Medicine, Health Care and Philosophy (2022) 25:165–166
https://doi.org/10.1007/s11019-022-10080-5

EDITORIAL

Medicine and machines

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Published online: 2 April 2022

Future medicine will be personalized and democratized because patients will manage their own care and make decisions about medical interventions with the assistance of artificial intelligence and robots. Medical care will no longer be controlled by physicians or medical experts. In the future, human beings will be digitized; everybody's genetic constitution will be known and digitally accessible so that precise and individualized care will be offered by robots. This prophetic vision of medicine is promulgated by Eric Topol, the Director of the Scripps Translational Science Institute in the United States. He argues that the current medical system is archaic, wasteful and should be creatively destructed since it does not draw on the advantages of information technology, social media, and artificial intelligence (Topol 2013). In contrast, the new medicine is participatory and democratic since it will empower individuals to manage their own health and illness, and this will emancipate medical consumers from the conservatism of medical professionals (Topol 2015). This vision seems to reactivate the ancient ideal of everybody being his or her own doctor, which was a prudent response as long as medicine was potentially harmful and not therapeutically effective.

Already, social networks, internet search engines, and smart machines generate so much information that health professionals no longer are the exclusive source of medical knowledge. Artificial intelligence and smart machines perform many medical functions faster and more efficiently than physicians. For example, deep learning algorithms accurately diagnose the presence or absence of tuberculosis in chest X-ray images, thus facilitating screening in areas where radiologists are not available. Artificial intelligence and machine learning are extensively used in drug discovery and vaccine design. The Covid-19 pandemic has only accelerated the application of smart machines and algorithms in health care and medical research (Arora et al. 2021; Lv et al. 2021).

When Donald Longmere published *Machines in medicine* in 1970 he listed 125 machines used by the medical profession, such as the electrocardiograph. A review in the *Archives of Internal Medicine* does not recommend the book for physicians, although it concedes that the book might provide beginning medical students some orientation into the use of machines in present and future medical practice (Auerbach 1971). Today, the assessment has drastically changed. Not merely have the number and type of machines multiplied, but they are significantly transforming the practice of healthcare as well as the role of the health professional.

Several contributions in this issue discuss the implications of these transformations. Funer (2022) shows how machine learning algorithms might produce automated recommendations for diagnosis and treatment to the physician in charge, making medical interventions more accurate and tailored to the individual patient, trimming down subjective bias, and thereby reducing harms and side effects. However, to problematize the view that machine learning provides a higher degree of certainty, accuracy, and reliability, Funer engages an epistemological argument. The expertise of the physician who is responsible for diagnosis, therapy and care of an individual patient is not simply the application of empirical and objective data but requires the interpretation of the relevancy of medical knowledge for the concrete individual patient. The physician has to deliberate with the patient, mediating between existing knowledge and the patient's values, thus empowering the patient to decide what to do. Algorithms provide generalizations, categorizations, and probabilistic evidence which are often characterized by 'epistemic opacity', as the reasons and justifications for the recommendations are not transparent. While machine learning recommendations suggest certainty and accuracy, the physician still has to explain and interpret them, and engage in deliberative communication with the patient, explaining and justifying his or her own advice. In this deliberative

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process of shared decision-making the fundamental uncertainty of medical practice cannot be eliminated. Funer concludes that as long as machine learning outcomes are not transparent they are problematic, since individual doctors and patients cannot automatically interpret and evaluate the recommendations provided and thus take responsibility for decisions. However, one can also conclude that the wealth of machine generated knowledge has fundamental implications for medical education. Since physicians are no longer exclusive sources of information, their role as humanistic and empathic providers of care becomes all the more important (Wartman 2021).

In their contribution to this issue Van Meenen et al. (2022) argue that scientific publications should be tailored so that they can be assessed, investigated, and catalogued by machines. This is unavoidable since the number of publications has become unmanageable to keep up for individual researchers. The plethora of information is only comprehensible if machine-based analytical systems inspect, analyze and interpret research findings. This can be achieved if manuscripts are also written for non-human readers. But then manuscripts should be structured in specific ways with similar styles and formats that facilitate readability by machines. It is not clear whether this proposal can be implemented for all disciplines. In this journal for example we do not prescribe the Introduction, Methods, Results, and Discussion (IMRaD) format. It is clear, however, that the proposal focuses primarily on research producing empirical data rather than theoretical studies exploring concepts and ideas. The effort to make scientific literature accessible to machines raises in another way similar questions as posed by Funer (2022). When machines 'read' publications, and produce analyses and interpretations, will it be transparent what reasons, justifications, and values guide the products?

In 2015 US President Obama launched the precision medicine initiative, employing AI to analyze large datasets to optimize diagnosis, therapy and prognosis and to offer tailored intervention to individual patients. As Fleck (2022) demonstrates in this issue, precision medicine increasingly produces targeted therapies, for example in the area of metastatic cancer. Generally, however, such therapies are extraordinarily expensive while the benefits in terms of life expectancy and quality of life are often marginal. As machines expedite the development of targeted drugs, humans are increasingly confronted with critical choices regarding the provision of such therapies, making it more and more challenging to uphold a commitment to solidarity and equal access to health care. Smart machines rapidly produce diagnostic and therapeutic recommendations, more accessible scientific information, and innovative, targeted drugs but their interpretation and application continue to require human, and thus normative deliberation.

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