties, systematizing them according to the parameters of strength, rhythmicity, frequency, and fullness. This is not merely a taxonomy: each type of pulse is correlated with a specific etiological profile, forming a system of "if–then" rules structurally identical to the production rules of expert systems.

Digital medicine is a set of technologies that transform medical knowledge into executable computational procedures. Among the key areas, the following are distinguished.

Clinical decision support systems (CDSS) are software complexes that formalize clinical knowledge in the form of rule bases or statistical models and provide recommendations based on patient data. The pioneering MYCIN system (Shortliffe, 1976) implemented the diagnosis of bacterial infections through approximately 500 production rules of the type "IF [symptoms] THEN [diagnosis] with probability P." This is a direct structural analogue of Avicennian diagnostic inferences formalized as computable operations.

Machine learning and neural networks make it possible to identify latent patterns in arrays of clinical data that exceed the possibilities of explicit logical description. Systems based on convolutional neural networks demonstrate accuracy comparable to that of expert dermatologists in recognizing malignant neoplasms from images. Transformer language models applied to electronic medical records make it possible to predict clinical outcomes and generate differential diagnoses.

Big data analysis in genomics, metabolomics, and pharmacogenomics opens up opportunities for personalized medicine. Here, the key tool becomes the identification of causal relationships between molecular markers and clinical phenotypes — a task structurally analogous to the Avicennian search for the "efficient causes" of disease.

Medical ontologies and knowledge representation standards — SNOMED CT, ICD-11, HL7 FHIR — formalize medical concepts and their relationships in the form of formal hierarchies that allow machine processing. These ontologies reproduce, in executable form, precisely the type of hierarchical taxonomy that Avicenna constructed in the "Canon" by means of Aristotelian logic.

The comparison of Avicennian medical logic with the principles of digital diagnostic systems reveals several levels of structural homology.

The first level is deductive-production structures. Avicenna's syllogistic inferences — "major premise, the general law of disease → minor premise, the signs of this patient → diagnosis" — are structurally isomorphic to the production rules of expert systems: "IF [condition] THEN [conclusion]." The key difference is that in Avicenna these rules are expressed in the natural language of Arabic-language science, whereas in CDSS they are codified in formal languages of knowledge representation. However, the logical form of reasoning is invariant.

The second level is taxonomic architecture. Avicenna's classification of diseases, medicinal substances, and symptoms is built on the principle of hierarchical division according to essential features. This structure is isomorphic to modern medical ontologies organized in the form of directed acyclic graphs. In both cases, the goal is to provide a machine-processable or mentally processable representation of medical knowledge that ensures navigation from class to subclass and from symptom to diagnosis.

The third level is parametric diagnosis. Avicenna's systematization of the pulse according to several independent parameters — strength, rhythm, frequency, and fullness — represents a direct analogue of multidimensional clinical monitoring in modern information systems of intensive care. The principle of processing several simultaneous variables in order to establish a diagnostic cluster is present in both systems.

The fourth level is uncertainty management. Avicenna does not ignore the problem of ambiguity of clinical signs: he systematically distinguishes between "pathognomonic" and "general" symptoms, recognizes that the same signs may indicate different diseases, and recommends taking into account contextual factors such as age, sex, constitution, climate, and season. This strategy of contextually weighted reasoning is reproduced in modern Bayesian networks and fuzzy logic systems used in medical diagnostics.

At the same time, the differences are no less significant than the similarities. The Avicennian system was built on the qualitative physics of humoral medicine; its "major premises" — statements about the nature of temperaments, elements, and vital forces — were not verified in the sense of modern experimental science. Modern algorithms, by contrast, are trained on empirical data and evaluated according to statistical metrics. Nevertheless, this difference concerns the content of knowledge, not its formal-logical structure. That is why the comparison is legitimate: it is conducted at the level of logical architecture, not ontological content.

The proposed comparison raises a number of fundamental questions requiring methodological reflection.

The first question concerns the limits of analogy. The structural similarity between Avicennian syllogistics and algorithmic systems does not mean identity. Avicenna did not possess the formalism of Boolean algebra, probability theory, or the concept of an algorithm in the Turing sense. His "programs" existed in the form of natural-language texts interpreted and executed by a trained physician. This is a fundamentally important limitation: the human interpreter is an integral link in the Avicennian diagnostic "system," whereas digital algorithms allow automatic execution.

The second question concerns the nature of medical knowledge. The homology between Avicennian methodology and digital algorithms indicates that certain logical structures are invariants of rational medical thinking, regardless of their specific technological embodiment. This observation is significant for the philosophy of medicine: it confirms the thesis that clinical reasoning is essentially a formal, that is, logically structured, activity, and not exclusively an intuitive "art."

The third question concerns interpretive risks. There is a temptation to "modernize" Avicenna by attributing to him categories that were fundamentally inaccessible to him. This study avoids this danger by limiting itself to the analysis of formal-logical structures and clearly distinguishing them from the ontological and epistemological content of specific theories. Avicenna "anticipated" AI not in the sense that he foresaw specific technologies, but in the sense that his methodology for producing medical knowledge satisfied the same formal criteria that we today apply to algorithmic systems.

The fourth question is related to the ethical dimension of the problem. Contemporary discussions about the responsibility of algorithmic diagnostic systems, their "explainability," and the epistemic status of their recommendations partially reproduce the questions that Avicenna raised in relation to the status of medical knowledge as such. His insistence on apodictic, evidence-based medicine is a requirement that the modern regulatory environment reproduces in the form of standards for clinical trials and certification of medical AI systems.

The analysis carried out allows the following conclusions to be formulated.

First, "The Canon of Medicine" contains a developed logical-methodological system based on Aristotelian syllogistics, dichotomous taxonomy, and multilevel causal analysis. This system is not a decorative philosophical framework: it structurally determines the way medical knowledge is produced and applied in the "Canon."

Second, there is a structural homology between the logical principles of Avicennian diagnosis and the formal principles of constructing modern algorithmic medical systems at four levels: deductive-production structures, taxonomic architecture, parametric multidimensionality, and uncertainty-management strategies.

Third, Avicenna can legitimately be regarded as a methodological precursor of algorithmic thinking in medicine — in the strict sense of structural correspondence, not historical teleology. His contribution consists in creating the first systematic formal methodology of clinical reasoning in the history of medicine.

Fourth, the historical-philosophical understanding of Avicennian methodology in light of digital medicine opens prospects for a deeper understanding of the nature of clinical reasoning as such — its formal invariants and historically changing ontological assumptions.

Prospects for further research include a detailed analysis of the correspondence between specific diagnostic algorithms of the "Canon" and the ontological structures of modern medical information systems; a comparison of Avicennian methodology with other classical medical systems, such as Galenic, Ayurvedic, and Chinese systems, from the point of view of their "algorithmic readiness"; and the development of educational programs integrating the historical-methodological dimension into the training of developers of medical AI systems.

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