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Redefining healthcare - The transformative power of generative AI in modern medicine

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Abstract

Over the last decade, technological advances in deep learning (artificial neural networks, big data and computing power) have made possible to build digital solutions that imitate human cognitive process (language, vision, hearing, etc) and are able to generate new content when prompted. This generative AI is going to disrupt healthcare. Healthcare professionals must get prepared because there are ethical and legal challenges that must be identified and tackled.

Keywords: AI. GenAI. Healthcare. Research. Education. Teaching. Care delivery. Management.

In 1950, shortly after the National Health Service was launched, Alan Turing published (1) what can be considered the foundation of what we now call artificial intelligence (AI), even though the term itself was coined five years later by a group of American researchers for a summer workshop at Dartmouth College (2). Inspired by the first chapter of Turing's work, "The Imitation Game," (1) AI can be defined as the ability of machines to mimic the cognitive processes and actions of the human brain. More specifically, generative AI consists of machine learning solutions that create new content based on large training datasets, simulating broad language-processing capabilities (3).

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If there is one sector that has an intensive and infinite demand for data processing and management capacity, it is healthcare. Generating knowledge, sharing it, incorporating it into clinical practice and care, and ultimately managing all this activity is central to modern societies. Since the scientific revolution some 500 years ago, it has been widely assumed that with more data, and better ways to convert these data into information and then into knowledge, we will be able to understand biological dysfunction more effectively. Consequently, we come closer to solving two issues that have obsessed us ever since humans became self-aware: disease and death.

Despite the advances in technology over the past decade (neural networks, big data, and vast computing power) enabling machines to think, see, or speak like humans, a new problem has emerged. We are redefining modern medicine but do not know who will prevail in this changing landscape (4). Will machines help us, deceive us, bias us, or simply replace us? Ever watched Star Wars? It shows that our collective imagination is drawn to AI that does what we do, only better: flawless and precise. How many human doctors are shown in that galaxy? None. This cinematic example might seem trivial if our species was not so adept at turning dreams into reality.

When we talk about redefining healthcare systems, three pillars come into play: business models, culture, and disruptive technology (5). Generative AI, at the forefront of such disruption, compels us to question how healthcare processes are organized, how professionals are educated, and which values should guide these transformations. We still think in terms of production (“more equals better”). To understand the current situation, it is crucial to explore the technological foundations of generative AI first, then examine its applications in research, education, clinical practice, and management, before finally turning to the ethical implications, risks, and challenges it poses.

Technological foundations

Generative AI is based on the principle of learning patterns from massive datasets and then producing new content that follows these patterns in a coherent way (6). Deep

neural networks, trained with advanced optimization techniques, drive much of this progress. One important approach involves large language models built on transformer architectures, which have demonstrated remarkable skills in reading and producing human language. By learning from big data, these models can predict the next word in a sentence and, through that ability, write entire paragraphs, answer questions, and summarize information.

Generative Adversarial Networks (GANs) have also attracted attention, employing two sub-models—generator and discriminator—that improve through competition. The generator produces new content, while the discriminator judges its authenticity, thus refining both components in the process. This results in increasingly sophisticated and realistic content, including images (Fig 1), audio, and text. Another line of research relies on diffusion models, widely used for image generation, which progressively remove noise from data until they yield high-fidelity, detailed results.

Big technology companies and research centers that control powerful hardware infrastructures, as well as massive datasets, are in the best position to develop highly effective models. Yet this leads to several concerns, including heavy dependence on major tech players, questions about data quality, privacy, security, and how these tools might impact both the business model and culture of healthcare organizations.

Use Cases

One should consider that this technology breaks silos down and can be applied across the entire healthcare value chain (4,7-9). In research, it can formulate new hypotheses by combining insights from scientific articles and clinical data, potentially uncovering novel causes of diseases or interactions among therapies. It can also propose experimental designs that maximize the likelihood of making a meaningful discovery, or help synthesize and review the literature, consolidating scattered data into coherent reviews more efficiently.

In education, AI-driven tools can generate specialized materials tailored to the learner's level, providing automated feedback, and identifying weaknesses (9). These

same technologies can enhance virtual-reality simulations, where students practice clinical scenarios in a realistic environment. Immediate feedback, guided by AI-based algorithms, helps learners refine clinical decision-making and improves the overall training process. It can also transform the way knowledge acquisition and skills are assessed.

Within clinical practice (4,7), generative AI can provide diagnostic support by detecting subtle patterns in medical images, including X-rays and MRIs, or in laboratory results. It can suggest treatment plans customized to a patient's genetic and clinical profile, offering greater accuracy by identifying relevant risk factors. Moreover, these systems can assist in decision-making by supplying predictive models that forecast patient evolution under different treatment options. The goal is not to replace medical professionals but to offer them advanced tools for managing vast amounts of information. In the administrative sphere, AI can be employed to predict patient influx in emergency departments, helping optimize staff and resource allocation; it can also automate documentation and monitor compliance with clinical protocols, driving higher quality and safety standards.

Ethical implications, risks, and challenges

Integrating such powerful tools into healthcare calls for thorough ethical reflection (4,7-9). One major issue is privacy and confidentiality: large training models trained on clinical data run the risk of re-identifying individuals, breaching medical confidentiality. Legal frameworks and reliable anonymization and encryption techniques are therefore essential.

Bias is another important concern, since any skew in the training dataset—be it demographic, ethnic, or socio-economic—can lead to discriminatory outcomes. Ensuring fairness means carefully auditing the data used and constantly monitoring results (10). Further, the question of responsibility arises: when a diagnosis aided by AI is incorrect, who is accountable? It becomes necessary to redefine liability and set clear boundaries around algorithmic autonomy. This redefinition could have profound implications for the way professionals practice medicine, or the skills needed to excel

in healthcare in the future.

A growing concern in healthcare is the proliferation of “shadow AI,” (11) where staff or departments adopt AI tools without official approval, oversight, or proper integration into hospital systems. This can happen, for instance, when clinicians use freely available diagnostic apps or unauthorized software to process patient data. Such unregulated use poses significant privacy, liability, and quality risks. Data might be uploaded to unsecured servers, algorithms could be trained on biased datasets, or clinical advice might not meet established professional standards. In many cases, decision-makers and IT departments are unaware of these clandestine deployments, so problems only surface after adverse events or data breaches occur.

Meanwhile, many traditional tasks could be replaced or radically transformed (12,13). Although complete substitution of human clinicians is still far from certain, new roles and job profiles will emerge, requiring different competencies than those currently emphasized. Dependence on complex technology and high infrastructure costs could potentially hand over significant control to major corporations, which may influence public healthcare systems and small providers who cannot afford the same scale.

Conclusion

The digital revolution, propelled by generative AI, is reshaping society from the ground up, and healthcare is no exception. We are moving from a model in which professionals have relied on experience, the scientific method, and collective evidence over decades, to an environment in which data analytics and sophisticated algorithms augment human judgment. Although this transition promises major benefits, including the possibility of more accurate diagnoses, personalized treatments, and efficient resource management, it also brings risks that need careful consideration.

On one hand, we are driven by the desire to conquer disease and extend healthy life spans, using every technological advantage available. On the other, healthcare is fundamentally human, built on trust, empathy, and ethical considerations that go beyond statistical probabilities. The biggest challenge, then, is to integrate generative

AI without losing sight of the patient-clinician relationship. The goal is to ensure technology remains a tool that amplifies human expertise, rather than a mechanism that marginalizes it. And let's not forget that over 5 billion people do not have access to safe care globally (14).

Generative AI's incorporation into medicine seems inevitable. As a result, healthcare professionals, administrators, policymakers, and society at large must participate in shaping how this transition is handled. We should envision a future where AI can generate scientific hypotheses, tailor treatments, and improve resource allocation, while keeping human-centered values—compassion, responsibility, and equity—at the core of healthcare. Achieving this balance will determine whether this digital revolution evolves into a sustainable, ethical, and transformative improvement for all.

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Figure 1. A hyperrealistic image of a male surgeon and a female surgeon in an operating room with motion blur effect. They are wearing blue surgical gowns. Image generated with a generative AI application (Dall-e, OpenAI, USA).