# Artificial Intelligence in the Healthcare Sector[*]

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ABSTRACT: To an extent as never before in the history of medicine, computers are supporting human input, decision making and provision of data.  In today's healthcare sector and medical profession, AI, algorithms, robotics and big data are used to derive inferences for monitoring large-scale medical trends, detecting and measuring individual risks and chances based on data-driven estimations. A knowledge-intensive industry like the healthcare profession highly depends on data and analytics to improve therapies and practices. In recent years, there has been tremendous growth in the range of medical information collected, including clinical, genetic, behavioral and environmental data. Every day, healthcare professionals, biomedical researchers and patients produce vast amounts of data from an array of devices. These include electronic health records (EHRs), genome sequencing machines, high-resolution medical imaging, smartphone applications and ubiquitous sensing, as well as Internet of Things (IoT) devices that monitor patient health (OECD 2015). Through machine learning algorithms and unprecedented data storage and computational power, AI technologies have most advanced abilities to gain information, process it

and give a well-defined output to the end-user. Daily monitoring thereby aids to create big data to recognize behavioral patterns' relation to health status in order to create predictions with highest mathematical precision based on big data capturing large-scale samples. AI thereby enlightens to analyze the relation between prevention and treatment and patient outcomes in all stages of diagnosis, treatment, drug development and monitoring, personalized medicine, patient control and care. Advanced hospitals are looking into AI solutions to support and perform operational initiatives that increase precision and cost effectiveness. Robotics have been used for disabled and patient care assistance. Medical decision making has been supported through predictive analytics and general healthcare management technology. Network connectivity allows access to affordable healthcare around the globe in a cost-effective way.

KEY WORDS: Access to healthcare, Advancements, Artificial Intelligence (AI), Corruption-free maximization of excellence and precision, Decentralized grids, Economic growth, Healthcare, Human resemblance, Humanness, Innovation, Market disruption, Market entrance, Rational precision, Social stratification, Supremacy, Targeted aid

## Opportunities

### Unprecedented access to healthcare

AI and robotics supported medial assistance and scientific discovery has increased steadily within the last decades. The big data revolution and hierarchical modelling advancements as well as computational power are starting to dominate an inference driven access to healthcare and medical prevention control. Therapeutic data-driven information and self-monitoring, as well as patient and claims data, to recommend treatments and impact outcomes have leveraged to unprecedented sophistication. With the growth of scientific evidence derived from big data, AI helps guide care, improve comprehension, analyze trends, and identify opportunities for further research (Groebel 2019). AI-powered engagement aids guide customer-facing resources through the planning and execution process; surfacing actions, evidence, and insights based on real-time, integrated data. Acting as a "virtual mentor," technology can guide engagements to meet both customer expectations and organizational objectives today, while further

future informing decisions (Groebel 2019). AI also helps inform provider therapeutic choice by presenting evidence-based recommendations to reviewers at larger, institutional networks (Groebel 2019). Online patient education means provide a complete view of the patient journey over time, covering the spectrum from early disease state, to management of health goals, therapeutic choices and therapy-specific outcomes, and future goals (Puaschunder 2019b).

As never before in history, improvements in data generation, storage and analysis coupled with unprecedented computational power and statistical means has resulted in optimal conditions for large-scale data collection and processing advancements. Growth of genomic sequencing databases but also widespread awareness and implementation of electronic health recording has improved the nature and quality of accessible preventive medicine. Health risk early warning systems through data collected via a mobile app but also pandemic spread visualized via google search mapping analytics are advancements based on big data, large-scale mapping sophistication and computation control. The wealth of electronic health records has excelled digitalized diagnosis and prevention of diseases and disease outbreak control.

Robotics have entered the medical field as assisted body parts or surgery devices as well as in the support of automated nursery and mental health stabilizers. Radiology and imaging benefit from computer-guided and big data enhanced capacities to diagnose and predict future outcomes at the same time based on large scale samples. Information and Communication Technologies (ITC) have broken a wave of hope in increasing the possibilities of telemedicine. Telehealth enables remote and instant monitoring and preventive control but also instant emergency outreach and remote diagnosis based on large-scale data-driven knowledge generation. The medical world has become flat and international development crisis management has profited from data-driven prevention. Instant messaging has opened the gates for remote access to affordable diagnostics. Networking data sharing capacities have reached unprecedented density and sophistication. Self-monitoring through diagnostic tattoos that change color when certain medical conditions – such as for instance diabetes or cancer – occur or development of programmable cells that destroy diseases naturally and internally are cutting

edge developments of the future on the intersection of self-determined prognosis led by algorithmic insights (Knapton 2016). Health-related data from personal and healthcare related self-diagnosis devices coupled with low-cost generation of big data and patient-led monitoring makes top-notch quality care more accessible in remote areas and developing nations. Self-led monitoring and remote diagnosis aided by machine learning mining through big data and algorithmic decision making are continuously meant to give access to affordable excellent healthcare around the globe in the future. Clinical decision support systems are expected to advance in the near future with 5G technologies arising, which will boost prognostic capacities.

*Rational precision and human resemblance*
Electronic health records decentralized via blockchain enhanced with machine learning systems help guide physicians with predictive medical advice based on previous patient outcome data and recommended treatments performance data. Especially in mental health, AI utilized new technologies are showing excellent results in the calibration of mentally and emotionally fragile patients (Meghdari & Alemi 2008). Artificial emotional intelligence is thereby programmed to understand, simulate and calibrate human emotions. In elder and patient care these tools are also currently applied to provide companionship to patients in the form of small talk, soothing music and adjustments to control anxiety. There is also another branch where AI offers new possibilities. By using sources like social media data, researchers were able to predict a future occurrence of depression based on linguistic cues. The prediction accuracies of language markers as sadness, loneliness, or increased self-reference are comparable to validated self-report depression scales (Eichstaedt et al. 2018).

The human perception of and interaction with robot machines with a higher quality physical appearance, however, still differs from interaction with a computer, cell phone, or other smart devices (Meghdari & Alemi 2018). For robotics technology to be successful in a human-driven environment, robots do not only need to meet a level of strength, robustness, physical skills, and improved cognitive ability based on intelligence but should also fulfil a social impetus and ethical conscientiousness. Brain-computer interfaces are

predicted to help those with trouble to move, speak and with spinal cord injury. AI thereby helps patients to move, communicate and decode neural activities on an individual basis (Bresnick 2018). *Socio-Cognitive Robotics* is the interdisciplinary application of robots that are able to teach, learn and reason about how to behave in a complex world (Meghdari & Alemi 2018). The design and construction of social robots faces many challenges, one of the most important is to build robots that can comply with the needs and expectations of the human mind with cognitive capabilities coupled with social warmth (Meghdari & Alemi 2018).

## *Targeted aid*

Healthcare has never been as individually targeted aid and accessible for everyone. For one, user self-reporting allows instant information generation and in-depth knowledge retrieval. Digital consultant apps use AI to give medical consultation based on personalized medical history record analyses and common medical knowledge derived from inferences from big data. Virtual nursing assistants are predicted to become more common to perform targeted patient aid that can run 24/7 at most efficient levels.

For another, technological development is bringing production and manufacturing closer to the end user in the sharing economy. Decentralized medical aid allows tapping into information closely and grants access to resources within the local networks. Remote communities thereby benefit from equal, easy and cheap access to medical aid. Information share among neighbors helps overcome shortages and enables fast paced aid that is faster, cheaper and more democratically distributed. Geopolitically the individual becomes more independent from centralized medical structures.

While many insights are observational in nature, the goal is to identify actionable insights that inform medical strategies, leading to improved interventions and better patient outcomes. This requires a human AI-enhanced relation to generate and understand the expert knowledge (Groebel 2019). Individuals will have to be trained to make full use of data driven insights and to master technological advancements at a fast-changing pace. Cross-trainings will become necessary to embrace novel insights derived from big data and integrate AI and robotics in teams that should have a diversified

use spectrum of the novel technologies to optimize the effect of medical aid. Hands-on education featuring test phases and role plays will become necessary to train and administer a smooth entrance of AI into our daily healthcare provision. Education may aid individuals making contemplated decisions and mastering privacy self-management (Sax 2016). This is especially true for specialty care areas and expert teams where a small community of experts are closely connected to each other. The leverage of a functioning expert team is high when considering them being at the forefront of scientific discovery determining the lives of millions of people. There is significant value in understanding those networks of interactions featuring highly-trained professionals and self-monitoring patients (Puaschunder 2019b).

*Corruption-free maximization of excellence and precision*
Today technology plays an important role to help analyze and identify actionable insights derived from a multitude of accessible data sources. The medical profession shifts towards precision medicine using a variety of complex datasets such as a patient's health records, physiological reactions and genomic data (OECD 2019). With medical literature doubling every three years, also the pharma industry now has access to unprecedented amounts of scientific data (Groebel 2019). Once tagged and compiled, AI tools that employ natural language processing help mine the data for new information. For the industry, this is an opportunity to gather actionable insights, leading to strategic data-driven interventions.

With the overwhelming growth of clinical data and the expansion of clinical care teams, life sciences will need to reconsider how share information with diverse stakeholders so excellency is accomplished while human dignity is upheld. This requires identifying the right stakeholders, assessing scientific need, and commanding solid knowledge of the data. Scientific excellency for advancing society most thereby be coupled with security attention and human dignity precaution.

While data collection is easier than ever, proper usage of linked data is and will be a key factor for productivity, quality and accessibility of AI-driven applications. The core promise of data-driven solutions is to collect data at a density that is not feasible for humans and identify patterns humans cannot

grasp. Hence, in most cases, the results cannot be easily questioned as the analysis is hardly scrutable. For this reason, a minimum level of statistical knowledge like statistical classification or predictive modelling will be necessary for everyone working in medical professions to secure a proper usage of AI-solutions.

Intriguing appears that AI, robots and algorithms differ from human healthcare providers by holding the potential to be more standardized, working 24/7 and less prone to corruption. If programmed to follow an ethical imperative, AI and robots being without self-enhancing profit-maximizing goals promises to grant healthcare free from any corruption, bribery or irrational price spikes faced by consumer-patients.

*AI innovation*

The healthcare AI market is expected to surge from with an expected compound annual growth rate of 50.2 percent from now until 2025 based on market innovations (Report Linker 2018). On a qualitative basis, the use of AI is predicted to improve the prevention of diseases, accuracy of diagnoses and predictions on treatment plan outcomes. In particular, AI is believed revolutionize healthcare in areas such as surgery, radiology and cancer detection with improved healthcare delivery and patient experience.

The hospitals and providers segment is expected to hold the largest size of AI in healthcare market in terms of end user. A few major factors responsible for the high share of the hospitals and providers segment include a large number of applications of AI solutions across provider settings, the ability of AI systems to improve care delivery, patient experience while bringing down costs and the growing adoption of electronic health records by healthcare organizations. Moreover, AI-based tools, such as voice recognition software and clinical decision support systems, help streamline workflow processes in hospitals at lower cost with improved care delivery and enhanced patient experience (Report Linker 2018). Utilizing the predictive power of big data has perpetuated the effectiveness and efficiency in the healthcare sector.

The adoption of electronic health records by healthcare organizations and the outsourcing of health monitoring by novel personal care products – such as routine check-up medical tools and wearable devices – is further

believed to better service quality and eventually bring down costs via improved prevention through higher frequency of checks at lower costs. Advanced computing power and the declining cost of hardware are other key factors in the projected market growth at lowering costs (Lagasse 2018). The growing adoption of applications such as patient-data and risk analysis, lifestyle management and monitoring, and mental health is further propelling technology use in the market (Puaschunder 2019b; Report Linker 2018).

*AI economic growth*

A 2017 Accenture Research and Frontier Economics report of economic growth rates of 16 industries concluded that AI has the potential to boost profitability on average by 38% by 2035 (Burke and Trazo 2018). This massive market entrance of AI in our contemporary economy imposes historically unique challenges. The emerging autonomy of AI holds unique potentials of eternal life of robots, AI and algorithms alongside unprecedented economic superiority, data storage and computational advantages. Yet to this day, it remains unclear what impact AI taking over the workforce will have on economic growth.

Machine learning's ability to collect and handle big data, and its increasing adoption by hospitals, research centers, pharmaceutical companies and other healthcare institutions, are expected to fuel growth in the healthcare sector with hospitals and provider segments holding the largest end user market for AI solutions (Lagasse 2018).

On the question of an AI market disruption, since AI in healthcare is currently utilized mainly to aggregate and organize data – looking for trends and patterns and making recommendations – a human component that is creative, cognitively highly flexible and compatible with AI sources is still needed (Puaschunder, 2019a; Report Linker 2018). Rather than replacing human medical doctors and staff, AI is therefore believed to support medical doctors and nurses alike and help on decision making predicaments, as burn out prevention by aiding on cognitive load capacity constraints with supremacy of excellence and precision. Radiology is a good example why technology often will not replace humans, instead giving them better tools (Hosny, Parmar, Quackenbush, Schwartz & Aerts, 2018; Pakdemirli 2019).

Outsourcing monitoring to patience and electronic recording devices but also tapping into the wealth of expert knowledge generated through big data helps classical human medical doctors and healthcare agents, who benefit from freed capacities for creative decision making and expert advice giving. In addition, advances in 3D printers may soon make it possible to substitute healthcare provision closer to the consumer, where the manufacturing process is simplified thanks to the reproduction of models.

In an attempt to align AI with classical growth theories, classical capital or labor components should be put in relation to AI. In a cross-sectional analysis over 161 countries of the world and a multi-decade time series, higher AI use appears to be associated with lower economic growth rates – a striking result which demands for revising growth theory in the artificial age (Puaschunder 2019i). AI hubs are speculated to have growth – e.g., such as gains from the sharing economy, cryptocurrencies and big data generated revenues – that conventional growth theory may not include (Puaschunder, 2019i). We may therefore advocate for revising conventional orthodox and heterodox growth theory for integrating AI led growth. The standard neo-classical growth theory featuring growth being a function of capital and labor should be revised insofar as labor could be split up in more flexible components describing AI and human labor being associated with more clay labor parts, hence a more inflexible workforce. When revising standard neo-classical growth theories to integrate AI components into growth theory, the derived modeling capacity will allow for a more precise description and prediction of current and future AI impacts on the overall economy (Puaschunder 2019b, c, d).

## AI advancements and decentralized grids

Decentralized information collection and storage grid as well as technological diversified data collection means are expected to revolutionize the healthcare sector. Thereby healthcare providers make sense of vast amounts of data to reach the optimum patient health or recovery potential.

Problematic appear technological barriers and that the compilation of data to generate insights is still in its infancy. Disconnected systems and fragmented data sources limit the flow of information and the development

of scientific insights. For instance, the European Union should introduce a fifth freedom of data transfer within the European Union could thereby aid in producing standardized data sharing and interpretation standards (The four freedoms of the European Single market are: free movement of goods, capital, services, persons). While AI appears to have most advanced data storage and computational capacities, AI lacks a reflective process on ensuring that the most relevant data and insights hit the most relevant key decision maker to enhance guidelines, pathways and treatment algorithms. Decentralized grids also open novel opportunities of monitoring and measuring, as information can be tracked and linked directly to the scientific and patient impact they are having, including knowing if the expert visited the medical portal, opened an email, or requested additional information. At the same time, privacy challenges arise from this kind of relationship building and hands-on monitoring in the search for a desired positive relationship outcome. Instant and continuous information tracking implying full transparency leads to the risk of stigmatization setting patients up in a path of discriminatory disadvantages or silos of sickness, when a diagnosis influences future diagnoses.

In the age of big data, many individuals heavily rely on web searches to find basic expert information. It is therefore a necessity to publish and monitor online information with caution. Attention should be focused on accurate description of medication and health control. Sources of healthcare information, including claims and referral data, trials, publications and clinical guidelines should constantly be tracked and monitored by algorithmic search function. The big data value from search term analyses should be used to detect prevalence and health risks but not directly influence insurance, educational or market performance. In the display of information, anonymity has to be upheld in order to combat stigmatization, discrimination and social stratification based on health performance that sets people on a trajectory. Regulation of online contents and discrimination combat are challenging for national governments to fully implement and should therefore become part of a European Union-wide endeavor. In a European-wide approach, the complex relations of multi-stakeholder engagement in the medical sector should be targeted.

Novel mapping tools can translate local search results and crowd media use into visible information display so it becomes more accessible in a broader way. Information on access to healthcare and healthcare performance is currently debated to be made available large scale. A combination of mobile technology and cloud computing naturally complements big data technologies and is well-suited for reliable storage and analysis of big data. Crowdsourcing comes in when a mapping type of search option would exist that displays all medical services in a map. In such a crowdsourced mapping, all medical services nearby could be displayed featuring a price scale and performance information based on consumer reviews. Advantages of individuals sharing information about price and quality of medical services would be the quality control, transparency and prospected price margin decrease. Downsides of an as such type of mapping comprise of social stigmatization and discrimination potential, competitive fraud, price decline leading to a natural service quality race-to-the-bottom. Information democratization as the equal access to information thus appears to be favourable. This is the especially demanded when information is used for the sake of access to quality but becomes problematic if inferences drawn are used against the individual, especially vulnerable groups.

Decentralized crisis management applications of AI and machine learning already range from data-driven assistance in crisis management and control to battling hunger and poverty as well as forced migration. In the future we may see a further development of an effective big data-driven crisis response ecosystem. Targeted aid can form a grid of medical specialists to work concurrently in the diagnosis of a patient. Integration of fragmented diagnosis and treatment results coupled with self-monitoring devices collecting data at hand on a constant basis are viewed as future medical necessities. An as such integrated diagnostic process fosters personalized treatment most suitable for patients under consideration. Data integrated grids can also combat fragmentation of different help groups and field workers responding to crises. Future challenges will comprise of medical data to help a targeted aid and understanding of data but also form a deep relationship that adds value and meaning to patients who get helped by AI remotely. Another challenge will be to ensure robust ecosystems to minimize digital security

threats related to AI. "Data poisoning" (i.e. feeding manipulated data into a grid on which an AI system is being trained) actors can intentionally cause misclassifications. Such adversarial examples can be created without effort, by printing images on normal paper and photographing it with a smartphone (OECD 2019). Transnational engagement should aid in re-evaluating and seeking out new competencies, technology solutions, and data sources that better support patient-centric outcomes. Patients must be trained to use digital channels and be open to remote assistance.

Democratization as the equal access to information of health data will need several countries coming together to construct large datasets as learning opportunities, which different stakeholders from government, healthcare, engineering and technology use to analyze and predict the prevailing health situation and outcomes. The more countries join, the more accurately the dataset will be able to draw inferences about diseases and epidemics spread. An environment should be established in which research, clinical practice and technological advancement are not performed in isolation. Big data should combine the medical sector with technology-driven self-monitoring directly applied to patients in a near real-time manner. Large data sets that glean context-based information thereby become early warning signs of imminent viral epidemic outbreaks. The wisdom of the crowds should be tapped into in citizen science – e.g., Massively Multiplayer Online Gaming (MMOG) techniques that have been used to incentivize volunteer participation. Such an approach helped gamers on a crowdsourced gaming science site (www.fold.it) helped decode an AIDS protein in 3 weeks, a problem that had stumped researchers for 15 years (Quadir, Rasool, Zwitter, Sathiaseelan & Crowcroft 2016).

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