AI in Healthcare II

Current state and the future of AI in clinical care

WORLD MEDICAL INNOVATION FORUM

The 2019 World Medical Innovation Forum focuses on Artificial Intelligence and its growing impact on clinical care. This document outlines the current state of AI in healthcare with a focus on clinical care.

When William Gibson said, "T**he future is already here, it's just not evenly distributed**," he could well have been speaking about AI in healthcare today.

Framework

In our perspective on AI in Healthcare I (Jan 2018) we suggested looking at AI applications across five healthcare domains. These domains were defined by the end-user whose judgment or capability was supported, enhanced, or even replaced by AI.

Domain	End-user
Patient engagement	Patient
Care delivery	Clinical professional
Population health	Population or public health manager
R&D	Researcher
Administration	Business manager

This paper is based on use-cases across these domains. These use-cases encompass three kinds of primary functions within which AI can be used: measure, decide, and execute. Within the Care Delivery domain for instance, for a patient with lung cancer, AI may be deployed to diagnose a condition by reading radiographic images (measure), to plan treatment through AI-driven decision support (decide), or to deliver treatment, say by robotic implementation of surgical or radiation procedures (execute).

Definitions and the list of use-cases considered are at recon.blog/Ai.

	Functions (illustrative)		
Domain	**Measure**	**Decide**	**Execute**
Patient engagement	Gauge status	Suggest action	Manage condition
Care delivery	Diagnose condition	Plan treatment	Deliver treatment
Population health	Predict risk	Determine intervention	Deliver intervention
R&D	Reveal causality	Determine approach	Carry out R&D
Administration	Reveal opportunities	Prioritize actions	Automate workflow

We considered the maturity level of each of these use-cases, not based on the sophistication of the AI technology but based on the stage of adoption. We assigned each use-case one of four maturity levels: Design, Test, Spread, and Established. We did not rate any of the functions as established at this point.

	Design	Test	Spread	Established
Maturity level	Being developed in academic or innovation settings	Being tested in controlled external environments to prove performance	Investments being made to scale the innovation	Is the norm in developed countries

Figure 1: Average maturity and relative intensity of use-cases across five healthcare domains

Current State of AI Across Healthcare

We find that AI has, in a few short years, moved from being a perennial underachiever to being accepted in a range of use-cases. There is, however, considerable heterogeneity in the level of activity and maturity across the different domains and functions (Figure 1).

Patient Engagement

With the rapid growth in wearables, home diagnostics, digital health apps, voice assistants etc., patient engagement is arguably the most mature domain for AI with lead applications entering the spread phase. The proposed accelerated approval processes from the FDA should further accelerate the innovation already being driven by ubiquitous connectivity and interfaces (including smart speakers).

Care Delivery

Unsurprisingly, the locus of AI in care delivery is in diagnosis, or more specifically to detect, characterize, and predict, where the technology is advancing rapidly to the point where in some instances it already surpasses human capability. This includes use-cases in adverse event prediction and detection (from tracking behavior and biometrics), medical image analysis (radiology and pathology), diagnostics from medical records (often NLP driven), and waveform analysis (in CV, ob-gyn, and neurology, for instance). We also see the emergence of use-cases in planning care, including drug regimen selection (for antibiotics, oncology, and other areas of personalized medicine) and other forms of decision support (recommended care pathways, radiation planning, and surgery planning). The barriers for AI to break into the delivery of care are for obvious reasons rather high. Even so, there are some areas where we see use-cases in care delivery such as with chatbots (software based Cognitive Behavioral Therapy), closed-loop medication administration (insulin/glucose), and robotic assisted treatment (rehab and surgery). We take a closer look at care delivery in the next section.

Population Health

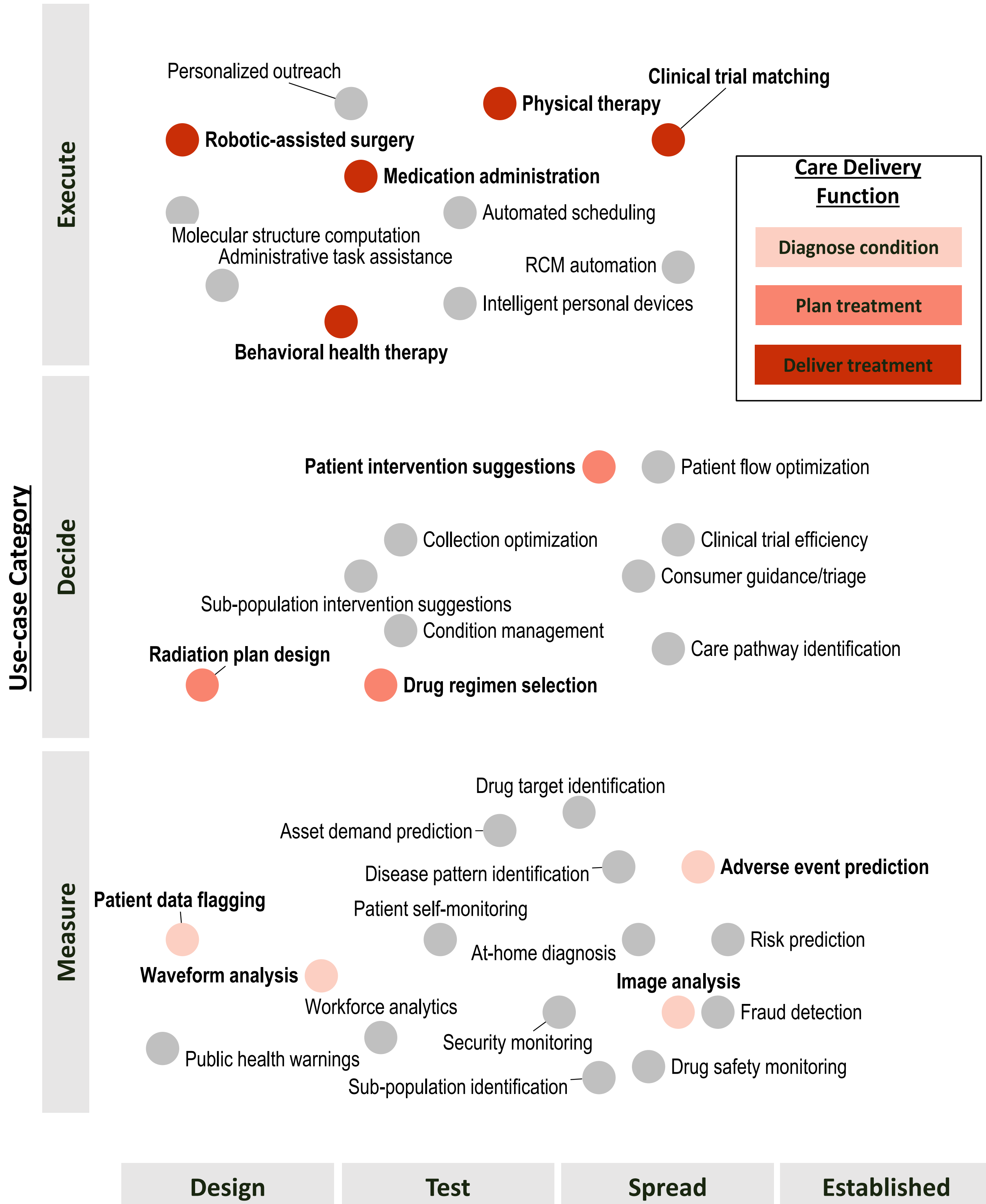
Machine learning algorithms are being used to predict, detect, and monitor epidemics (from the common flu to rare Ebola) using data sources as varied as health data, social media posts, satellite imagery, connected apps, and more. We also see many AI techniques in population risk stratification that identify patient segments (or individuals) who would benefit from proactive outreach and in some cases recommend interventions. A few solutions carry out some level of patient outreach automatically.

R&D

R&D is essentially a prediction and prediction-validation process. AI can help to improve the success rate of prediction and speed up the process of validation, and consequently, reduce the cost of R&D. In research, machine learning approaches are being used not just to select targets but also to help select or design molecules. Innovators are using it to understand biological interactions and compute molecular structures for drugs. In development, AI is being used as a "crystal ball" to draw insight from data we have about data we don't e.g. to develop biomarkers using data that's more readily accessible to draw insight about data that's not accessible. Multiple innovators are using such methods to identify novel therapies and combinations and to gain a deeper understanding of the impact of existing treatments. AI is also being used to develop real-world evidence and for drug safety monitoring. Fairly advanced as well are AI approaches to identifying research sub populations, matching individuals to clinical trials, and finding "Goldilocks individuals" who might be best-suited for a particular care pathway being researched.

Admin

AI has gained considerable traction in administrative functions and we expect to see these applications move along the maturity scale quickly. It's easier to gain organizational buy-in for these use-cases and they often have a clear ROI or patient and provider benefit with little downside. Machine learning is being used to measure and reveal opportunities for value such as by predicting demand for assets (e.g. provider capacity and equipment availability) and detecting cyber-security violations and fraud. Products with AI built in are also being used to improve revenue cycle management (coding and adjudication). Additionally, we see AI addressing provider administrative pain points such as EHR documentation (voice-powered clinical assistants and scribes), and patient no-shows (smart scheduling systems).



Source: Recon Strategy analysis.

Figure 2: Healthcare AI use-cases with care delivery examples highlighted. Interactive chart at http://recon.blog/AiExamples

Future of AI in Care Delivery

While the progress over the last few years has been impressive, we have barely scratched the surface of what could be possible, particularly in the Care Delivery domain. The opportunities to deploy AI in clinical care will increase exponentially as we become better at capturing and integrating vast amounts of data from multiple sources, making sense of this data in a clinically relevant way, and acting on this insight.

Those areas within clinical care that will see the fastest adoption are likely to be those that have well-established input data, clear validated outcomes, and a relatively high level of computational complexity. We highlight example areas in which we expect a high level of AI activity in reference to Figure 2.

Measure: Diagnose Condition

Not surprisingly a major focus of AI thus far in clinical care has been in diagnosis and specifically in image analysis. This area is poised to move into large scale spread in the next several years. Inevitably AI systems will ultimately perform clinical diagnostics on medical images at levels equal to or better than experienced clinicians. Expect radiology, pathology, dermatology, and ophthalmology to continue to be areas of innovation with proven AI applications becoming the norm and enabling not just more efficient and accurate diagnoses but new diagnoses that are not feasible today.

In the same way, AI approaches will also increasingly be used to detect abnormalities in waveform readings in areas such as cardiovascular disease, obstetrics, and neurology. There will be challenges including, for instance, unnecessary care due to "incidentalomas"—either false positives or transient artefacts—but as the technology and our ability to interpret data evolves, this will also be an area of rapid innovation.

Predictive models will improve alerts in the care setting by using data from a range of sources including medical equipment, sensors, and clinical/administrative applications to better anticipate adverse events while reducing "alert fatigue" (lower false-positives).

NLP (natural language processing) is already being used in several ways to aid diagnosis, such as interpreting unstructured data in clinical records and powering chatbots to interact with patients. As voice processing gets even better over several years, you could see diagnoses being done by AI systems in more human-like ways.

Finally, as genomic (and other -omic) data become more widely available, AI approaches will be necessary to make sense out of all the noise and help make personalized medicine a reality.

Decide: Plan Treatment

AI is already being used to predict patient responses to treatment pathways and to optimize drug selection for patients based on their specific health situation, demographics, and genetic profile. Expect AI-based decision support for clinicians to become more common.

Another area of significant research is in using AI to augment physician decision-making during treatment such as in surgery, anesthesiology, and interventional radiology.

Execute: Deliver Treatment

AI will increasingly be seen in the actual delivery of treatment. For instance, smart medical devices that monitor a patient's health status and administer drugs at the right time and dose combination are being rapidly developed in diabetes with closed-loop CGM (continuous glucose monitors) and insulin pumps. Expect to see these become better, cheaper, and more prevalent and to see similar ideas play out in many different conditions and settings.

In physical therapy, robotic systems augment therapists by providing precise guidance and feedback in ways that are hard for a human to do. AI takes this a step further by powering assistive and rehabilitative devices (including active exoskeletons and smart prosthetics). In surgery, AI-enabled robotic systems will enable greater precision and less invasive procedures.

Mental health is another area of active AI interest as AI-based programs can not only alert caregivers to mental health situations as they develop through passive monitoring but can also intervene directly with patients to provide therapy and guidance in increasingly sophisticated ways.

Challenges

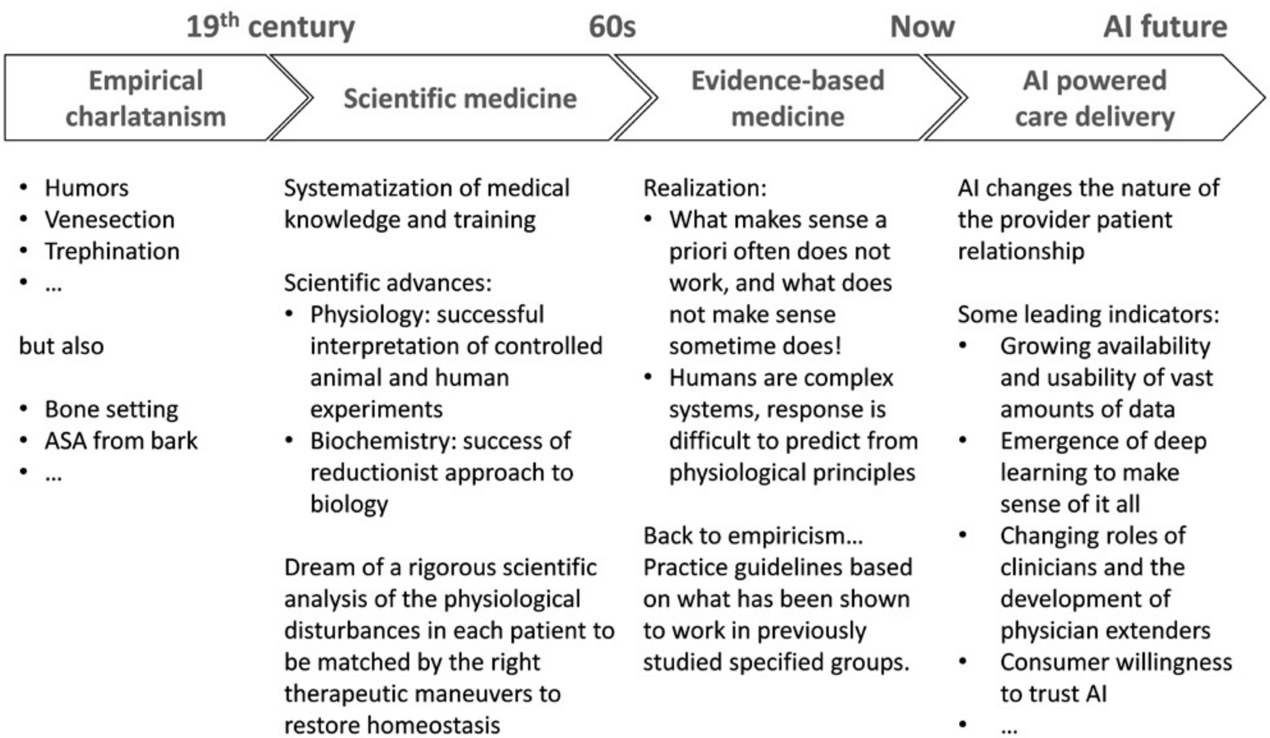
This is not to say that it's going to be an easy pathway to achieving the potential of AI. Key barriers include:

Technology Gaps and Data Issues

Today's successful applications utilize narrow AI systems that focus on specified tasks in controlled contexts. It's been hard to generalize applications across different contexts much less move to any kind of broad AI. Meanwhile, data issues abound, primary among them the insufficiency of current semantics and ontologies to makes sense of the wide range of data (genetic, phenotypic, environmental, process, etc.) required for AI applications. Additionally, even our properly curated data sets may contain implicit biases that are then propagated by AI systems. Meanwhile, data access issues will continue to be major challenges particularly as data security and privacy concerns remain. There is a tremendous amount of focus and effort in these areas and we will continue to find ways to overcome these barriers.

Need for "Explainability"

With the goal of providing patients high quality care, clinicians will require that AI solutions in healthcare provide plausible reasoning and transparency into the decisioning that they can trust. In medicine, risk-averse tendencies, centered in the Hippocratic Oath, are further reinforced by liability fears that may impede the acceptance of these tools in clinical practice without a clear legal framework. Additionally, the practice of medicine has for many years been rooted in science-based explanatory models. As such, clinicians crave a level of mechanistic understanding that is difficult to obtain with machine learning techniques as we often cannot pinpoint which features a machine uses to generate its predictions. While machine learning is very good at finding weak signals it's also very good at finding signals in data artifacts or making specious correlations (e.g. using the watermark in an image). All these factors make the need for transparent AI more acute. This is also not an insurmountable problem and many teams are working on addressing this, for instance with local-interpretable-model-agnostic explanations (LIME) and attention techniques. Stanford researchers, for example, use saliency or attention "heatmaps" to highlight the areas in an image most relied on for AI predicted pneumonia.



Source: Adapted from Working paper: the coming age of algorithmic medicine, Marc Herant, MD (2015)

Figure 3

Changed Role of the Physician

Ultimately the most profound and hardest-to-solve challenge for AI in healthcare is a human one. AI will affect the place physicians hold in society because it dramatically reduces information asymmetry between physicians and everyone else.

This is a magnitude of change that physicians have only seen twice before. First, as the practice of medicine moved from "empirical charlatanism" to "scientific medicine" and second in the shift to the current era of "evidence-based medicine" (Figure 3).

> "The place that the physician holds in a given society is determined by a variety of factors of which the most important are: the social and economic structure of that society, the valuation of health and disease by that society, the tasks it sets to its physicians, and finally the technology of medicine available to the doctors in such a period. These factors have changed a great deal in the course of time and so has consequently the position of the physician."[1]
>
> HENRY E. SIGERIST (MEDICAL HISTORIAN) IN 1946

[1] Sigerist (1946), Proceedings of the American Philosophical Society, Vol. 90, No. 4

Takeaways

AI is here in healthcare today, just as it is in other parts of our society, and it's here to stay. It will have a tremendous impact mostly for the benefit of patients, providers, and payers. In some cases, it will replicate human intelligence, in others it will surpass it, but mostly it will augment what we can do to improve health and lower cost.

There is much work to be done on the technology, the use-cases, and the underlying need to get the requisite data and governance in place. This work will continue to advance rapidly and it's only a matter of time before many (perhaps thousands) of AI applications mature through the test, design and spread phases with a few moving into the established phase. In other areas, though, it will take several years before AI is broadly utilized.

AI driven changes in society over the next few years (such as self-driving cars) will create an environment conducive to the acceptance of AI in healthcare. But make no mistake, this is a paradigm shift, and paradigm shifts are hard and can take a generation especially in healthcare where behaviors are sticky, and evidence-generation is somewhat constrained by the pace of human biology.

> "We tend to overestimate the effect of a technology in the-short run and underestimate the effect in the long run."
> - Amara's Law

Acceptance will require that AI solutions not only deliver the right measurement, decision, or execution, but also provide us mere humans with believable rationale.

Looking forward to an AI-powered future, successful leaders need to understand and act on not just the technology issues but also the people issues centered on how the physician patient relationship will change.

> "AI is going to get me better at looking at statistics, drawing conclusions, and being more efficient. But in fact, the essential skill that I need as a physician in a world with AI is that ability to share those tears, to wipe them off, to explain to the patient that we will get through this together, and to offer reassurance and hope."
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