Expert Insights

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Exploring quantum computing use cases for healthcare

Accelerate diagnoses, personalize medicine, and optimize pricing

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It has been proven that quantum computing can have an advantage over classical approaches.

Talking points

Disruptive healthcare use cases

In the healthcare industry, quantum computing could enable a range of disruptive use cases for providers and health plans by accelerating diagnoses, personalizing medicine, and optimizing pricing. Quantum-enhanced machine learning algorithms are particularly relevant to the sector.

Benefit from multiple data sources

As access to health-relevant data sources continues to grow, the potential for the combination of quantum computing and classical modeling to save lives and reduce costs increases.

Time to act is now

Healthcare is likely to benefit significantly from quantum computing. However, much of the early intellectual property in quantum computing may be proprietary, raising the urgency to get started and engage with partners and ecosystems today.

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Data for improved healthcare experiences and results

Healthcare data—such as information from clinical trials, disease registries, electronic health records (EHRs), and medical devices—is growing at a compound annual growth rate of 36 percent.[1] Increasingly, this data helps address challenges associated with the "quadruple aim" of healthcare: better health, lower cost, enhanced patient experiences, and improved healthcare practitioner work lives.[2] At the same time, healthcare consumers are making more decisions and have to navigate an increasingly complex system.

Significant investments are being made to deliver the right data and powerful insights at the point of care. Industry incumbents and new entrants alike are trying to create digital experiences that reinforce healthy, preventive behaviors. Despite that, accounting for the exponential possibilities from this diversity of new data is stretching the capabilities of classical computing systems.

Enter quantum computing.

A century after the birth of quantum mechanics, it has been proven that quantum computing can have an advantage over classical approaches.[3] Quantum computing does not merely provide an *incremental* speedup. It is the only known technology that can be *exponentially* faster than classical computers for certain tasks, potentially reducing calculation times from years to minutes.[4]

Quantum computing necessitates a different way of thinking, a new and highly sought-after set of skills, distinct IT architectures, and novel corporate strategies. The technology also has immediate implications for security.[5] Security is an area of particular relevance for healthcare, given the sector's data privacy responsibilities and challenges.

Insight: Bits and qubits

Quantum computers process information in a fundamentally different way from traditional computers. Previous computer technology advancements—such as integrated circuits—enabled faster computing, but were still based on classical information processing. Quantum computers manipulate *quantum bits* (qubits).

These are unlike classical bits, which store information as either a 0 or 1, and they can display uniquely quantum properties, such as entanglement. As a result, it becomes possible to construct quantum algorithms that can outperform their classical counterparts which are not able to leverage quantum phenomena.

Quantum computers could be particularly useful in tackling problems that involve:

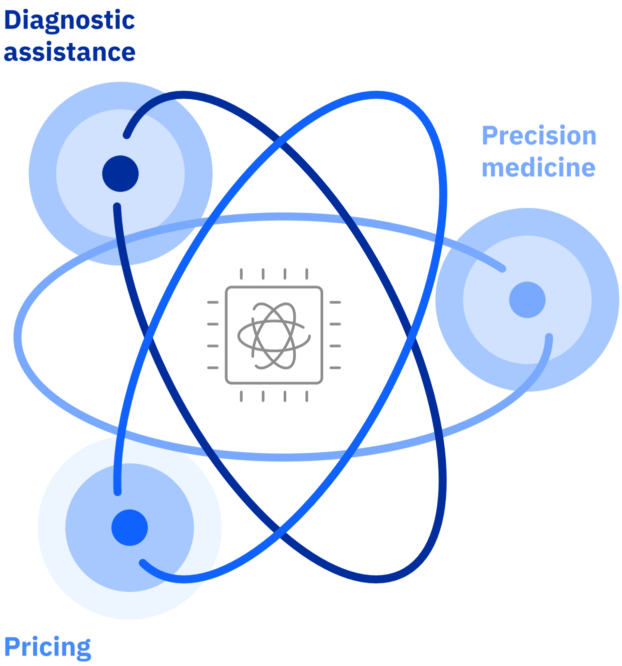
- Chemistry, machine learning/artificial intelligence (AI), optimization, or simulation tasks. In fact, machine learning has shown potential to be enhanced by quantum computing and is symbiotically helping drive quantum advances[6]
- Complex correlations and interdependencies among many highly interconnected elements, such as molecular structures in which many electrons interact
- Inherent scaling limits of relevant classical algorithms. For instance, the resource requirements of classical algorithms may increase exponentially with problem size, as is the case when simulating the time evolution of quantum systems.[7]

In healthcare, as in other industries, using quantum computers in concert with classical computers is likely to bestow substantial advantages that classical computing alone cannot deliver. As a result, there is now a race toward quantum applications. Following are three key potential quantum use cases that are central to the healthcare industry's ongoing transformation (see Figure 1):

1. *Diagnostic assistance:* Diagnose patients early, accurately, and efficiently
2. *Precision medicine:* Keep people healthy based on personalized interventions/treatments
3. *Pricing:* Optimize insurance premiums and pricing.

Figure 1

Quantum computers may enable three key healthcare use cases that reinforce each other in a virtuous cycle. For instance, accurate diagnoses enable precise treatments, as well as a better reflection of patient risks in pricing models.



Quantum computing has the potential to improve the analysis of medical images, including processing steps, such as edge detection and image matching.

Together, these use cases significantly help advance healthcare's quadruple aim. Diagnostic assistance could improve health, cost, experience, and jobs, while precision medicine should enable better patient outcomes and experiences, and pricing is expected to help reduce costs.

Use Case 1: Diagnostic assistance

Early, accurate, and efficient diagnoses usually engender better outcomes and lower treatment costs. For example, survival rates increase by a factor of 9 and treatment costs decrease by a factor of 4 when colon cancer is diagnosed early.[8] At the same time, for a wide range of conditions, current diagnostics are complex and costly.[9] Even once a diagnosis has been established, estimates suggest that it is wrong in 5–20 percent of cases.[10]

Medical imaging techniques, such as CT, MRI, and X-ray scans, have become a crucial diagnostic tool for practitioners over the last century. Computer-aided detection and diagnosis methods for medical images have been rapidly developing. At the same time, many of these images are impacted by noise, poor resolution, and low replicability.

One of the reasons for these challenges is the need to adhere to strict safety protocols. Quantum computing has the potential to improve the analysis of medical images, including processing steps, such as edge detection and image matching. These improvements would considerably enhance image-aided diagnostics.

Furthermore, modern diagnostic procedures may include single-cell methods.[11] In particular, flow cytometry and single-cell sequencing data typically require advanced analytical methods, especially when considering combining datasets from the different techniques.[12]

One challenge is the classification of cells based on their many physical and biochemical characteristics. These cause the feature space, that is, the abstract space in which the predictor variables live, to be large (high-dimensional). Such classification is important, for example, in distinguishing cancerous from normal cells. Quantum-enhanced machine learning approaches, such as quantum support vector machines, appear poised to enhance classification and could boost single-cell diagnostic methods.

Moreover, discovering and characterizing biomarkers may necessitate analysis of complex "-omics" datasets, such as genomics, transcriptomics, proteomics, and metabolomics.[13] These can entail a large feature space, as well as many interacting features leading to interdependencies, correlations, and patterns that are challenging to find with traditional computational methods.[14] Further extending biomarker insights down to the level of the individual naturally requires even more advanced modeling. These characteristics suggest that quantum computing could help discover biomarkers, perhaps even for individuals.

Through quantum computing, care providers may be able to improve diagnoses while simultaneously eliminating the need for repetitive invasive diagnostic testing. They may be able to continuously monitor and analyze the health of individuals. In addition to helping patients, health plans and providers could also benefit from reduced treatment costs as a result of earlier diagnoses. It might even become possible to carry out meta-analyses for more elaborate diagnostic procedures in order to determine which procedure should be carried out, and when. This could help further cut costs and enable more data-driven decisions by health plans and governments for providers and individuals.

Quantum-enhanced machine learning techniques could allow earlier, more accurate, and more granular risk predictions.

Use Case 2: Precision medicine

Precision medicine aims to tailor prevention and treatment approaches to the individual.[15] Due to the complexity of human biology, individualized medicine requires taking into account aspects that go well beyond standard medical care. In fact, medical care only has a relative contribution of 10 to 20 percent to outcomes; health-related behaviors, socioeconomic factors, and environmental aspects account for the other 80 to 90 percent.[16] Computationally, the interdependencies and correlations among these diverse contributors create formidable challenges with regard to optimizing treatment effectiveness.

As a result, many existing therapies fail to achieve their intended effects due to individual variability. For example, only a third of patients respond to drug-based cancer therapies. In some cases, consequences of drug therapies can be disastrous; in Europe alone, up to 200,000 people die each year due to adverse drug reactions.[17]

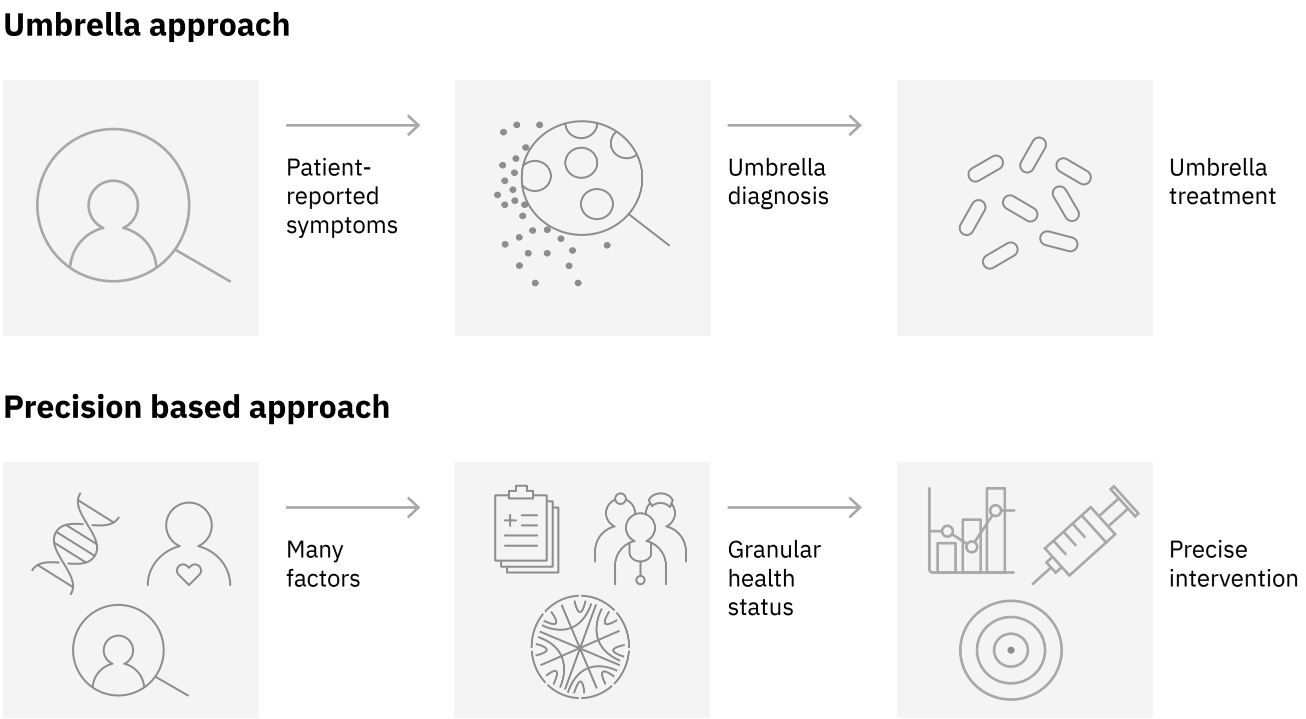
A key aspect of tailoring medical approaches is proactivity. As mentioned, early treatments and preventive interventions tend to drastically improve outcomes and optimize costs. Classical machine learning has already shown some promise in predicting the risk of future diseases for a range of patient groups based on EHRs.[18] Nevertheless, challenges remain due to the characteristics of EHRs and other health-relevant data, including the level of noise, size of the relevant feature space, and complexity of interactions among the features. This suggests supervised and unsupervised quantum-enhanced machine learning techniques could allow earlier, more accurate, and more granular risk predictions.[19] Eventually, medical practitioners might even have the tools to understand how an individual's risk for any given condition changes over time, enabled by continual virtual diagnostics based on ongoing data streams from individuals.

Knowing an individual's disease risk is not sufficient, however. Just as important is knowing how to effectively medically intervene for any given individual. One avenue in this endeavor is the study of drug sensitivity at the cellular level. For example, by taking into account the genomic features of cancer cells and the chemical properties of drugs, models that can predict the effectiveness of cancer drugs at a granular level are already being investigated.[20] Quantum-enhanced machine learning could support further breakthroughs in this area and ultimately enable causal inference models for drugs.

The goal of precision medicine is lofty. Identifying and explaining relationships among interventions and treatments on the one hand—and outcomes on the other—in order to provide the next-best medical action at the individual level. Traditionally, diagnosing a patient's condition has been based heavily on patient-reported symptoms, which is time-consuming and results in an umbrella diagnosis and associated treatment that frequently fails. We are now moving toward a setting where insights from additional health-relevant data can be obtained to efficiently arrive at a continuous and precise health status, along with personalized interventions (see Figure 2). While we are still a long way from realizing this, quantum computing may be able to accelerate our progress toward such a new framework by addressing problems of the type described in Use Cases 1 and 2.

Figure 2

Quantum computing has the potential to accelerate the transition from umbrella diagnosis and treatment to precision health status and intervention.



This framework would allow healthcare organizations to optimize and personalize their services throughout the continuum of care. Moreover, adherence and patient engagement are also key aspects to be considered when a decision is made as to the next-best medical action for a given individual. Perhaps advanced computational modeling might be able to address this area, too.[21] Eventually, population health management on a personal level could become possible.[22]

One key area in which quantum computing may help optimize pricing is risk analysis.

Use Case 3: Pricing

Determining health insurance premiums is a complex process. A number of factors need to be taken into account by a health plan in the process of developing a general pricing strategy (recognizing that regulations in some countries, such as the US, may limit the number of factors used to calculate premiums).[23] These include complex interdependencies, such as population health levels and disease risks, treatment suitability and costs, and the risk exposure a health plan is willing and able to accept based on corporate strategy and regulations. While health plans have already made considerable progress in this space by applying classical data science methods, achieving more granular models with lower uncertainties remains difficult.

One key area in which quantum computing may help optimize pricing is risk analysis. Use Case 2 discussed how quantum computing could help better assess the risk a given patient has for a given medical condition. Leveraging these insights about disease risk at the population level, and combining them with quantum risk models that can compute financial risk more efficiently, could allow health plans to achieve improved risk and pricing models.[24]

Another important lever through which quantum computing may support pricing decisions is enhanced fraud detection. Currently, healthcare fraud costs hundreds of billions of dollars in the US alone.[25] Classical data mining techniques already help with detecting and reducing healthcare fraud; nevertheless, more computationally efficient methods are needed.[26] Quantum algorithms could enable superior classification and pattern detection and thus help uncover anomalous behavior and eliminate fraudulent medical claims.[27] This is expected to allow health plans to further optimize pricing strategies and offer reduced premiums as a result of having lower costs associated with fraud loss and prevention schemes.

Quantum computing's novel algorithms may be able to significantly improve pricing computations. This could result in lower average premiums, as well as better-tailored premium options. The complexity of healthcare is reflected in the challenges associated with making pricing strategies easily understood. New regulations that require transparency and lower average healthcare costs make it even more important to enhance pricing models.[28]

Outlook

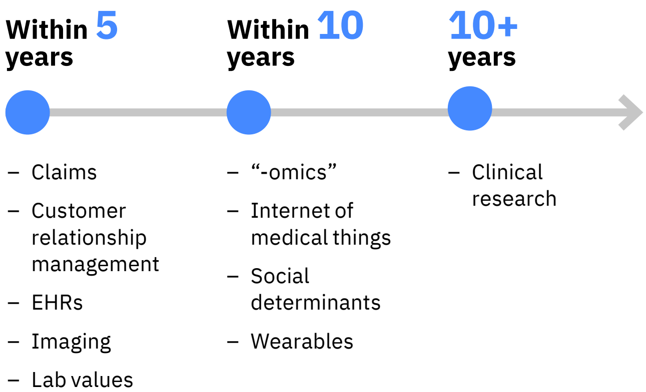
Healthcare data—collected from the many different modalities and locations that surround patients—is underused today. Clinical factors only account for a small percentage of health-relevant data. Therefore, obtaining actionable insights from other areas, including genomics, behavior, and social and environmental influences, is critical.

Of the different types of quantum algorithms relevant to the healthcare sector, quantum-enhanced machine learning algorithms stand out for their breadth of application. This is because we are entering an era where the characteristics of health datasets, such as being frequently heterogeneous and unevenly distributed, are producing complex computational challenges for modern AI. For instance, researchers have been exploring how to speed up the computationally expensive algorithms that are at the core of machine learning and AI modeling with quantum approaches, including operations with large matrices.[29]

The maturity horizons of quantum computing use cases in healthcare depend not only on cross-industry quantum algorithm and hardware developments, but also on the increasing availability of relevant data (see Figure 3). While certain modalities are already being leveraged for advanced computational modeling, health-relevant datasets are rapidly growing from increases in both the number of people being "instrumented," as well as the data types being collected. As the number of accessible health-relevant data sources continues to grow, the potential for quantum computing to add value likewise increases.

Figure 3

Relevant healthcare data sources and when they may start driving significant value.



Anthem: Enhancing the consumer healthcare experience

Anthem, a leading health benefits company, is expanding its research and development efforts to explore how quantum computing may further enhance the consumer healthcare experience. Bringing its expertise in working with healthcare data to the IBM Q Network, Anthem is exploring how quantum computing may help in developing more accurate and personalized treatment options and improving the prediction of health conditions.[30]

Action guide

Exploring quantum computing use cases for healthcare

Healthcare organizations are expected to reap considerable business and scientific benefits in the era of quantum computing. In addition to the benefits described above, this powerful technology may also create other advantages, such as attracting talent interested in working with next-generation technology.

Quantum advantage is likely to be proprietary, bestowing benefits on early movers. In order to start the journey and prepare for quantum advantage, healthcare organizations should take the following steps:

– *Engage quantum champions.* Identify, enable, and hire quantum champions in your organization—including both technology and healthcare professionals. They can serve as focal points to connect quantum expertise with healthcare imperatives. These quantum champions are tasked with staying up-to-date with the latest quantum developments and driving quantum initiatives in the enterprise.
– *Explore and prioritize.* Explore potential quantum use cases and prioritize the ones with the largest impact for your organization. This includes determining how quantum computing fits into your corporate and technology strategies. Update your priority use cases over time based on the latest corporate strategy and quantum computing developments.
– *Experiment.* Implement relevant quantum applications and experiment with real quantum computers.[31] This will allow you to drive toward quantum advantage and provide your employees with hands-on enablement.

These steps should be iteratively pursued. Accomplishing them can be accelerated by joining a quantum ecosystem, a group of industry and technology participants sharing risks and rewards in pursuing common quantum computing goals.[32]

Quantum computing has the potential to become a transformative enabler for healthcare organizations in their core mission: sustainably saving and improving lives. Thus, the time to get started with quantum computing is now.

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