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Health

AI and the Future of Healthcare

Where Does the Research Point?

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Defining AI for Healthcare

"AI is the ability for machines to mimic the cognitive functions and decision making of humans with limited human intervention."

Robert Daigle, Lenovo Artificial Intelligence Innovation and Business Leader

Artificial intelligence (AI) has a growing range of applications in healthcare, including the use of computer-driven analysis for clinical decision support, streamlining both clinical and administrative workflows, and moving precision medicine forward.

AI transformation

Artificial intelligence (AI), in one form or another, is widely predicted to transform healthcare. In many ways, it already has.

The Brookings Institution's Artificial Intelligence and Emerging Technology (AIET) Initiative identifies four areas where AI is expected to benefit healthcare:[1]

- Pushing boundaries of human performance
- Democratizing medical knowledge and excellence
- Automating drudgery in medical practice
- Managing patients and medical resources

According to market analysts at Deloitte, tasks performed by AI "...can range from simple to complex, and include everything from answering the phone to medical record review, population health trending and analytics, therapeutic drug and device design, reading radiology images, making clinical diagnoses and treatment plans, and even talking with patients."[2]

Not surprisingly, while the goal is to deliver better-quality healthcare less expensively, incorporating AI capabilities into a healthcare organization requires a considerable upfront investment. Market research predicts that healthcare spending on AI by 2025 will range from $31.3 billion[3] to $36.1 billion.[4]

Despite high expectations for transforming healthcare delivery, most AI applications are in the early stages. Research suggests a variety of powerful applications that may revolutionize prediction, prevention, and treatment of disease.

AI Technologies at a Glance

- **ML** Machine Learning
- **FL** Federated Learning
- **NLP** Natural Language Processing
- **CV** Computer Vision
- **DL** Deep Learning
- **IA** Imaging Analytics

Anatomy of AI

The broad term "artificial intelligence" includes subsets of related technologies, which often work together to enable healthcare capabilities and breakthroughs.

Machine learning (ML)

Machine learning gives systems the ability to automatically learn and improve from experience without being explicitly programmed. ML uses algorithms to analyze data, detect patterns, form conclusions, and make predictions. Most traditional ML algorithms need structured (labeled) data.

Natural language processing (NLP)

Natural language processing is a subset of machine learning used to convert human language into computable data formats, which can be compared and analyzed.

Deep learning (DL)

Deep learning is a subset of machine learning. A deep learning model analyzes data not unlike the way a person would. It uses a layered structure of algorithms called an artificial neural network that imitates the way the human brain filters information and learns to classify and predict. In this model, an algorithm can determine on its own if a prediction is accurate or not. While ML requires the features used for classification to be provided (labeled data), DL can automatically figure out the features. It allows machines to solve complex problems even with diverse, unstructured data. DL requires huge amounts of data and therefore powerful computing capability.

Federated learning (FL)

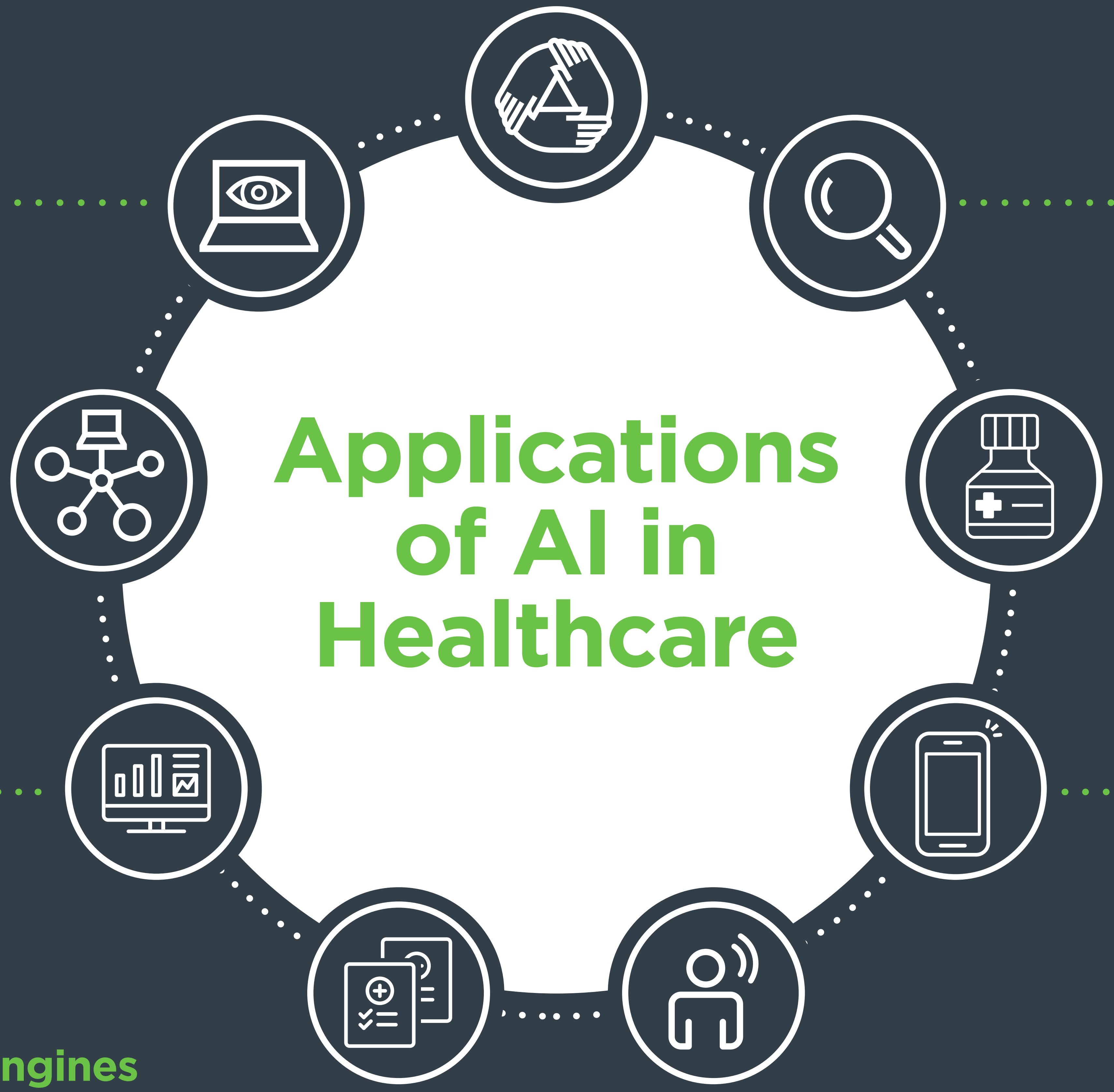
Federated learning allows AI algorithms to use and learn from data located at different sites. This means organizations can collaborate on the development of models without needing to directly share sensitive clinical data with each other.

Computer vision (CV)

Computer vision is the use of AI to compare and analyze images — training computers to see and interpret them the same way human vision does. Computer vision models take information from thousands of images and outcomes, then apply deep learning to analyze and reach conclusions.

Imaging analytics

Medical image analysis applies deep learning and computer vision to provide clinical decision support to clinician specialists, including oncology, cardiology, pathology, and more.



Diagnosis and Treatment

Clinical Decision Support
Symptoms Analyzer
Treatment Efficacy vs. Effectiveness

Computer Vision

Radiological Image Analysis
ECG and EEG

Discovery

Clinical Trials
Hypothesis Generation
Proof of Concepts

Workflows

Patient Flow Optimization
Detect Process Inefficiencies

Precision Medicine

Genomics

Predictive Modeling Risk Stratification

Readmission Rate
Hospital Acquired Infections
Emergence of Complications

Mobile Apps

Wellness
Chronic Disease Management

Matching Engines

Patients with Similar Profiles
Treatments with Similar Cost-Benefit Ratios

Virtual Assistants

Source: Cognity AE.

Applying AI in Healthcare Today and Tomorrow

Diagnosis and Treatment | Workflows | Precision Medicine

1 Diagnosis and Treatment: Imaging and Clinical Decision Support

AI uses computer-driven analysis to support clinician decision-making in diagnosis and treatment and to provide deeper insights to healthcare researchers, providers, and patients.

Imaging is one of the top expense categories for hospitals.

An early application of AI in healthcare is medical image analysis in radiology, where understaffing, increasing demand, and rising costs are significant concerns. IBM researchers estimate that medical images, the largest and fastest-growing data source in the healthcare industry, account for at least 90% of all medical data.[5] And imaging is one of the top expense categories for hospitals.

Reducing invasive procedures

Deep learning is being used in radiomics, a technology that detects an image's clinically relevant features beyond what can be perceived by the human eye.[6] This is increasingly being applied in oncology and holds promise for better accuracy than the currently used computer-aided detection (CAD).

Another advantage of AI in imaging is the potential to reduce the need for tissue samples and their risk of infection in favor of far less invasive MRIs, CT scans, and X-rays. In the future, images analyzed by AI could become "virtual biopsies."

In addition to diagnostics, AI in imaging may also aid treatment by speeding the discovery of new drugs and vaccines. Machine vision image analytics is an emerging technology that can identify which molecules might be effective for which biological targets.

Easing workloads

AI helps ease radiology workloads by conducting initial image screening for indicators of disease. It can also offer radiologists additional insights, confirming a diagnosis or flagging a possible human error. Based on these deeper, data-based insights, radiologists can more confidently make a final diagnosis. While computer models do not yet match experienced radiologists, a few early studies show that some computer models approach the diagnostic accuracy of trained physicians.[7]

Breast cancer screening

Millions of women worldwide have routine screening mammograms every year. The majority of them show normal, healthy breast tissue. Yet reading those images to confirm breast health represents a substantial burden on radiologists.

AI stands to transform the reading workflow — making worklists intelligent and highlighting and prioritizing studies that need deeper review and evaluation. Early evidence indicates that AI-based computer models have the potential to perform initial mammogram review and identify normal images. These models show that by using deep learning, computers can be programmed to recognize the difference between images of healthy and diseased tissue, often with accuracy similar to that of radiologists.[8] This analysis, however, was conducted with small data sets. More evaluation is needed in real-world conditions with larger data sets to confirm that AI can accurately recognize normal versus diseased breast images.[9]

Detecting hypoglycemia in diabetes patients

Tracking blood sugar levels is essential in diagnosing diabetes and even more vital for patients undergoing treatment. A sudden drop in blood sugar resulting in hypoglycemia can have serious consequences, including death.

A study by researchers at the University of Warwick found that by using deep learning technology, they could detect hypoglycemic events from raw electrocardiogram (ECG) signals acquired with non-invasive wearable sensors. Because the heart's electrophysiology is affected by hypoglycemia, an ECG can be used to detect onset.

The research was innovative in two ways. First, by using deep learning, researchers could monitor for and automatically detect hypoglycemia non-invasively with ECG beats, which can be detected in any circumstance, including during sleep. Second, they used a personalized medicine approach, training the AI model with each subject's own data. This was done to avoid problems past research had encountered where tests were impacted by differences among cohort patients.

A further advantage is that clinicians can adapt treatment based on this individualized information.

In two pilot studies, the technology worked with 82% reliability, which is comparable to the performance of a continuous glucose monitor (CGM) — but unlike a CGM, is non-invasive.

The researchers also developed a visualization method to show physicians which part of the ECG signal was associated with the hypoglycemia in each study participant.[10]

Although the study was small and only meant to test the feasibility of using deep learning-based solutions to monitor for hypoglycemia, the results are promising for both future elimination of finger-prick testing and further applications for machine learning.

Early and effective prostate cancer detection

Prostate cancer affects one in eight men. A current study at the University of Chicago School of Medicine uses deep learning to examine multi-parametric MRIs of prostate glands to detect cancer. The goal is to develop a screening method that is more accurate than any currently available, thereby assisting radiologists in diagnosis. By preventing false positives as well as identifying early-stage cancers, the system could prevent unnecessary prostate biopsies. The result would be better quality of life for millions of men and substantial cost savings.[11]

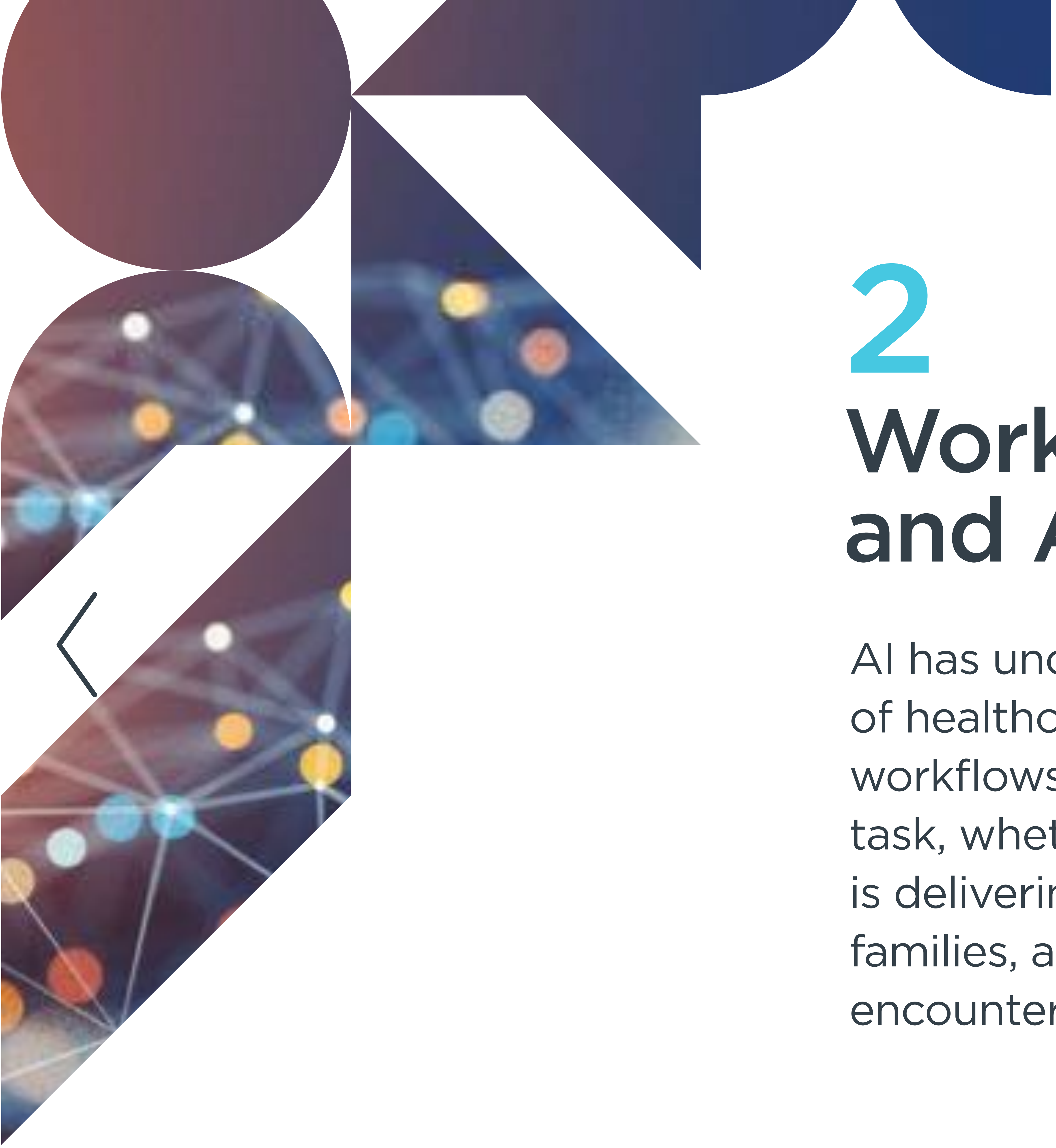
Heart attack prevention

Researchers at the Iowa Institute for Biomedical Imaging of the University of Iowa are studying the use of AI and optical coherence tomography (OCT) imaging to detect changes in heart tissue. They are using AI to help predict the likelihood of a patient having a heart attack.

The project uses AI to classify coronary tissues and predict coronary plaque vulnerability over the year following an initial physician visit. The study also evaluates the likelihood of future cardiovascular events. Researchers are using the power of deep learning to analyze coronary OCT images together with patient-based biomarkers. And they are using AI techniques to learn the relationships between the earliest information about the status of the coronary wall and clinical outcomes observed one year later.

> AI is being used to help predict the likelihood of a patient having a heart attack.

Successful AI-based prediction of coronary plaque vulnerability allows physicians to take preventive action at the first visit, making future heart attacks less likely to occur.[12]



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Workflows: Clinical and Administrative

AI has undeniable potential to transform many aspects of healthcare. One big category is the streamlining of workflows by building efficiency into each role and each task, whether clinical or administrative. The ultimate goal is delivering better quality of experience for patients, families, and providers — from first contact through every encounter, whether in the office, the hospital, or at home.

Clinical workflows

On the clinical side, AI can significantly impact efficiency by reducing the time to develop treatment plans. A good example is in oncology. These plans are complex and time-consuming, with consideration for available treatment modalities and targeting cancer cells while preserving healthy tissue. With thousands of ongoing clinical trials, there is more data than one oncologist could possibly synthesize. Yet this information could be critical to the patient.

ML and NLP can interpret volumes of study results and compare the data to a specific case — informing not only the treatment, but the best way to deliver it (another painstaking process that takes significant time). ML systems are able to create a treatment plan in minutes or even seconds.[13] Respondents in prostate cancer clinical trials, comparing ML-generated treatment plans with those created by expert human planners, ranked the ML plans as equivalent.[14] Moreover, most respondents had difficulty differentiating between plans created by human experts and those created by the ML system.

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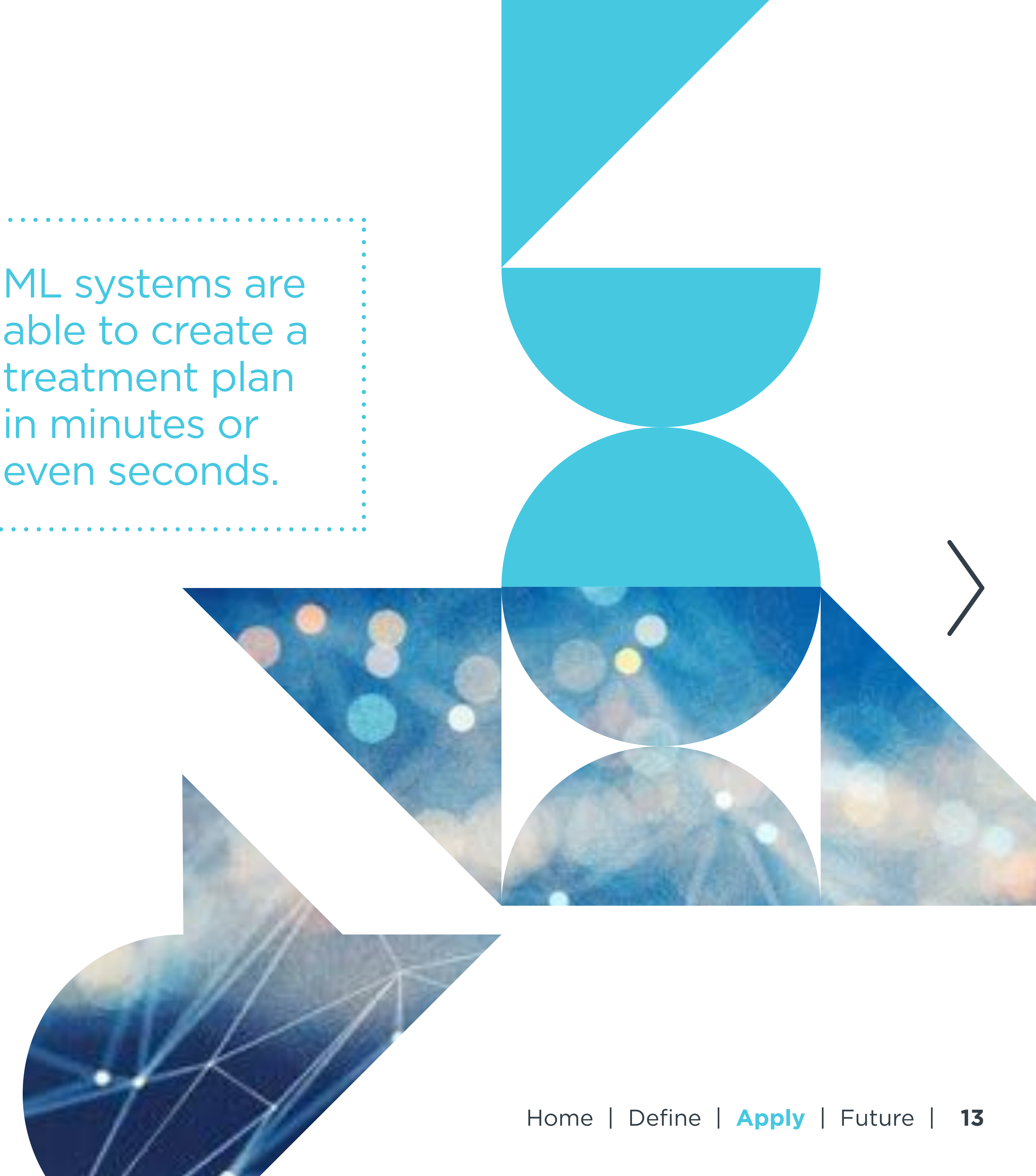

Administrative workflows

The administrative side of healthcare is one of the most recognized areas of AI value. According to *Business Insider Intelligence*, 30% of healthcare costs are associated with administrative tasks.[15] Many of these tasks are ripe for automation, including pre-authorizing insurance, following up on unpaid bills, and maintaining records.

NLP can be used to parse data from electronic health records (EHRs) and to convert unstructured data into computable form. This is valuable in consolidating handwritten notes, voice dictation, and computer-entered information into a patient's EHR.

The average nurse in the United States spends 25% of work time on regulatory and administrative activities.[16] Robotic process automation (computer programs, not physical robots) can be applied to a wide range of these, including patient scheduling, claims processing, and medical records management. This technology performs structured, repetitive tasks involving information systems — much like a person would follow a script or set of rules. It is a relatively low-cost technology and easy to program. AI could also help process routine inbox requests like medication refills and test result notifications.

All these AI use cases let front office staff spend more time addressing patient concerns and less time checking people in. Physicians and nurses can spend more time on patient interaction and less on paperwork, electronic or otherwise. Data analytics has also become a key component of organizational operations and efforts to increase efficiency and profitability — from reception to back-end offices, even to supplies inventory.

Streamlining clinical documentation

The advent of dictation and voice recognition has made the clinical documentation process somewhat easier, but some believe NLP tools could go much further.[17] They could bring changes like video-recording clinical encounters and using AI and machine learning to index the recordings for information retrieval. The future could also bring virtual assistants' embedded intelligence to the bedside for clinicians to use for order entry.

Patient engagement and convenience

Industries are increasingly adopting self-service models that allow customers to complete tasks when and where they want, on their own devices. AI can help healthcare do the same. Self-service benefits could include reduced cost, reduced patient waiting times, fewer errors, easier payment options, and increased patient satisfaction. Some provider organizations are also offering interactive online portals with NLP-driven chatbots to help with medication refills and other simple administrative tasks for a personalized, always-available experience.

3

Precision Medicine: Individual and Population

One of the most exciting and fastest growing areas in healthcare is precision medicine. What this means is diagnosis, treatment, and prognosis personalized to an individual patient — informed by analysis of data not only from that patient but from millions of patients, now and over time. This level of insight is what many believe will allow scientists and clinicians to predict and begin to prevent today's chronic diseases and much more.

Making it personal

On a more modest scale, this insight allows, for each patient, more accurate diagnosis and more effective treatment. In precision medicine, these are tailored to the patient's unique manifestation of their illness and receptivity to therapies — based on their genetic and environmental backgrounds. Life experience includes the social determinants of health (SDOH) like birthplace, housing, diet, workplace, and income that the World Health Organization has linked to differences in people's health status.[18]

The core building blocks of precision medicine are AI and genomics. Breakthroughs in next-generation sequencing and genomics analytics opened up a world of understanding. Genomics and AI, together powered by high-performance computing, are giving scientists innovative ways to mine and integrate healthcare and genomics data to make precision medicine a reality.

ML provides physicians with more information than has ever been available to help diagnose and design treatments individualized to the patient. One example is data from the fast-growing number of wearable devices that track heart rate or blood pressure. ML compares data collected on an individual patient to data from a group of patients. This comparison is made possible in large part by NLP, which standardizes patient records into data sets, aggregating information from large numbers of patients. This information can then be used to identify disease trends and predict which treatments are most successful within certain categories of patients. And it helps forecast the likelihood of a specific patient contracting a disease based on genetic predisposition and SDOH.

Genomics and AI, together powered by high-performance computing, are giving scientists innovative ways to mine and integrate healthcare and genomics data to make precision medicine a reality.

Accelerating high-performance computing (HPC) for population-level genomics[19]

Achieving population-scale precision medicine requires unprecedented levels of high-performance computing. In fact, two out of three analysis stages in genomics-based biomedical analyses require supercomputer power. Scaling up genomics production largely depends on scaling high-performance computing technologies. Performing the scope of analytics needed to gain timely, meaningful insight across populations means speed as well as processing capacity. Technology companies are working to develop hardware and software that will optimize existing systems so they can perform orders of magnitude more analytics in shorter timeframes.

Lenovo accelerates genomic analytics

Lenovo has extensively tested the performance of the Broad Institute's Genome Analysis Tool Kit (GATK) Germline Variant Calling Workflow — tools used by researchers to perform genomics analytics. The project examined variants in hardware, system tunings, data types, execution modes, and software implementations. The goal was to find the optimum configuration to accelerate the speeds at which genomes are assembled and analyzed. As a result, Lenovo developed its Genomics Optimization and Scalability Tool (GOAST).

For data centers not using optimized hardware and software, processing a single genome takes 150 to 160 hours. Work by Intel® in 2017 reduced that processing time to 10.8 hours. Now, with Lenovo's GOAST, a whole genome can be processed in just about one hour. Using Lenovo's genomics-optimized hardware, a data center can expect to process 23 whole genomes per node per day.

Better Human Health Enabled by AI

Developing artificial intelligence solutions to improve healthcare delivery around the world is the work of many organizations and thousands of individuals. As research and development continue, new possibilities and potential healthcare applications will emerge, expanding the horizon still further.

Even as scientists work to fulfill the promise of AI for moving healthcare from treating disease to preventing it, early applications are making their way into clinical settings.

For clinicians, that means easing their workload — streamlining patient screening and expanding the diagnosis and treatment of disease. For health systems, it means greater efficiency, better use of resources, and improved patient outcomes. For patients, it means a more convenient healthcare system, physicians able to make more informed diagnoses, and treatments tailored to the individual.

AI research and application add up to better human health — the goal of everyone involved in the quest.

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