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Algorithms

Public debate needed on the limits and opportunities of technological developments in medicine

- Algorithms and artificial intelligence are changing health care – at a rapidly increasing pace
- New technologies can significantly improve medicine and help make the use of resources more efficient
- The use of machine-reading technology also raises fundamental ethical questions and demands new regulatory requirements
- We need a public debate on the potential pros and cons of technological change and how to deal with it
- Proactive health policies with impact should draw upon public debate

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Much of the public discussion of artificial intelligence (AI) in medicine shifts back and forth between hope, hype and fear. Hopes rest on the idea that physicians and researchers can detect diseases much earlier and more precisely than before, and that medications can be developed more quickly. The hype is driven by the regular reference to "supercomputer" systems in headlines. And the fear is that computers could one day replace physicians – leaving patients to rely on a machine's diagnosis.

However, the use of digital support for physicians is nothing new. Algorithms have long been used in medicine – for example in triage software applied to assess incoming patients in the emergency room. Algorithms and the use of artificial intelligence clearly have the potential to improve both health care and treatment processes significantly and to facilitate a more efficient use of resources. Nevertheless, many people view their application in the field of medicine with skepticism, and for a variety of reasons. Due to the at times intransparent or seemingly incomprehensible processes these machines use and the considerable impact on decisions they can have, many people, including experts, feel at unease with the use of AI.

Many patients are for good reason concerned that computers can only provide general recommendations that do not take into account their individual situation and personal needs. But physicians, too, are often skeptical of the progress made in the development of algorithmic systems – particularly when it's difficult to determine which data basis a result derives from and whether the result is plausible and free of errors.

Being able to contextualize the issues at hand is essential if we are to hold a fact-driven public debate on the topic that focuses on leveraging the opportunities AI provides. With this goal in mind, the ceres research institute, headed by ethicist Christiane Woopen, was commissioned by the Bertelsmann Stiftung to conduct an exploratory analysis of the use of algorithms in digital healthcare. The analysis focused on the following questions:

> "We need to discuss what we expect from a digitalized healthcare system. How much in the way of resources do we as a society want to invest in prevention? What price are we willing to pay for medical advances?"
>
> Prof. Dr. Christiane Woopen, ceres, University of Cologne

- In which areas of healthcare are algorithms currently used and will be used in the future?
- What improvements are expected from the use of algorithms?
- What new challenges does their use involve for individuals, institutions and society?

The results summarized in this issue of Spotlight show: We need a public debate about the potential positive and negative effects of the use of algorithms in medicine and on the future-oriented design of digital health care.

Rapid pace of technological development

The pace at which new technologies in medicine are developing is rapid. There are developments on the horizon that have the potential to radically alter healthcare. Yet there are algorithms already in use or being tested in several areas. A recently published and widely regarded German study showed that AI performed better in the diagnosis of black skin cancer than 136 of 157 dermatologists from twelve German university hospitals. And in 2017, the journal Nature published a study on an artificial neural network for the digital detection of skin cancer: In a test, researchers at Stanford University presented 370 photos of skin changes to an adaptive algorithm and 21 experienced U.S. dermatologists – with the result that the AI and physicians performed equally well in diagnosing

Opportunities and challenges involving algorithms in healthcare

Opportunities	Challenges
Improves the early detection of diseases	Not a substitute for human judgment Lacks differentiation between correlation and causation
Faster, more accurate diagnoses	Lack of control if processes proceed automatically (black-box effect) Safety risks due to complexity and lack of transparency
Improved safety standards	Makes assuming responsibility more difficult
Therapies tailored to individual patients	Promotion of automatism & threat to right to self-determination
Increased efficiency and cost-effectiveness and reduction of burden on med. staffers	Bias risks related to how threshold levels are set Bias risks from insufficiently large underlying dataset
Less susceptible to error than human actors (increased patient safety)	Re-identification produces threat to informational self-determination rights Risk of data theft and data misuse
Discovery of correlations in massive quantities of data for the purposes of generating hypotheses, with ultimate goal of identifying causalities	New professional demands on healthcare actors

Figure 1 BertelsmannStiftung

Ethically relevant levels

Individual level
The individual actor – the individual affected person

Institutional level
Design and organization of framework conditions

Societal level
Political and legal decisions, social and cultural impact

Term definitions

An **algorithm** is a procedure designed to solve a problem that involves a finite set of clear instructions and executable tasks. To calculate a solution, algorithms (which are increasingly reproduced on computers) require specific information (data) and concrete instructions for actions to be taken (code / program).

Artificial intelligence (AI) is a field within computer science aimed at emulating human approaches to problem-solving on computers.

Machine learning is based on the idea of gaining knowledge from experience: Machine-learning algorithms can help us identify complex relationships within large amounts of data without having to program each individual computational step. Instead, a computer receives sample data from which it then derives a generalized rule.

skin cancer. Prof. Axel Hauschild, head of the Dermatological Oncology working group at the Universitäts-Hautklinik in Kiel, Germany characterized the study as a "sensation that every dermatologist should be aware of."

Particularly in the area of diagnostics, we see several examples in which algorithms and AI can be applied. In many cases, the use of technology involves being able to identify specific patterns more quickly while at the same time reducing the error rate. Typical scenarios involve radiology examinations: The technology is intended to help radiologists manage their growing workloads without sacrificing quality. The sheer volume of millions and millions of clinical image data makes it possible to develop adaptive algorithms that can identify – in a matter of seconds – metastasizing tumors, hemorrhages, calcified coronary vessels or even malignant skin alterations.

But algorithms are also already being used in other areas of medicine, for example in prevention, therapy and healthcare research (see box). All these applications have one thing in common: In ethical terms, they areneither good nor bad per se. Their moral value or ethical significance must

Areas in which algorithms can be applied – a selection

Public health: Systems that identify prescription errors and draw on patient data to warn physicians of certain risks associated with a medication.

Healthcare provision processes/health services research: Quality management systems collect patient and prescription data, generating automated reports as feedback to physicians and caregivers.

Medical research: Search algorithms evaluate available Patient Registers and identify research-relevant health events in patient populations.

Prevention: Inpatient monitoring systems use AI technology to monitor patient's vital signs and provide an early warning of potentially life-threatening situations.

Prediction / Risk profiling: Smartwatch applications combine an ECG device with AI analysis to monitor heart activity and detect potential heart disease or cardiac arrhythmia.

Diagnostic procedures: Radiology support systems automatically analyze CT scans for a variety of diagnostic results and, if required, forward the data in real time to physicians or hospital systems.

Therapeutic procedures: Specifically designed applications continuously send blood-sugar levels to diabetes patients' smartphones by means of a subcutaneous sensor. The algorithm recognizes patterns in changing levels that occur, for example, during certain physical activities.

Rehabilitation: A bicycle ergometer for Parkinson's patients uses an algorithm to automatically analyses their speed and provides real-time acoustic feedback in the form of music, which helps patients maintain a steady pace.

Nursing care: Algorithm-controlled systems in residential communities for senior citizens use sensors to register outliers in the daily routine of residents and warn nursing staff.

be evaluated in the context of their applications and functions.

Our assessment shows that the development and use of algorithms in healthcare arise different types of opportunities and challenges at three levels of ethical consideration: personal, institutional and societal.

Ethical questions for individuals, institutions and society

As individuals, patients can benefit from the improved diagnostic possibilities. The price they may have to pay for this, however, is the surrender of their personal health data. In this case, it's not only the patients who are asked to make a decision. Healthcare professionals are also called upon to carefully weigh the value of different things – such as healthy well-being against the protection of privacy. They must ensure that the rights of patients are respected – and enable them to make informed choices.

There are also a number of new responsibilities at state level: In many areas, governments must take action to create the conditions needed to ensure that health-relevant data is properly processed and used to achieve high standards in healthcare.

If at some point AI can detect skin cancer better than a dermatologist – will it be necessary to train specialists in detecting malignant alterations? Educational institutions thus bear the responsibility for developing curricula that ensures that specialists are able to use algorithm-based systems, as well as monitor and interpret their automatically generated results. This kind of approach also helps counter the concerns of many physicians for whom AI still represents a black box of sorts.

Similarly, institutions are called upon to address legally relevant questions such as those regarding

Almost every

2.7

minutes a new publication in cardiology is published. Without machine support, it's increasingly difficult for medical to keep track of the current state of medic al knowledge.

57%

Germans believe that artificial intelligence can improve diagnostic procedures

> "Physician-patient interaction must always be human-human interaction."
>
> Dr. Thomas Kriedel, Member of the Board of the German National Association of Statutory Health Insurance

responsibility when mistakes are made: What happens if an algorithm makes a mistake? Are the programmers responsible for the mistake? Or should the physician using the algorithm be held responsible?

We need public debate and democratically legitimized solutions

Similar questions must be discussed and answered at the socio-political level, for example when it comes to defining the goal and purpose of the development of algorithms. Should the use of algorithms reduce healthcare costs? Should they also serve commercial purposes? And how do we deal with the fact that algorithms can entail different advantages and disadvantages for different groups in society?

Algorithms, for example, can be used to identify specific groups of people whose lifestyle leads to an increased risk of certain illnesses or conditions. Would it be legitimate for a health insurance company to exclude certain services for this risk group? Or should, given the new possibilities brought on by the technology, it become mandatory to record and collect a person's vital data in order to identify the potential risk of a disease at an early stage and thus be able to treat it with greater cost-efficiency? These questions draw red lines for a health system anchored in principles of solidarity in need of protection.

One thing's for sure: The use of algorithms in healthcare has given rise to many hopes and expectations for more accurate, safe, efficient and cost-effective medical care. However, many of these expectations are also associated with specific challenges. The study provides a comprehensive overview of these (for examples, see Figure 1).

Complex diseases require massive amounts of data and extensive knowledge

Real-life application scenarios from current practice and research illustrate these challenges. Researchers at TU Dresden, for example, have developed a therapy recommendation system that functions similarly to online trading, where users receive personalized product recommendations based on their previous purchasing behavior. The algorithm predicts whether and how patients respond to a therapy by considering how it has affected other patients. The system evaluates data from the results of a patient's previous medical consultations as well as any available patient-related data.

The researchers tested the system with psoriasis patients. It was based on the medical records of 213 individuals with data from over 1,100 medical consultations and includes demographic data, information on a patient's health status, comorbidities, and past and current treatments. Drawing on this data, the system recom-

Application scenarios for algorithms in healthcare – selected examples from the study

Prediction of mental illnesses among social-media users:
Researchers have developed a software for analyzing images posted on social media that can identify typical markers of depression through the images posted by users and other aspects such as the number of "likes" a posting receives.

Voice as an indicator of mental illness:
With the help of voice recordings, algorithms can identify certain characteristics, for example, of depression and distinguish these from other conditions such as post-traumatic stress disorder.

Data-driven support for physicians' therapeutic decisions:
Algorithms can predict which therapy is advisable for a particular patient at a particular time and how the patient will respond to it.

Prediction models for illnesses and drug effects:
The Deep Patient system, which draws on all the data about a person available within an electronic health record, predicts how effective specific therapies are or the likely course of a specific illness.

Activation and restoration of paralyzed persons' mobility:
Algorithms can decode signals from the cortex and process them in real time. When combined with robotic systems, they can return some mobility to those that have been paralyzed.

Alarm systems in residential communities for senior-citizens:
Sensor networks in home environments detect signs of illness or accidents, for example, by monitoring movement patterns, and can readily alert physicians or nursing staff.

mends the most potentially effective therapy for individual patients. This marks a step which, for dermatologists, will become increasingly more complex given the rapidly growing number of new drugs for psoriasis with different modes of action and application requirements that are entering the market.

So far, such therapy recommendation systems are rare in medicine, but they have great potential: They can significantly improve prognostics by combining the systematic collection of structured information from a patient's file with the latest findings from clinical trials, while identifying relevant patterns such as potential drug interactions. As a result, human errors due to insufficient knowledge can be avoided and patient safety increased. In addition, a physician will ideally have more time for what matters: communication with patients.

Risk-benefit analyses are necessary

The use of such systems demands that they actually deliver better recommendations than a physician and that they make fewer mistakes – something which only risk-benefit analyses can prove. Whether or not the use of such systems could lead to treating physicians losing control over medical decisions is a matter of contentious debate. Will physicians become mere assistants and translators of the recommendations delivered by algorithms? Or will their use support a physician in delivering medical services? And how does all this affect patient confidence?

If a physician pays less attention to the specific observations of their patients than they do to the information generated by an algorithm, they are subject to what is known as "automation bias." Decisions made on this basis are understandable, as the automated recommendation is based on massive amounts of complex data. However, this means that contextual knowledge that a physician can gain only by consulting with the patient may not be taken into account. The human ability (of the physician) to respond to (a patient's) personal needs and fears must be retained in making a joint decision on a particular therapy.

Due to liability issues, tomorrow's physicians may also be inclined to follow an algorithm's recommendation. If a physician's decision differs from that of the algorithm and the patient suffers harm as a result, the physician's deviation may be more difficult to justify than if the patient suffers

harm after treatment based on an algorithmic decision. This raises a question that must be answered on an institutional level: How do we deal with an algorithm that has, in effect, co-decision making power, but is not an actor per se?

All systems involving machine-learning algorithms pose specific challenges here

One solution that has been suggested is to leave the final decision up to the doctor exclusively. However, many experts believe that a human being is unlikely to go against the preliminary decision made by an algorithm. In processes involving machine-learning algorithms, it's difficult for both physicians and programmers to gain a sufficient overview of the processes relevant to the recommendation made and to be in a position to understand and follow the automated decision. As a result, the likelihood of a human being deviating from the preliminary decision made by an algorithm is reduced.

One critical task is to clarify the conditions under which physicians should be allowed to ignore recommendations issued by the system. We therefore urgently need public debate on questions of liability in medical decision-making, that is, when mistakes are made, and/or when errors in the recommendation system arise. In addition, we need regulations that ensure the transparency and comprehensibility of algorithms at work. We also need comprehensive, continuing education and training measures that enable professionals to assess and understand the benefits and limitations of each system.

How far should we let algorithms go?

What kind of progress do we want as a society? How far should the reach of algorithms in health care be? Should they be used in decisions regarding the termination of life-support measures? Or should they be used to help predict the quality of life and how much time a critically ill patient has left? This is just one of the debates triggered by the findings of a study released by Aspire Health, a U.S. company co-financed by Google. The company tested an algorithm-based system that made it possible to predict with high probability whether a critically ill patient would die within a certain period of time. The company's spokespersons emphasize that this information allows patients themselves to make better and more informed decisions about the time they have left. One matter of concern, however, is the role of economic considerations.

> "I don't think artificial intelligence will make us obsolete. But it will certainly make us better."
>
> Prof. Michael Forsting, Director of the Institute for Diagnostic and Interventional Radiology and Neuroradiology at Essen University Hospital

Certain algorithms could make it possible to generate statements as to whether costly therapies are economically "worthwhile" in a specific fight-for-life situation. This issue also demands public discussion: Will this kind of algorithm-driven optimization of cost-benefit analyses undermine our confidence in the healthcare system? Ultimately, medical and policy decisions alike must be driven by the need to protect the dignity of the individual and a patient's right of self-determination.

Our report "Algorithms in Digital Healthcare" and our Spotlight Healthcare are available free of charge at https://www.bertelsmann-stiftung.de/en/our-projects/the-digital-patient/project-news/algorithms-in-digital-healthcare/

Recommended actions

Foster public discussion and proactively shape digital transformation

The use of algorithms and new technologies offers several opportunities to improve and render more efficient healthcare. But this also brings challenges. Leaders in politics, healthcare and society need to engage in a rigorous opportunity-oriented debate, and healthcare policy must be designed to proactively shape the changes – with measures to be taken at different levels.

- **Foster public and interdisciplinary discussion:** A public dialogue on the opportunities and risks of algorithms requires innovative communication approaches that raise awareness regarding recent developments and potential effects among the medical lay public. This dialogue should involve both stakeholders and ethics, legal and social policy experts.
- **Strengthen cooperation between humans and machines:** Promoting the acquisition of technical skills and a critical sensitivity to the use of algorithms among healthcare professionals is crucial. Algorithms should be designed for use as meaningful tools; handling them with confidence requires greater attention. This means that healthcare professionals must be able to understand what algorithms do and assess their results, decisions and limitations.
- **Ensure informed consent:** Proper patient education on the use of algorithms and their benefits and risks is crucial to ensuring public confidence in a healthcare system. This involves clarifying the right to informational self-determination and to ignorance. It is therefore advisable to develop innovative, educational materials that target a lay audience.
- **Ensuring algorithms are programmed ethically:** Clear rules of conduct and transparency must be defined for the design and programming of systems. While developing an algorithm, interdisciplinary teams should work together to consider and reflect on the potential ethical risks and consequences of an algorithm – from different perspectives.
- **Create the technical conditions for reliable application:** We need to establish uniform and binding standards for data collection and the exchange of data in diagnosing illnesses. In order to reduce the risk of distortions and false correlations, underlying data (e.g., electronic health records) must be structured and complete.
- **Develop algorithm control:** Overall, the need to control algorithms in healthcare is growing. Exercising such oversight requires creating the structures and processes that focus on ethical requirements such as privacy protection and avoiding discrimination. This does not necessarily require that new legislation and institutions be established, as existing standards can be supplemented and existing institutions strengthened to carry out these new tasks.

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Further information at www.patient-mit-wirkung.de
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