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Quantum Technologies: Strategic Imperatives for Health and Healthcare Leaders

WHITE PAPER

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Contents

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Foreword

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Health and life sciences leaders are entering a period of growing complexity and pressure to deliver more effective, efficient and secure care. Quantum technologies are beginning to play a role in this shift, introducing new ways to model biological systems, improve diagnostic precision and strengthen the protection of sensitive health data. However, progress depends not only on exploring these technologies but also on understanding the pathways to operationalize them at scale. By building the right partnerships, frameworks and investment strategies, organizations will advance the responsible and effective usage of quantum technologies in the health and life sciences ecosystem.

The World Economic Forum and Accenture, through the Forum's Quantum Economy Network and the Centre for Health and Healthcare and its Digital Healthcare Transformation initiative, have convened experts from multiple disciplines to explore these questions. This white paper, which is part of an industry series building on insights from *Embracing the Quantum Economy: A Pathway for Business Leaders*, illustrates early progress, major challenges and enablers that will determine the pace of adoption. It captures examples of how leading institutions are thinking about quantum technologies, and maps readiness for broader implementation. Finally, the paper identifies the key regulatory, standards and talent foundations needed to translate emerging research into practical applications that enhance patient outcomes and strengthen health systems.

We thank all contributors who shared their time and expertise in shaping this work. We hope it supports decision-makers seeking to understand where quantum technologies can make a credible contribution to healthcare and life sciences, and what steps are needed to prepare for their integration in the years ahead.

Executive summary

Quantum technologies have the potential to disrupt the health industry and change the future of medical care forever.

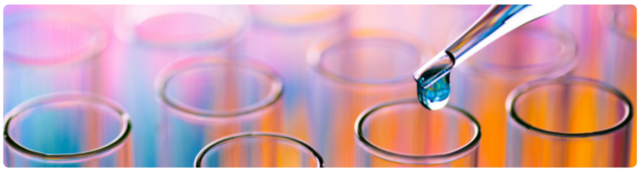
Quantum technologies are beginning to reshape many industries. The health and life sciences sectors stand out as being uniquely positioned to benefit from this change. Many of the most difficult challenges in these two fields, from simulating molecular interactions to measuring faint biological signals, are rooted in quantum physical phenomena. Advances that make it possible to model these processes accurately or measure them more precisely translate directly into new pathways for understanding the human body. The result is a sector where quantum computing, sensing and communication are not only relevant, but could accelerate drug discovery, enable earlier and less invasive diagnostics, improve patient outcomes and safeguard sensitive data. Forward-looking organizations are already investing, piloting and integrating quantum hardware, shaping their long-term strategy and developing talent to secure their place in this next wave of biomedical innovation.

Quantum solutions offer high-impact benefits for targeted use cases across health and life sciences. While quantum hardware for sensing, communicating and processing data continues to evolve, promising applications are gaining traction and maturing across four value pillars:

FIGURE 1 **Value pillars for quantum technologies**

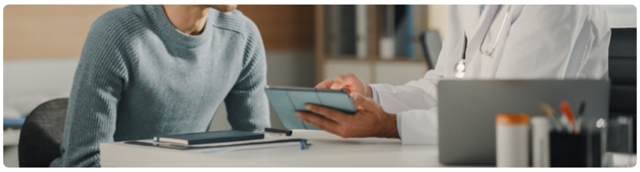
Discovery acceleration

Speeding up simulation-intensive R&D and reducing cost and time to market for new therapies



Operational optimization

Enhancing scheduling, logistics and care coordination across complex payer-provider networks



Trusted data infrastructure

Securing medical records, clinical workflows and artificial intelligence (AI) models across digital health systems

Precision diagnostics

Improving early disease detection and patient data analysis using quantum sensors

Source: World Economic Forum and Accenture.

Leaders in healthcare and life sciences are driving value through technological innovation by systematically exploring opportunities, both within their domains and in adjacent sectors, to determine where quantum has a role to play and can provide a competitive advantage.

Though still embryonic, the ecosystem around quantum technology in health is rapidly expanding, supported by prize-based challenges, pre-competitive R&D, international collaborations and government-backed initiatives. Private organizations are increasingly partnering with public institutions to advance clinical trials to protect patient safety, uphold ethical standards and ensure an optimal integration of quantum technologies in health systems. These combined efforts are improving biomedical R&D efficiency, accelerating learning and clinical insights, and de-risking investments by enabling shared infrastructure and alignment with trusted standards.

Quantum computing, in tandem with quantum sensing and quantum communication, hold great promise for revolutionizing health and life sciences. Quantum computing is expected to drastically accelerate applications that are currently unfeasible for traditional systems, significantly impacting the cost and time-to-market of multibillion-dollar projects. Quantum sensing is leading to breakthroughs that will move the needle on patient care standards and ultimately save lives. In the increasingly digital reality of health networks, quantum communication may drastically reduce the risk of breaches and tampering in electronic health records (EHRs), automated AI systems and remote procedures. Taken together, these transformative technologies offer a path to capabilities that were previously out of reach. The question is no longer whether quantum will transform health, but how pioneering organizations from biopharma creators to health deliverers and ecosystem enablers will lead in shaping that future.

Introduction

Leading organizations are at an inflection point, propelled by quantum breakthroughs in health.

Quantum technology represents a paradigm shift in healthcare, with the potential to redefine its entire value chain. Beyond enabling tailored treatment, quantum can accelerate the pace of drug discovery, safeguard sensitive data in increasingly digital healthcare ecosystems, and create more immersive and effective diagnostic tools. The convergence of quantum computing, sensing and communication will not simply enhance today's systems; it will open entirely new frontiers in medical science, shaping a future of healthcare that is more predictive, precise and patient-centred than ever before.

Quantum solutions for health can be categorized into three domains, each exploiting distinct principles of quantum physics to address specific bottlenecks.

FIGURE 2 **Quantum technology domains**

Quantum technologies

Quantum computing

Quantum computing takes advantage of quantum mechanics to solve complex problems that classical computers can't solve or can't solve quickly enough.

It uses entanglement and superposition to simulate molecular properties and interactions, accelerate structure-based drug design, model complex biological systems and optimize business processes that are computationally intractable.

Quantum sensing

Quantum sensors detect and measure tiny changes in time, gravity, temperature, pressure, rotation, acceleration, frequency, magnetic and electric fields.

They enable ultra-sensitive diagnostics and imaging by detecting subtle magnetic and bioelectric fields *in vivo*, supporting breakthroughs in neural mapping, cardiology, early disease detection and pharmaceutical production.

Quantum communication

Quantum communications involves the generation and use of quantum states for communication protocols.

It secures sensitive health data and clinical infrastructure through quantum key distribution (QKD) and quantum random number generators (QRNGs), offering protection based both in algorithms and the laws of physics.

Source: World Economic Forum and Accenture.

Quantum technology matters now because rapid technological advancement is converging with leading organizations' adoption and integration. This unique moment marks the transition from potential to real impact, positioning quantum as a catalyst for innovation across health institutions and life science firms.

Overall venture capital funding for quantum start-ups reached nearly $2 billion in 2024,[1] signalling not just speculative interest but a significant commitment to long-term value creation. The question is no longer whether quantum will matter, but why leading organizations are prioritizing it now – and how they are positioning themselves to capture its benefits.

C-level sponsorship is one of the key elements for quantum programme success. When asked about barriers to funding their quantum programme, Clemens Utschig-Utschig, Chief Technology Officer (CTO) and Chief Architect from biopharma company Boehringer Ingelheim, remarked: **"Securing board approval for our quantum programme was straightforward – there was clear understanding of its strategic importance and potential."**

This perspective underscores a critical shift: quantum is no longer viewed as an experimental technology on the periphery of R&D but rather as a strategic enabler of core business goals. Executive boards' willingness to approve significant investments reflects both the scale of the opportunity and the risk of inaction in a competitive landscape.

The current environment mirrors the early days of personal computing in the 1980s, when multiple architectures and operating systems competed for dominance. Today, development of quantum computing is advancing along many modalities, each with distinct advantages and disadvantages. At the same time, diverse pathways are being explored in quantum sensing and communication, laying the groundwork for their transformative roles in future biomedical innovation. This diversity reflects a competitive frontier, where leadership will be determined by pioneering health and life science organizations' ability to identify high-value applications and scale them effectively.

Momentum is further amplified by national funding programmes, health-focused quantum testbeds and cross-disciplinary partnerships that are accelerating algorithm development for biomedicine. Hospitals and research institutions are emerging as early adopters and co-developers, piloting solutions that integrate quantum capabilities into clinical and operational workflows. These dynamics point to a clear trajectory: the organizations making strategic, well-informed investments today will shape the standards, ecosystems and value chains of tomorrow.

Around the world, leading institutions are taking concrete steps to integrate quantum technology into health systems. Cleveland Clinic and IBM[2] – supported by the National Institute of Health, US – are advancing biomedical research using an on-site quantum computer. In the United Arab Emirates, the Technology Innovation Institute (TII) is partnering with regional hospitals and global quantum firms to explore sensing and simulation applications.[3] A cross-border EU consortium of universities, start-ups and pharmaceutical companies is developing quantum-enhanced healthcare solutions under the Horizon Europe framework.[4] Many of these entities are actively engaged with the World Economic Forum, whether through the Quantum Economy Network[5] or the Digital Healthcare Transformation Initiative.[6]

This report includes five sections, exploring the potential of quantum technology in addressing different health challenges:

Section 1: **Quantum's role in next-generation (next-gen) healthcare**: Outlines healthcare's core challenges and why quantum is uniquely suited to accelerate delivery, resilience and discoveries in pharma and human biology

Section 2: **Quantum for creators**: Explores how quantum can transform biomedical R&D, from target discovery to trials and manufacturing

Section 3: **Quantum for deliverers**: Assesses how quantum sensing, computing and communication can improve diagnostics, care and operations

Section 4: **Quantum for enablers**: Examines how regulators, infrastructure providers and funders shape adoption through standards, access and incentives

Section 5: **Strategic actions for healthcare innovators**: Highlights practical steps and collaborations that leaders can take to capture value and accelerate adoption.

These insights synthesize expert voices from across the quantum for health ecosystem. They are a guide to evaluating where quantum technologies offer practical advantages, how to allocate resources and when to engage.

1 Quantum's role in next-gen healthcare

Harnessing the transformative potential of quantum technology to advance the future of healthcare.

Technology-enabled healthcare innovation is increasingly recognized as a global priority, driving advances and collaboration across borders. Current achievements, gaps and future opportunities are best examined through the lens of distinctive health ecosystem roles across the value chain, from creators and deliverers to health enablers. This categorization lays out the argument for quantum technology as a catalyst for disruptive healthcare transformation, in view of current technologies' limitations and constraints when solving major industry challenges.

FIGURE 3 **Health ecosystem roles to drive quantum innovation**

Creators
Life sciences

Genetics research institutes, pharmaceutical labs, pharma companies, biotech firms, diagnostics providers, technology start-ups

Deliverers
Health

Hospitals, clinics, medical device providers, payer-provider networks, pharmacy chains

Enablers
Health and life sciences

Regulatory authorities, standard setters and global health agencies, national health agencies, technology and infrastructure providers (IT networks, security, hyperscalers, HPC centres)

← Health ecosystem roles →

Source: World Economic Forum and Accenture.

As observed in Figure 3, each role plays a cohesive part in delivering health outputs, from creating innovative drugs and treatments to ensuring they ultimately reach and benefit patients. A collaborative, interdisciplinary health ecosystem will be crucial for realizing quantum's potential by overcoming technical, ethical, economics and regulatory challenges.

Creators: the originators of scientific and biomedical breakthroughs

Creators play a critical role in shaping the future of healthcare. Recent achievements, including the rapid development of mRNA (messenger ribonucleic acid) vaccines, the deployment of AI-enabled diagnostics, and the rise of digitally coordinated global trials, have demonstrated how new tools and platforms can transform the pace, precision and reach of care. Yet barriers, from fragmented regulation to isolated research infrastructure, continue to constrain their global impact. Looking ahead, the greatest opportunities lie in integrating emerging technologies, including advanced AI, quantum computing and synthetic biology, expanding access to innovation, and building the collaborative foundations needed to turn discovery into scalable, real-world solutions.

Regulatory guidance for emerging technologies in clinical use is still limited and many systems lack the capacity to manage the growing volume of imaging, genomic and longitudinal patient data.

Deliverers: the providers of health-related services

From hospitals and clinics to pharmacy chains and care networks, deliverers are at the front line of patient care, turning innovation into tangible health outcomes. In recent years, they have rolled out telemedicine platforms, started using AI to support diagnostics and triage, and connected patient data through EHRs. These tools have helped speed up care by reducing manual work and facilitating early diagnosis of illnesses. But many systems still rely on outdated technology, which cannot easily and securely share data or employ policies that don't encourage innovation. Modernizing healthcare delivery will require building clear pathways and technical trust to drive the adoption of advanced technologies like quantum diagnostics, and ensure innovation that enhances patient care across multiple dimensions.

Enablers: the catalysts of the quantum for health ecosystem

Regulators, standards bodies, infrastructure providers and cloud platforms shape how new technologies are adopted and scaled in healthcare. In recent years, they have introduced fast-track approvals for digital health tools, launched frameworks for health data interoperability like Fast Healthcare Interoperability Resources (FHIR), and expanded access to cloud and high-performance computing for genome sequencing and large-scale clinical research. These advances have helped researchers and providers build, share and deploy new technologies more effectively. Regulatory guidance for emerging technologies in clinical use is still limited, however, and many systems lack the capacity to manage the growing volume of imaging, genomic and longitudinal patient data that is essential for personalized medicine. To enable the future of healthcare, regulators and industry must collaborate to create clear policies and standards for emerging tools and ensure the infrastructure exists to securely store, process and exchange complex health data.

Limitations of classical technologies in health and life sciences

The frontier of health and life sciences has been shaped by technological advances, but also by the inherent limitations of classical solutions. As observed in Table 1, the development of new underlying quantum technologies is now enabling a wave of innovation aimed at meeting critical strategic needs.

TABLE 1 **Quantum innovations across the value chain to meet strategic needs in healthcare**

Industry function	Current constraint	Strategic need	Quantum response
Discovery and development	Despite major AI advances, key gaps remain in predicting toxicity, translating lab results to real-world biology, generalizing to new targets and interpreting underlying mechanisms, limiting precision in next-generation therapeutic design.	Predictive and measurement tools that reduce cost, time and uncertainty in early-stage research, especially in drug development.	Quantum chemistry and machine learning for accurate modelling of molecular and biological systems; quantum sensing for ultra-precise detection and characterization at the molecular and cellular levels.
Detection and diagnosis	Diagnostic tools miss early signals or require invasive methods.	High-sensitivity, real-time detection to enable early intervention.	Quantum sensors for real-time, non-invasive detection of magnetic and bioelectric signals.
Decision and delivery	Growing risk of data breaches and fragmented digital systems.	Secure, integrated infrastructure for AI-driven healthcare delivery.	Quantum and post-quantum communication systems to secure EHRs, clinical workflows and AI pipelines.
Optimization and operations	Classical optimization is too slow for real-time decision-making in complex systems.	Adaptive, large-scale optimization to manage care delivery and resource use.	Quantum and hybrid solvers for dynamic scheduling and logistics in hospital and payer-provider networks.

Source: World Economic Forum and Accenture.

Quantum technology as a catalyst for disruptive healthcare transformation

Research and biomedical initiatives around the globe are already piloting the first wave of quantum technologies in healthcare and life sciences. Precision medicine, accelerated drug discovery, enhanced diagnostics and secure data transmission are all promising areas of research and focus. The following sections dig deeper into the value chain for creators, deliverers and enablers, to understand how quantum technologies can be a catalyst for disruptive healthcare transformation.

2 Quantum for creators

Creators ignite discovery and pioneer quantum breakthroughs for future therapies.

The pharmaceutical and biotech industries face some of the largest innovation barriers of any sector. Developing a new therapy can take more than a decade and cost billions of dollars in R&D, with high attrition rates at every stage. Each additional day of research represents millions in sunk costs, while unmet medical needs and competitive pressure demand faster and more precise solutions. Global pharmaceutical R&D investment in 2024 reached nearly $288 billion[7] despite economic headwinds. High-performance computing (HPC) and AI have pushed discovery forward, but encounter scalability limits for problems rooted in understanding quantum-level molecular behaviour. Likewise, classical sensing technologies have reached their limits of fidelity, constraining what can be measured and modelled in living systems.

Quantum technologies are emerging as a breakthrough solution for transcending these limits. By realizing new levels of accuracy, speed and scalability, they are beginning to unlock advantages in complex, time-critical areas of biomedical research. Some applications will disrupt existing solutions, while others will enhance critical stages of the research and development cycle, accelerating the path to new therapies. In a landscape where the pace of innovation is a major component of success, quantum-enabled platforms will be essential for accelerating development timelines and securing competitive advantages in the years to come.

Today, quantum applications for health are at different maturity stages. Some quantum sensing solutions are already showing real-world commercial potential, while quantum computing applications are either in the prototype phase or still in experimental mode, and require further advances in hardware.

2.1 Assessment of use cases maturity for creators

Stage 1: Commercial readiness (0–2 years)

A first wave of quantum sensing technologies is already in commercial use, bringing immediate value to biomedical research and production. Table 2 includes some of these examples. It must be noted that although the end-user and the ecosystem partner are essentially co-developers, they are presented separately hereafter for didactic purposes. The **end-user** is the final recipient of the solution, directly using it to meet its own business goals, while the **ecosystem partner** provides the underlying quantum hardware and expertise.

These use cases have marketed products and active research use only (RUO) deployments. They represent the entry point for quantum technologies into health creator workflows, where performance is already benchmarked against industry standards and adoption can generate near-term return on investment (ROI).

Actionable items to unlock value

- Identify specific quality assurance for biomanufacturing workflows where quantum sensors can replace or augment existing measurement systems.
- Partner with quantum technology providers to run comparative pilots in real-world conditions.
- Track yield, reliability and cost-of-ownership metrics to demonstrate value and build a case for scaling.

First-mover advantage: Improve process fidelity, reduce batch failures and establish leadership as the first to operationalize quantum sensing in health.

TABLE 2 | Commercial examples

Use case examples	End user	Ecosystem partner
Quantum photonic particle sensing for inline bioprocess control	Festo LifeTech Division	Q.ANT
NV-diamond biosensing for nanoparticle/biomarker assays	Harvard University and Boston Area Hospitals	Quantum Diamond Technologies (QDTI)

Stage 2: Prototype readiness (3–5 years)

The largest group of use cases sits here. The following is a non-exhaustive list of quantum use cases as they are being explored by large pharma R&D labs to demonstrate their feasibility and advantage when compared to classical systems.

These use cases already have enterprise prototypes and academic validation in place, and data assets exist to test their performance against classical baselines. They represent the frontier for near-term competitive advantage; early movers can shape intellectual property (IP), attract scarce quantum talent and build proprietary workflows.

Actionable items to enable prototype readiness

- Launch targeted pilots in collaboration with pharma companies, contract research organizations (CROs) or hospitals.
- Define clear key performance indicators (KPIs) (e.g. solution diversity, time-to-insight, attrition delta).
- Engage regulators early to align validation standards.

First-mover advantage: Accelerate development timelines, reduce attrition and establish stronger drug pipelines.

TABLE 3 | Prototype examples

Use case examples	End user	Ecosystem partner
mRNA secondary structure prediction	Moderna	IBM
Molecular dynamics simulation	Qubit Pharmaceuticals	PASQAL, NVIDIA
High-throughput ligand-protein interaction simulation	Qubit Pharmaceuticals	PASQAL
Bio-silico peptide screening for biomolecules and biomarkers	São Paulo State University (UNESP)	Qnity
Cohort selection optimization	Cleveland Clinic	IBM

Stage 3: Experimental readiness (6–10 years)

A second wave of applications is progressing from proof-of-concept towards maturity, including the use case examples in Table 4.

These examples are not yet enterprise-ready, but active pilots are demonstrating technical feasibility. Stakeholders who invest now can shape benchmarks, data standards and infrastructure integration, ensuring they capture the upside when these technologies move to production.

Actionable items to enable experimental readiness

- Establish joint industry and academic research to validate performance on real datasets.
- Build hybrid workflows that anticipate future integration with HPC/AI pipelines.
- Develop workforce skills around quantum-classical simulation synergies.

First-mover advantage: shorten routes to adoption, enhance the ability to shape market expectations and build defensible positions.

TABLE 4 **Experimental examples**

Use case examples	End user	Ecosystem partner
Protein folding prediction	Cleveland Clinic	IBM
Photodynamic property modelling	Cleveland Clinic	Algorithmiq, IBM

Stage 4: Theoretical readiness (10+ years)

Table 5 contains some transformative but longer-term applications.

These examples remain theoretical, requiring breakthroughs in fault-tolerant hardware and scalable algorithms to be business-ready. With long-term investment, however, success could fundamentally reshape how therapies are designed, tested and approved.

Actionable items to enable theoretical readiness

- Invest in exploratory research consortia.
- Define data-sharing and ethical frameworks that anticipate future capabilities.
- Begin horizon-scanning with regulators to avoid bottlenecks when breakthroughs arrive.

First-mover advantage: Redefine therapeutic frontiers and create a unique advantage when full-scale quantum modelling becomes possible.

TABLE 5 **Theoretical examples**

Use case examples	End user	Ecosystem partner
Predictive toxicology modelling	Yale University, Purdue University, Tokyo Tech	IBM
Biological simulation of treatment responses	Cleveland Clinic	IBM

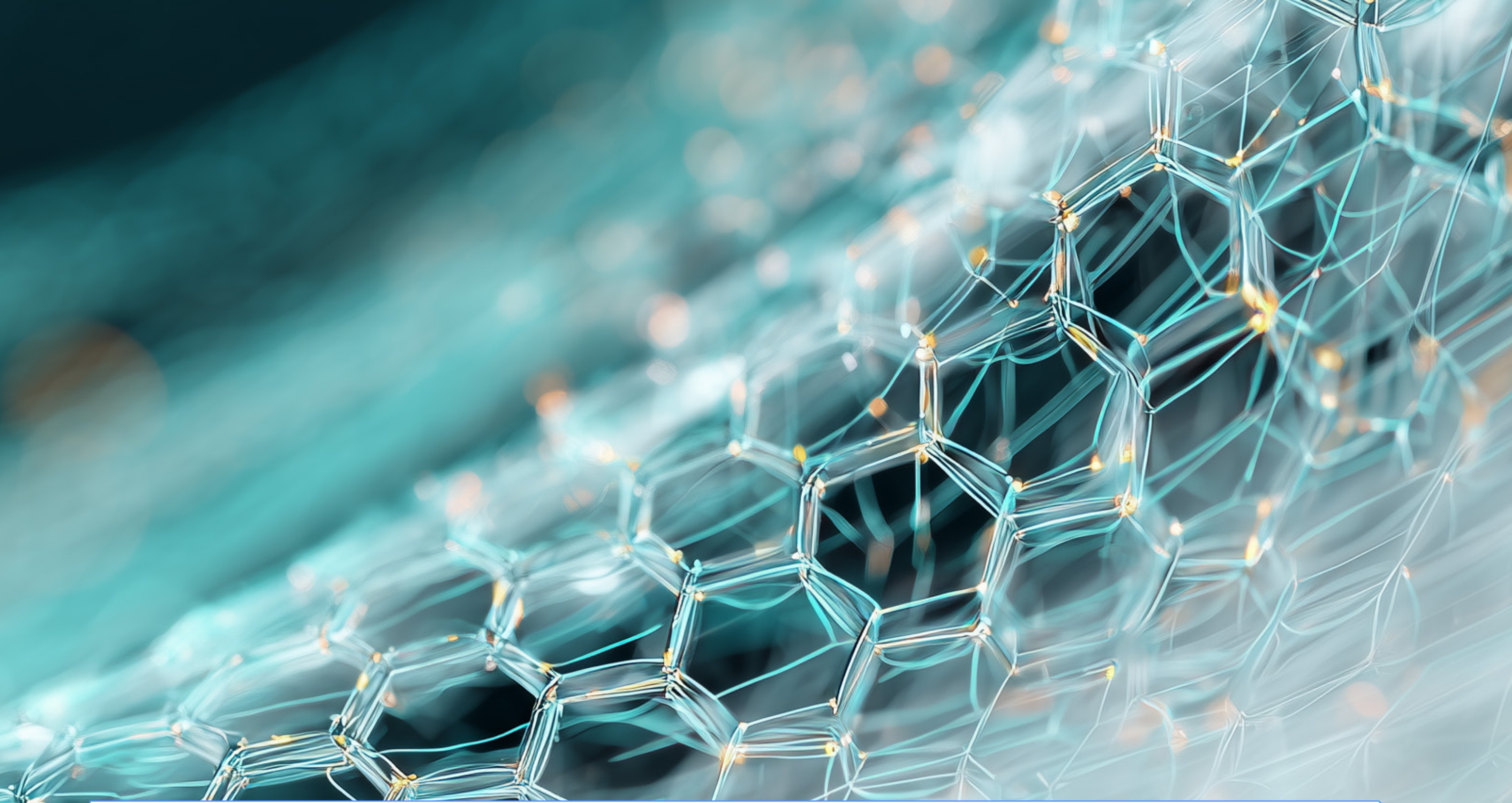
2.2 Quantum value chain for creators

From drug discovery to manufacturing, a growing number of organizations are experimenting with quantum technologies across the biomedical value chain to create business value. Most efforts remain in early stages; however, select examples help illustrate both the potential and the challenges involved in applying quantum solutions to health R&D.

TABLE 6 **Mapping use case maturity and benefits across the value chain**

Value chain stage	Quantum use cases	Maturity	Business benefits
Target identification	mRNA secondary structure prediction	Prototype (3–5 years)	– Cost and time savings – New revenue streams
Simulation and measurement	Molecular dynamics simulation	Prototype (3–5 years)	– Cost and time savings – New revenue streams
	Protein folding prediction	Experimental (6–10 years)	
	Photodynamic property modelling	Experimental (6–10 years)	
Candidate screening	High-throughput ligand-protein interaction simulation	Prototype (3–5 years)	– Cost and time savings – Enhanced clinical success
	Bio-silico peptide screening	Prototype (3–5 years)	
Preclinical modelling	Predictive toxicology modelling	Theoretical (10+ years)	– Enhanced clinical success – Cost and time savings
	Biological response simulation	Theoretical (10+ years)	
Clinical trials	Cohort selection optimization	Prototype (3–5 years)	– Cost and time savings – Enhanced clinical success
Biomanufacturing optimization	Quantum photonic particle sensing for inline bioprocess control	Commercial (0–2 years)	– New revenue streams – Cost and time savings
Quality assurance	Quantum diamond sensors for high-throughput magnetic bioassays	Commercial (0–2 years)	– Increased revenue – Cost and time savings

Source: World Economic Forum and Accenture.



CASE STUDY 1

Moderna – mRNA optimization using quantum computing

mRNA has become central to the development of vaccines and next-generation medicines. With this innovation comes the challenge of predicting how an mRNA strand folds into its functional shape. This process is extremely complex; the number of possible folds grows exponentially with sequence length, and current methods often miss key features such as pseudoknots – overlapping folds that play a crucial role in how RNA behaves. These gaps limit accuracy and reduce the number of viable candidates that can move forward in drug development.

Moderna, a leader in the creation of the field of mRNA medicine, is working with IBM to test the use of quantum computing to address these limitations. The team ran hybrid quantum-classical experiments on IBM's newest quantum processors. Even with today's quantum hardware limits, the results were comparable to classical methods, and in the future, quantum approaches could provide a more diverse set of possible structures for researchers to consider. This "solution diversity" is important because it increases the number of promising, unique candidates entering the pipeline, improving the odds of finding effective medicines.

In early pilots, workflows that would have taken weeks on HPC clusters were completed in hours using the hybrid approach. The ability to model structures more quickly and more completely could shorten development timelines, reduce costly failures and accelerate the pace at which new RNA therapies reach patients.

While the exact cost of production-scale quantum runs cannot yet be measured, Moderna has set a clear benchmark: cost-of-ownership parity when running quantum solutions, including infrastructure and talent, becomes comparable to the best classical alternatives. The company estimates this could be achieved by the end of the decade, when fault-tolerant machines with approximately 100 reliable logical qubits are expected.

> **Demonstrating quantum advantage alone is not sufficient; cost considerations are critical. The tipping point for us will be cost-of-ownership parity, when the full solution is less expensive than the best classical system.**
>
> Alexey Galda, Associate Scientific Director, Quantum Algorithms and Applications, Moderna.

Moderna is also investing in strong ecosystem ties to help ensure readiness, collaborating with IBM on quantum infrastructure. The company is participating in Wellcome Leap's Quantum for Bio (Q4Bio) programme to align with long-term stakeholders and safeguard continuity beyond early pilots. To tackle broader shortages of skilled quantum computing talent, Moderna is collaborating with top universities to create joint PhD programmes and using training partnerships, while also engaging early with regulators to de-risk adoption.

By building proprietary workflows and datasets now, Moderna is well-positioned to move quickly when cost parity is reached, opening the door to more efficient RNA design and the ability to solve problems that classical methods exclude.

CASE STUDY 2

Qnity – faster molecular screening with quantum-level precision

Start-ups are playing a critical role in bringing quantum technologies into the field of health by partnering with large enterprises and academic researchers. Qnity, a start-up based in the US and Brazil, is collaborating with a global pharmaceutical company to validate promising biomolecules in the context of drug discovery. Qnity's platform employs specially engineered electrodes to measure, with high resolution, the molecular affinity between biomolecules and different targets of interest. This approach enables scientists to more reliably assess whether a molecule has the potential to advance through the stages of new drug development. In pilots, Qnity is benchmarking the precision of its system against established methods such as surface plasmon resonance, a tool currently used in production systems across the pharmaceutical industry. Traditional approaches have been invaluable, but they often face sensitivity challenges, particularly when analysing small molecules.

Qnity's approach offers higher resolution data on these molecular interactions, accelerating target selection and validation throughout the drug discovery process. The system is adaptable: while initial work focuses on proteins, the same platform can be tuned to study small molecules, significantly broadening its potential use in pharmaceutical research and clinical testing. For the pharmaceutical partner, this collaboration provides a way to compare cutting-edge quantum-enabled sensing with industry-standard methods and build confidence in the technology. For Qnity, it is an opportunity to generate the extensive datasets needed to demonstrate value at scale, attract regulatory attention and secure adoption in enterprise R&D pipelines.

By linking start-ups, established companies and university researchers, projects like this create a pathway for quantum sensing technologies to move beyond proof of concept into the mainstream of biomedical research. The expected impact ranges from faster identification of biomolecules for novel therapeutics to more precise and cost-effective diagnostics platforms, and the emergence of a new generation of analytical tools that surpass the limitations of current measurement systems.

Our work can pave the way for identifying functional biomolecules that accelerate the discovery of new drugs, and in the future, it may also be extended to extremely precise early diagnosis and interventions in complex diseases such as Alzheimer's disease.

Diego Stone Aires, Co-Founder and Chief Executive Officer, Qnity

3 Quantum for deliverers

From hospitals to clinics, deliverers turn quantum promise into medical care.

In frontline healthcare, speed, accuracy and seamless data integration are critical for delivering better patient outcomes. Quantum sensing technologies are detecting biological signals with new levels of sensitivity as they move from research to early clinical trials in diagnostics, patient monitoring and imaging. Quantum communication is strengthening security for critical infrastructure in payer-provider networks, and quantum computing shows promise to drive advanced optimization for treatment planning, hospital operations and cold-chain logistics. Many systems are advancing towards cost-effective and portable form factors; however, pilots already show that quantum-enabled solutions can improve clinical outcomes and operational efficiencies.

3.1 Assessment of use cases maturity for deliverers

Stage 1: Commercial readiness (0–2 years)

Table 7 includes a first group of quantum-enabled technologies, which are already in commercial and early clinical use in the US.

These use cases have marketed products or live deployments. They represent the entry point for quantum technologies in frontline delivery workflows, where performance is already benchmarked against existing standards and adoption can generate near-term ROI.

Actionable items to unlock value

- Evaluate quantum imaging solutions and measure economic/diagnostic trade-offs to complement existing diagnostics.
- Pilot quantum-inspired scheduling tools in operating theatres to optimize use, cancellations and throughput.
- Track patient outcomes, cost savings and workflow efficiency to demonstrate value.

First-mover advantage: Improve patient outcomes, reduce wait times and capture cost efficiencies; establish leadership in applying quantum tools in clinical care.

TABLE 7 **Commercial examples**

Use case examples	End user	Ecosystem partner
Magnetocardiography (MCG) for cardiac imaging	West Virginia University Heart and Vascular Institute, The Christ Hospital Health Network	Genetesis (CardioFlux)
Operating room block scheduling and utilization optimization	Baptist Health South Florida	Fujitsu

Stage 2:
Prototype readiness
(3–5 years)

The largest group of "pilotable today" use cases are in this category, and is laid out in Table 8.

These use cases already have enterprise pilots and clinical validation studies under way. They represent the frontier for near-term competitive advantage; early movers can secure partnerships, access scarce talent and build proprietary clinical datasets.

Actionable items to enable prototype readiness

- Launch pilots in neurology or cardiology departments to evaluate OPM-MEG and bedside MCG performance in real patient cohorts.
- Partner with hospitals or telecommunications companies (telcos) to create QKD-secured links for imaging or EHR transfers and benchmark against cybersecurity standards.
- Define clear KPIs (diagnostic accuracy, time-to-triage, key exchange stability, avoided breaches).

First-mover advantage: Generate faster and more accurate diagnostics, reduce cyber risk and improve patient trust in data handling.

TABLE 8 **Prototype examples**

Use case examples	End user	Ecosystem partner
Wearable OPM-MEG (optically pumped magnetoencephalography) for paediatric/neurology diagnostics	SickKids, Toronto	Cerca Magnetics
Bedside/portable AI-assisted MCG	Mayo Clinic	SandboxAQ
Quantum biomarker algorithms for multimodal cancer data	University of Chicago	Infleqtion
Quantum-secure hospital data links	Abeer Group	Quantasphere

Stage 3:
Experimental readiness
(6–10 years)

A second set of applications is progressing from proof-of-concept towards prototype.

These are not yet enterprise-ready, but pilots are showing that quantum tools can capture real-world complexity in ways that classical methods struggle with. For providers, this points towards faster and more accurate treatment planning and improved surgical outcomes.

Actionable items to enable experimental readiness

- Engage in pilots using actual hospital scheduling or treatment datasets to benchmark quantum against best-in-class classical optimization and AI.
- Develop hybrid workflows where annealers or quantum neural networks (QNNs). complement machine learning for staffing, treatment planning or surgical decision support
- Invest in workforce readiness by training clinical operations teams and data scientists in quantum optimization and modelling.
- Shape evaluation standards in consortia with other providers, to ensure reproducibility, regulatory compatibility and sufficient capacity as these systems mature.

First-mover advantage: Accelerate deployment, improve treatment precision, and reduce complications and patient wait times.

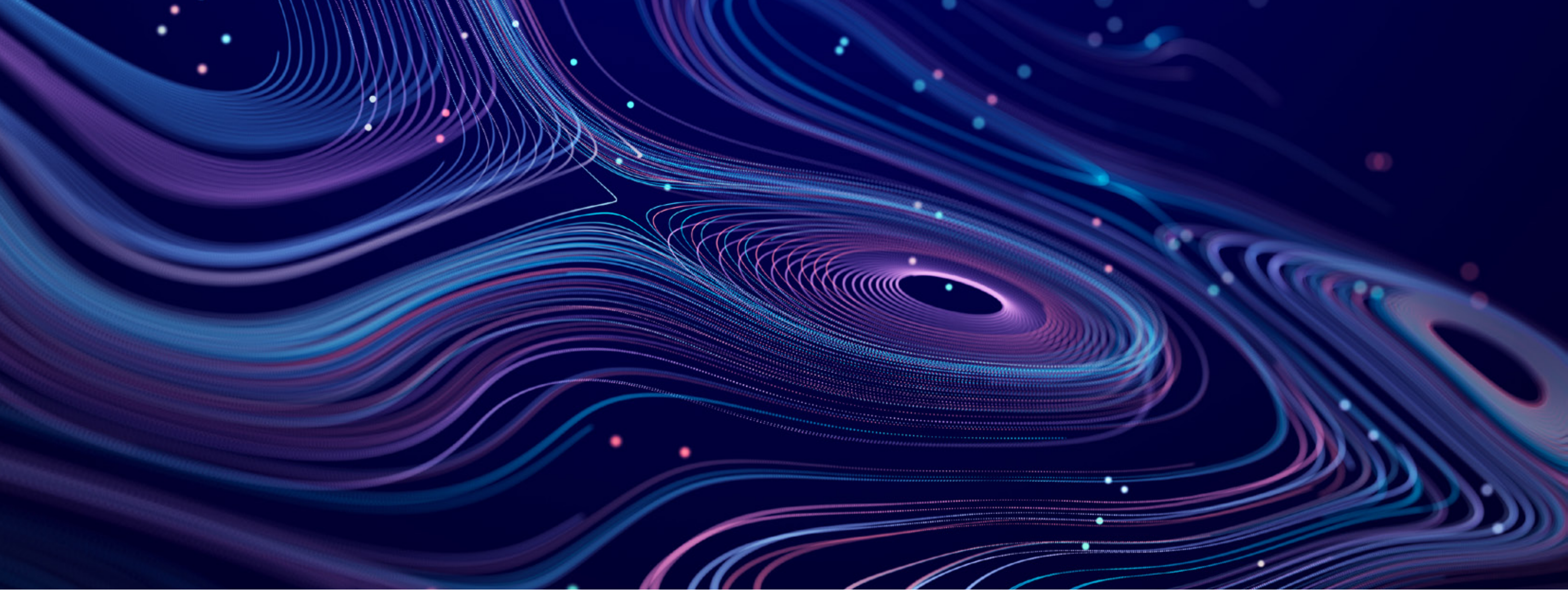


TABLE 9 | **Experimental examples**

Use case examples	End user	Ecosystem partner
Early lung cancer detection biomarkers using hybrid quantum-classical biomarker modelling	Cleveland Clinic	IBM
Quantum neural networks for surgical risk prediction	University Hospital Ostrava, Czechia	IT4Innovations National Supercomputing Center
Fluid dynamics of brain aneurysms	Albert Einstein Jewish Brazilian Hospital	UNESP, QuaTI.tech

Stage 4: Theoretical readiness (10+ years)

Some transformative but longer-term applications are detailed in Table 10.

These remain theoretical, requiring breakthroughs in scalable hardware and integration. Success could, however, fundamentally reshape aspects of how hospitals forecast demand, allocate resources and deliver preventive care.

Actionable items to enable theoretical readiness

- Join exploratory consortia on oncology modelling, quantum networking and biomedical imaging, aligning with both hospitals and quantum technology providers.
- Define governance frameworks for integrating real-time clinical data into quantum-enhanced models, with attention to privacy, ethics and regulatory oversight.
- Monitor hardware and sensor roadmaps closely, ensuring early exposure to scalable architectures (fault-tolerant qubits, entangled-photon sources, integrated OPMs).
- Build capacity for clinical validation by investing in protocols for measuring cost-effectiveness, safety and workflow integration once prototypes become testable.

First-mover advantage: Secure hospital network data exchange and healthcare delivery, improve the safety and effectiveness of preventive diagnostics.

TABLE 10 | **Theoretical examples**

Use case examples	End user	Ecosystem partner
Continuum of quantum-secure healthcare networks	Medical University of Graz	ID Quantique; fragmentiX; OPENQKD
Low-dose, high-contrast quantum biomedical imaging solutions	University Hospital Ostrava	NIST (National Institute of Standards and Technology)

3.2 Quantum value chain for deliverers

Across the patient care continuum, healthcare organizations are beginning to explore quantum technologies in ways that align with core delivery functions, from diagnosis to treatment, operations and supply chain management. Although most deployments are in the early stages, a growing set of pilots demonstrates how quantum sensing, computing and communication could enhance precision, efficiency and security in the health delivery value chain.

TABLE 11 **Mapping use case maturity and benefits across the deliverers' value chain**

Value chain stage	Quantum use cases	Maturity	Business benefits
Diagnostics and screening	Wearable OPM-MEG for paediatric/neurology diagnostics	Prototype (3–5 years)	– Time savings – Enhanced clinical success – Cost savings
	Quantum biomarker algorithms for multimodal cancer data	Prototype (3–5 years)	
	Early lung cancer detection using hybrid quantum-classical biomarker modelling	Experimental (6–10 years)	
	Low-dose, high-contrast quantum biomedical imaging	Theoretical (10+ years)	
Treatment planning	Quantum neural networks for surgical risk prediction	Theoretical (10+ years)	– Enhanced clinical success – Cost savings
Patient monitoring	Bedside/portable MCG	Prototype (3–5 years)	– Time savings – Enhanced clinical success – Cost savings
	Low-dose continuous biomedical imaging	Theoretical (10+ years)	
Hospital operations	Operating room (OR) block scheduling and use optimization	Commercial (0–2 years)	– Cost savings – Time savings
Payer-provider coordination	Quantum-secure hospital data links	Prototype (3–5 years)	– Cost savings – Reduce risk
	Continuum of quantum-secure healthcare networks	Theoretical (10+ years)	

Source: World Economic Forum and Accenture.

CASE STUDY 3

Mayo Clinic – quantum magnetocardiography for cardiac diagnostics

Cardiovascular disease remains the leading cause of death globally, yet the diagnostic tools available to clinicians often face trade-offs in speed, resolution and cost. Electrocardiography (ECG) is the gold standard method to diagnose acute ischaemia in patients with chest pain. ECG does, however, have considerable limitations that contribute to over- and under-diagnosis in up to 25% of patients. Mayo Clinic is using longstanding leadership and partnerships to investigate a new modality: MCG.

In collaboration with SandboxAQ, Mayo is running an observational study in Rochester, enrolling 150 patients with suspected acute coronary syndrome. The study hypothesizes that a novel quantum MCG device (CardiAQ®; SandboxAQ) and AI analysis can improve the diagnosis of coronary artery disease. Unlike traditional methods, MCG measures the magnetic fields generated by the heart, the strongest bio-magnetic source in the human body. Introduction of MCG devices in clinical settings could open up possibilities for simplified workflows, data-rich outputs and potentially earlier detection of cardiac abnormalities. The clinic now has two MCG machines on site and expects major outcomes within the next year. Mayo's cardiology team, working closely with AI researchers, is examining how MCG data can be integrated into existing reporting and electronic medical record systems with minimal infrastructure overheads.

The key challenges that have been identified are twofold. First, completing rigorous clinical research to prove MCG's distinct advantage and cost effectiveness; second, positioning MCG as a credible platform technology within an ecosystem of competing modalities. As Mayo's representative noted, the pathway resembles a platform adoption curve (early validation followed by network effects) as hospitals and clinics adopt the technology at scale.

Looking forward, Mayo envisions two tracks. In the near term (3–5 years), MCG could become a standard fixture in major clinics, enabling effective triaging of chest pain patients. In parallel, "blue sky" research led by SandboxAQ imagines portable devices deployed in pharmacies or homes, extending preventive care into community settings. Such a proliferation could shift cardiac care from reactive interventions to proactive prevention, while also offering cost efficiencies that are critical to healthcare systems worldwide.

CASE STUDY 4

University of Chicago and Wellcome Leap Q4Bio – quantum biomarker algorithms for multimodal cancer data

Biomarkers are essential for cancer care, helping doctors identify the type of cancer and choose the right treatment. Yet finding reliable biomarkers that fully use the vast and complex amount of biological data collected from patients remains one of the hardest problems in oncology. Today's approaches often rely on hundreds or thousands of data points, which are costly to measure, difficult to interpret and not always accurate. The result is an industry that spends tens of billions of dollars each year on biomarker discovery and testing, without a clear path to decreasing costs and increasing precision.

With support from the Wellcome Leap Q4Bio programme, researchers at the University of Chicago, Massachusetts Institute of Technology (MIT) and Infleqtion are exploring whether quantum computing can provide a step forward. The team has concentrated on feature selection, the process of identifying the smallest set of data points that are most predictive of cancer outcomes. Their approach has shown that it may be possible to classify dozens of cancers using as few as 10 to 35 genes, instead of hundreds or thousands. Smaller, more focused biomarker sets could dramatically reduce the cost of testing, make the results easier to interpret and improve how well findings translate into real-world clinics.

Early results are promising. The team has demonstrated that quantum methods can highlight patterns across large, complex cancer datasets that are hard to uncover with today's best tools. This work is now being benchmarked against leading classical approaches and scaled towards demonstrations on new generations of quantum hardware. If successful, it could help doctors more easily determine the tissue of origin in cancers that have already spread and, in the future, predict which patients will respond best to specific therapies.

> **We can now begin to see what resources will be needed, and how quantum could change the way we discover and use biomarkers in cancer.**
>
> Alexander T. Pearson, Director, Data Science and Head/Neck Cancer Programs, University of Chicago

4 Quantum for enablers

Enablers set up the infrastructure, standards and security frameworks to advance health-focused pilots.

With record patient backlogs, healthcare systems are under mounting pressure to deliver faster, more precise and more resilient care. Yet adoption of advanced technologies often stalls when infrastructure, standards and security frameworks are not in place. Data networks remain vulnerable to emerging threats, interoperability gaps slow clinical integration and hospitals face barriers accessing the computational resources needed to evaluate new solutions.

Frontier diagnostic solutions face their own adoption constraints, as hospitals operate under tight capital budgets and must meet multiple layers of regulation requirements before those diagnostic tools can reach patients. Talent pipelines are also strained, with limited programmes preparing clinicians, data scientists and IT staff to operate at the frontier of quantum-enabled care. Without coordinated action, promising pilots risk remaining isolated rather than scaling into daily practice.

Shaping the future of healthcare will require regulatory authorities, standard setters, global and national health agencies, and infrastructure providers to work collaboratively, establishing clear rules for quantum technologies deployment while ensuring the infrastructure is in place to protect patients' health.

FIGURE 4 **Key enablers to advance health-focused pilots**

Source: World Economic Forum and Accenture.

Post-quantum standards are already being embedded into health IT foundations, while interoperability frameworks need to evolve to enable secure data exchange across systems.

Regulatory uncertainty is a barrier that delays the availability of frontier technologies to support better health systems. A robust and ethical framework is essential to maintain momentum and build trust, balancing innovation with patient safety. For quantum devices, the pathway to adoption will hinge on rigorous standards of safety, ethics and clear evidence from clinical trials. Regulatory bodies such as the US Food and Drug Administration (FDA), European Medicines Agency (EMA) and others will require proof that these innovations deliver clear benefits without introducing new risks (e.g. cryogenic or magnetic field exposure).

Moreover, quantum-enhanced AI models could introduce algorithmic bias and a lack of explainability, raising ethical concerns in medical treatment decisions. Regulatory frameworks are therefore critical for providing the credibility and trust needed to move quantum technology from experimental promise to clinical reality.

Building a robust and safe **health infrastructure** is equally complex. Healthcare organizations deliver critical services where any breach can compromise patient safety and the confidentiality of medical records. In the last few years, cyberattacks have grown exponentially. For instance, a recent ransomware attack against UK-based pathology provider Synnovis, a partnership between two London-based hospital trusts and SYNLAB, caused severe shortages of O-type blood because the ransomware disrupted the ability to process and transfuse blood efficiently.[8]

Quantum communication will not only safeguard data now and for the future, but will also enable healthcare providers to focus on their core businesses. Post-quantum standards are already being embedded into health IT foundations, while **interoperability frameworks** need to evolve to enable secure data exchange across systems. Joint provider-industry testbeds are validating new models of protection, ensuring resilience against future threats. At the same time, access to infrastructure is broadening – through cloud platforms, on-premises systems, and integrated HPC-quantum resources – requiring secure interconnected systems.

The gap of professionals with **expertise in quantum** within the healthcare sector is huge. More academic and training programmes are critical for building the necessary talent, from cardiologists trained in quantum innovations to quantum experts that combine biology, statistics and computer science skills to develop algorithms.

Finally, **public and private incentives** will be pivotal to advancing health-focused quantum pilots. Organizations such as Wellcome Leap are already backing the Q4Bio challenge to accelerate breakthrough solutions, while government bodies like the US National Institutes of Health (NIH) are establishing dedicated programmes and grants for quantum biomedical research. Over the longer term, sustained investment and innovative funding mechanisms will be essential, not only to scale promising pilots but also to embed quantum as a durable and trusted pillar of the healthcare ecosystem.

4.1 Building the pillars of healthcare enablement

Stage 1: Establish the foundations (0–2 years)

The immediate focus is to build the technical and institutional foundations that allow quantum technologies to enter the healthcare ecosystem safely. This involves embedding cryptographic standards, creating first secure links between hospitals, provisioning access to quantum infrastructure, and launching funding programmes that **de-risk investments** while encouraging start-up participation.

Key enablers

- Adoption of NIST post-quantum cryptographic protocols across health IT baselines and procurement frameworks
- Launch of hospital-to-hospital QKD pilots to validate secure quantum communication in clinical contexts
- Targeted funding programmes that lower the investment barrier for start-ups and research groups
- Foundational governance and compliance runbooks to standardize early adoption

How to act now

- Run mission-driven quantum for health challenges to unite start-ups, clinicians, academic and industry partners.
- Update IT and cybersecurity baselines to incorporate post-quantum cryptography.
- Deploy the first QKD-enabled hospital pilots with standardized operational procedures.
- Offer compliant HPC/quantum access services for health-sector experimentation.
- Embed quantum-readiness criteria in early-stage health technology grants.

Sustained public and private funding and accelerator programmes help ensure start-ups can grow beyond pilots and contribute to system-level adoption.

First-mover advantage: Reduce cybersecurity risk and increase resilience, demonstrate secure integration of quantum technologies and attract start-ups into the ecosystem by lowering investment barriers.

Stage 2: Scale across health systems (3–6 years)

With initial standards and pilots proven, the priority shifts towards scaling across health systems. Enablers at this stage expand secure testbeds, integrate quantum with national HPC infrastructures, align procurement standards and scale talent pipelines. Sustained public and private funding and accelerator programmes help ensure start-ups can grow beyond pilots and contribute to system-level adoption.

Key enablers

- National alignment on QKD, post-quantum and HPC-integration standards across hospitals and agencies
- Integration of HPC plus quantum in national supercomputers (coupling quantum systems to Tier-0 HPC)
- Expansion of OPENQKD-style healthcare testbeds to multiple clinical domains
- Public-private funding continuity for accelerators and applied research consortia
- Scaled workforce programmes linking academia, hospitals and industry

How to act now

- Embed QKD evaluation metrics and quantum-readiness criteria into health procurement and certification.
- Publish validated results and KPIs from scaled testbeds to drive interoperability.
- Integrate quantum simulation and secure data pipelines into national HPC systems.
- Expand accelerator and talent programmes (e.g. through Discovery Accelerator-style models).
- Align funding with verified healthcare use cases to support the transition from pilots to production.

First-mover advantage: Enable pathways for start-ups to scale beyond pilots, provide hospitals and industry with interoperable, production-ready quantum solutions, and improve economics and operational efficiency through secure, scalable infrastructure.

Stage 3: Institutionalize (7–10 years)

The longest-term priority is embedding quantum into the healthcare ecosystem as a regulated, durable and funded component of national infrastructure. This includes co-funding secure continental networks, aligning standards with regulatory frameworks and building long-term financing mechanisms that sustain adoption beyond pilot programmes. At this stage, public and private investments ensure quantum becomes part of the healthcare backbone rather than an experimental add-on.

Key enablers

- Cross-border data-sharing frameworks integrating quantum security for clinical and research exchange
- Long-term public-private investment dedicated to quantum-health networks
- Alignment of reimbursement, certification and procurement rules with quantum-secure standards
- Governance frameworks that enable international coordination, interoperability and oversight

How to act now

- Co-fund continental quantum-health networks (e.g. EuroQCI extensions) to link hospitals and research hubs.
- Formalize multilateral coordination to harmonize standards and accelerate trust in cross-border health data exchange.
- Create regulatory sandboxes to manage compliance as quantum becomes integral to digital health infrastructure.
- Secure long-term public-private financing to scale quantum health infrastructure and drive cross-functional innovation.
- Embed quantum-secure requirements into national reimbursement, certification and procurement policies.

First-mover advantage: Establish the governance, standards and infrastructure that embed quantum as a trusted element of healthcare systems, ensuring secure data exchange, sustained public-private collaboration and the safe translation of emerging breakthroughs into improved patient outcomes.

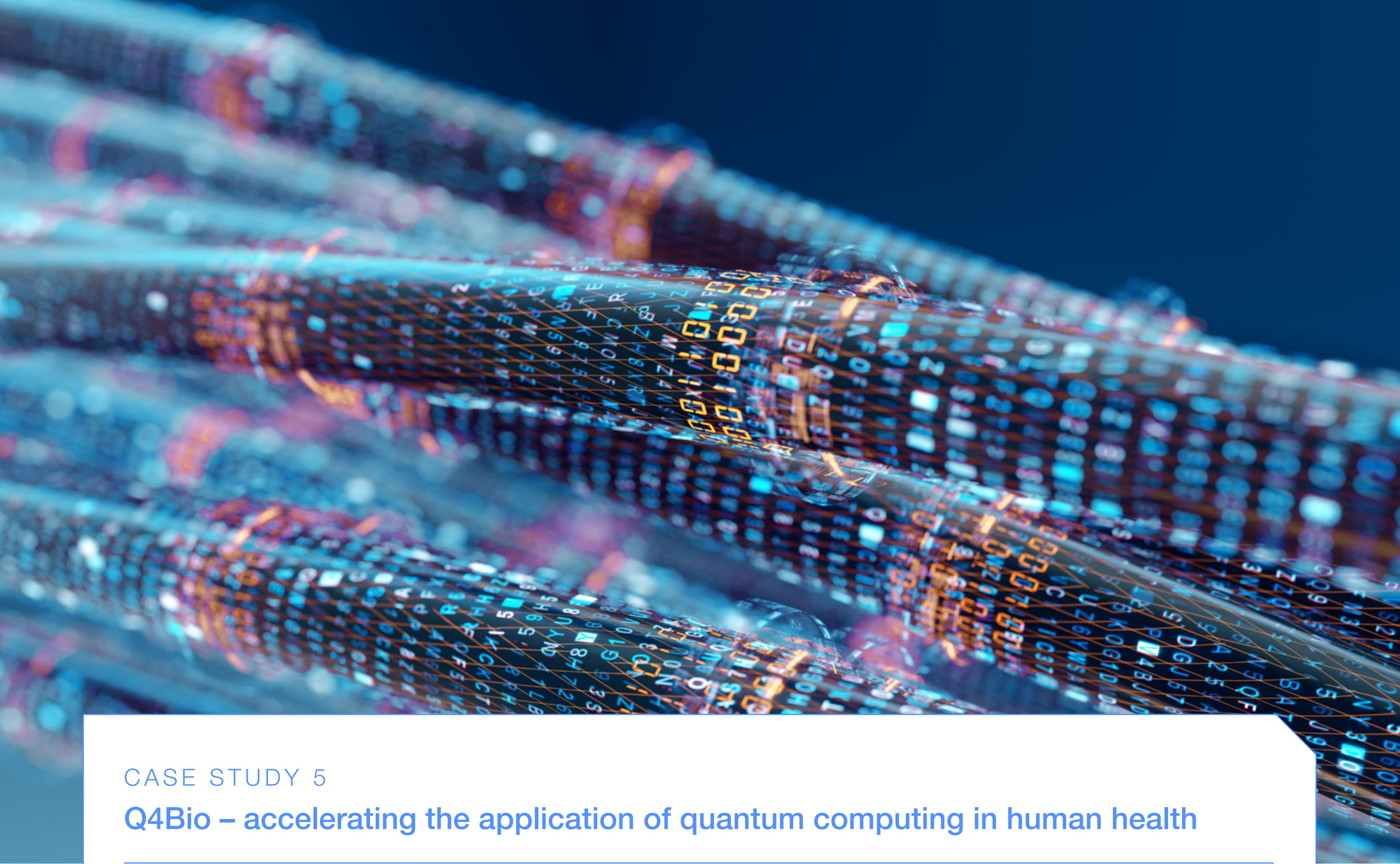
4.2 Quantum value chain for enablers

From financing and standards to infrastructure and workforce, a growing set of enablers is taking coordinated action to prepare the health ecosystem for quantum adoption. These efforts range from embedding secure frameworks and building testbeds, to funding new innovative projects and scaling networks. A number of initiatives are at the establishment stage, and select examples already demonstrate how enablers can reduce systemic risk, attract investment and create the conditions for start-ups and enterprises to scale quantum solutions in healthcare.

TABLE 12 **Mapping strategic actions across the enablers value chain**

Value chain stage	Strategic action	Timeline	Ecosystem benefits
Financing and incentives	Run mission-driven quantum-for-health challenges **(Wellcome Leap Q4Bio)**	Establish (0–2 years)	– De-risking investment
	Co-fund continental secure network build-out with health in scope **(EuroQCI, ESA-EC partnership)**	Institutionalize (7–10 years)	– Risk reduction – Cost savings
Standards and interoperability	Adopt NIST post-quantum cryptography in health IT baselines **(NIST CSRC)**	Establish (0–2 years)	– Risk reduction
	Reference QKD evaluation standards in procurement/assurance	Scale (3–6 years)	– Risk reduction – Cost savings
Cybersecurity and data governance	Create hospital-to-hospital QKD links **(Telefónica and Vithas)**	Establish (0–2 years)	– Risk reduction
	Use OPENQKD healthcare testbeds to harden operations and report KPIs/performance. **(OpenQKD)**	Scale (3–6 years)	– Risk reduction – Cost savings
	Scale towards EuroQCI health-sector infrastructure for national networks. **(Digital Strategy EU)**	Institutionalize (7–10 years)	– Risk reduction
Infrastructure provisioning	Provide healthcare-grade quantum access via cloud/HPC **(IBM Quantum Network, AWS Bracket, Azure Quantum)**	Establish (0–2 years)	– Time savings – Cost savings
	Deploy on-site hospital testbeds (e.g. IBM Quantum System One at Cleveland Clinic under the 10-year Discovery Accelerator). **(IBM and Cleveland Clinic)**	Establish (0–2 years)	
	Integrate HPC and quantum in national supercomputers (EU HPCQS, LUMI-Q; coupling quantum systems to Tier-0 HPC). **(EuroHPC)**	Scale (3–6 years)	
Pilot and testbed coordination	Use OPENQKD and partner sites to run healthcare pilots (medical data/EHR, imaging) and publish methods/metrics. **(OpenQKD and ID Quantique)**	Scale (3–6 years)	– Risk reduction – Cost savings
	Create joint provider–industry testbeds around secure data exchange and clinical pipelines **(Telefónica)**	Establish (0–2 years)	– Risk reduction
Training and workforce development	Launch quantum-for-health talent pipelines (e.g. Cleveland Clinic –IBM Discovery Accelerator internships and education pillar). **(Cleveland Clinic and IBM)**	Scale (3–6 years)	– Increased talent pipeline
	Fund national QIST (Quantum Information Science and Technology) workforce programmes (NSF Quantum Leap Challenge Institutes with explicit training mandate; QuBBE focus on bio/biophysics). **(NSF – National Science Foundation)**	Scale (3–6 years)	– Increased talent pipeline – De-risking investment

Source: World Economic Forum and Accenture.



CASE STUDY 5

Q4Bio – accelerating the application of quantum computing in human health

The Wellcome Leap Q4Bio supported challenge programme was launched in September 2023 with $50 million in funding to accelerate quantum applications in biology. The programme is structured as a DARPA-style challenge but with a global mandate, and is designed to move from problem identification to feasibility demonstrations on real hardware within just thirty months.

Q4Bio unfolds in three phases. Phase 1 identified health problems most likely to benefit from quantum approaches, starting with twelve initial teams. Phase 2 supported eight teams in simulating and verifying algorithms. Phase 3 now supports six finalists who must demonstrate working solutions on near-term quantum computers. These collaborations bring together multidisciplinary teams from universities, start-ups, technology companies, national labs and healthcare leaders. Each team combines expertise in hardware, software and biology to ensure that algorithms are both scientifically rigorous and clinically relevant.

Six finalist teams

- Algorithmiq, IBM and Cleveland Clinic
- Nottingham, Phasecraft and QuEra
- Harvard, MIT and QuEra
- Infleqtion, MIT and University of Chicago
- Oxford University, Cambridge University and Wellcome Sanger Institute
- Stanford University, NASA, Brown University, Virginia Tech, Michigan State University and the Lawrence Berkeley National Lab

The programme's goal is not to wait for fully mature machines, but to demonstrate meaningful progress with the quantum computers expected in the next three to five years, while they are still advancing towards technical maturity. By requiring solutions that can be realized in this timeframe, Q4Bio helps close the gap between emerging hardware and pressing health applications. Teams are also required to benchmark their approaches against best-in-class classical algorithms in healthcare, ensuring that progress is measured against the strongest existing standards rather than theoretical baselines.

For Q4Bio, success is measured in frameworks that connect biological problems to quantum solutions end to end, creating meaningful scientific results while building confidence for adoption. Teams are already attracting additional funding and partnerships, extending the impact beyond the programme's initial investment.

“In a fast-moving and competitive field like health and life sciences, waiting for a clear tipping point is a risky strategy that could leave you outpaced – and once that happens, catching up may prove improbable, if not impossible. The edge will belong to those who act while others hesitate.

Shihan Sajeed, Program Director, Q4Bio

CASE STUDY 6

Merck – driving quantum innovation through collective strength

Merck is a founding member of the Quantum Technology and Application Consortium (QUTAC), established to explore, together with peer companies, how quantum computing can complement existing methods for material and drug development. Traditional molecular simulation techniques face unavoidable trade-offs that make them either limited in precision or constrained in the size of the systems they can model. This creates bottlenecks for innovation in pharmaceuticals and advanced materials, where higher accuracy and larger system sizes are often critical.

Through QUTAC, Merck collaborates with BASF, Boehringer Ingelheim and other German industry leaders in a pre-competitive setting. Together, members co-develop intellectual property, define reference problems and establish benchmarks that guide the development of algorithms and hardware towards applications with measurable industrial impact. By contributing R&D use cases, data and scientific expertise, Merck helps ensure that the most pressing challenges in chemistry and pharmaceuticals are represented in the early stages of ecosystem building.

This work is aimed at embedding quantum components into established R&D workflows, overcoming the precision/efficiency trade-off in molecular simulations, and benchmarking problems of industrial importance. It also seeks to create shared intellectual property that de-risks early exploration and to strengthen Europe's digital sovereignty by ensuring critical health and materials challenges are included in the industrialization of quantum technologies.

This approach positions Merck as both a user and an enabler. By shaping shared frameworks and participating in collaborative IP development, Merck supports Germany's ambition for digital sovereignty while helping bridge the gap between world-class scientific research and commercial leadership. The company's engagement illustrates how industrial actors can strengthen the foundations of an emerging quantum ecosystem while preparing their own pipelines for future breakthroughs.

The development of effective quantum algorithms is still a major challenge that we need to overcome. It's a long journey ahead, but one worth taking.

Philipp Harbach, Global Head, Group Digital Innovation, Merck

CASE STUDY 7

Abeer Group – securing healthcare data in preparation for a post-quantum era

Abeer Group, a regional healthcare provider, is one of Saudi Arabia's largest groups in the affordable healthcare segment, serving more than 4 million patients a year. As part of its ethos, patient confidentiality and the confidential nature of EHR are of paramount importance from an ethical, operational and regulatory perspective. With the recent surge in AI-driven cyberattacks and the future vulnerability of data, given the emergence of quantum computing, Abeer seeks long-term security through a quantum-safe solution.

Quantasphere, a quantum communications company, will enable Abeer Group to protect patient data and ensure healthcare operations are secure against cyber threats. Both companies have signed a memorandum of understanding (MoU) to implement quantum solutions in two phases. The first step will enable Abeer clinics and remote staff to safely exchange information by using the provider's API-based quantum entropy engine (QEE). This engine harnesses quantum entanglement to deliver the highest level of randomization for encryption keys, so confidential records and communications always stay private – without the need for any extra equipment at the clinics.

The second phase will add an on-site QEE, strengthening protection for critical internal networks across facilities and sensitive mobile devices. This advanced capability will give Abeer full control over its own security systems and support safe connections between clinics, medical staff and external partners. By doing this, Abeer Group will be one of the first healthcare providers in Saudi Arabia to use quantum technology to keep patient data safe.

Abeer Group is committed to being at the forefront of all technological advances. Our partnership with Quantasphere will reduce our cybersecurity budget by 50%, creating a robust long-term framework for our data and ensuring that we are fully compliant with regulatory requirements even before they are instated.

Ahmed Alungal, Executive Vice-President, Abeer Group

5 Strategic actions for healthcare innovators

Key imperatives for unlocking the full potential of quantum for health.

Leaders across the health and life sciences industry share common priorities that shape investments, strategic alliances, operations and talent. Creators can strengthen innovation leadership by combining C-level sponsorship, sustainable R&D funding, and pre-competitive collaborations with efforts to integrate AI, HPC and quantum across discovery pipelines, partnerships and emerging diagnostic platforms. Deliverers, meanwhile, can enhance healthcare performance by embedding quantum-secure architectures into digital health roadmaps, piloting optimization programmes in supply chains and scheduling, and preparing technology procurement strategies that integrate quantum sensing and future-ready logistics. Finally, enablers can accelerate responsible adoption by coordinating funding streams, advancing interoperability standards and aligning public-sector roadmaps with quantum-safe cryptography and regulatory readiness.

Together, these perspectives create a foundation that links sector priorities with actionable pathways, clarifying how quantum can deliver tangible outcomes across research, care delivery and governance.

5.1 Common strategic actions

- **Build coordinated partnerships to accelerate quantum innovation across the ecosystem**: Collaboration between health organizations, quantum developers, cloud platforms and research institutions enables emerging methods to be explored and refined in step with health innovation priorities. Co-designed solutions help mitigate risks related to access, integration and supply chain limitations.

- **Participate in structured pre-competitive and interdisciplinary efforts to advance the validation of quantum computing and sensing tools**: Engaging in collective modelling benchmarks, shared evaluation studies and cross-domain working groups enables stakeholders to define the validation criteria that will guide how quantum techniques are assessed. It also allows them to determine where methods show meaningful technical gains and identify which sensing approaches exhibit credible early clinical feasibility across research and care-delivery settings.

- **Coordinate modernization and investment strategies to strengthen quantum-safe digital resilience and ecosystem-wide readiness**: Aligning digital transformation programmes with PQC preparedness, crypto-agile design principles and co-investment in secure infrastructure and talent development reinforces data protection and builds the capabilities required for responsible adoption across the sector.

5.2 Creators

- **Ensure C-level sponsorship to focus quantum exploration on priority scientific objectives**: Executive alignment provides clear direction for where quantum experimentation supports core R&D priorities and ensures the organization develops the capabilities and structures needed to evaluate emerging approaches as they mature.

- **Integrate AI and advanced computing systems across R&D to harness the combined impact of next-generation technologies**: Coordinated efforts across strategy, R&D and technology teams enable quantum methods to be incorporated alongside AI-driven modelling and high-performance simulation, creating opportunities to broaden the landscape of computable biological questions.

- **Advance quantum-enabled measurement and laboratory innovation where R&D teams control the scientific workflow**: Assessing emerging quantum-enhanced laboratory and measurement technologies such as advanced sensing, molecular readout and precision assay tools helps R&D groups determine where new capabilities could raise data quality, reduce experimental bottlenecks or deepen visibility into biological processes that current tools cannot reliably measure. This supports more reliable early discovery and strengthens the scientific foundation for downstream clinical translation.

5.3 Deliverers

“ Healthcare operations can be transformed by solving complex optimization challenges such as demand forecasting, surgery scheduling and inventory control.

- **Implement quantum-safe protection for clinical systems, device fleets and hospital data flows**: Upgrading EHR exchanges, medical-device connectivity and intra-hospital network traffic to PQC-aligned and QKD-ready architectures protects critical care workflows against long-horizon decryption risks. Focusing on high-exposure areas such as imaging transfers, remote monitoring, pharmacy systems and interfaces between hospitals and diagnostic partners, helps ensure sensitive clinical information remains protected as encryption standards evolve.

- **Launch a next-generation operations programme that pilots quantum-inspired optimization to achieve operational excellence in health delivery**: Applying quantum-inspired techniques to scheduling, forecasting and resource allocation enables more adaptive operating models, supports better alignment of staff and clinical capacity, and improves the responsiveness of complex care delivery systems.

- **Integrate quantum sensing and diagnostic decision-support tools into clinical evaluation and procurement processes**: Assessing emerging sensing modalities and computational diagnostics within triage, imaging and monitoring workflows helps identify high-feasibility use cases, align device requirements with long-term clinical strategies and prepare health systems for adoption of next-generation diagnostic capabilities. This enhances clinical outcomes, reduces downstream treatment costs and supports proactive models of care.

5.4 Enablers

- **Lead multistakeholder working groups to define how quantum-safe encryption integrates into emerging health interoperability standards**: For health organizations, this involves incorporating quantum-resistant cryptographic algorithms and QKD into the newly established protocols.

- **Publish healthcare industry guidelines for transitioning to quantum-safe cryptography, coordinated with NIST timelines**: Organizations must adapt cryptographic solutions to meet new compliance standards without disrupting patient care. Some actions are already taking place. For instance, the FDA's 2023 Premarket Cybersecurity Guidance[9] explicitly requires manufacturers to ensure crypto agility throughout the product's use and provides reasonable assurance that devices can be kept secure over their life cycle.

- **Mandate roadmap alignment for all public-funded healthcare IT projects to adopt post-quantum cryptography (PQC) readiness milestones**: Healthcare organizations should start planning and migrating now to prepare for future regulatory readiness, mitigate the risks of "harvest now, decrypt later" attacks, and maintain credibility by adopting quantum-safe encryption for their sensitive patient data.

- **Accelerate quantum for health public and private funding and promote quantum challenges**: To unlock the value of quantum technologies, multiple public and private funding streams will be required to boost the health industry. A few funded initiatives are already under way, including governmental programmes like the NIH's SEED programme[10] and Australia's Critical Technologies Challenge Program.[11] Private initiatives such as Wellcome Leap's Q4Bio funds might also bring transformative improvements in human health in the next five years.

Conclusion

Quantum technologies are poised to transform healthcare, advancing drug discovery, diagnostics and treatment, and safeguarding sensitive patient data. The integration of quantum computing, sensing, communication and security opens up new frontiers for life sciences and healthcare. As quantum technologies continue to evolve, opportunities that can benefit the health industry grow exponentially. Major barriers such as hardware limitations and scalability issues persist, however, while significant ethical and regulatory challenges require further attention.

Now is the time for life sciences and health leaders to begin to shape our future use of quantum technologies. Finding sponsorship from the executive board to initiate pilot projects is an essential step for testing quantum for health solutions and gathering initial outcomes. Businesses should identify key areas for investment, considering the market potential and the talent required to achieve the desired results. Due to safety risks concerning unknown long-term effects of exposure to quantum devices or materials on human health, a rigorous set of standards and multilayer regulations will be needed to move from clinical trials to actual deployment. Potential bias in quantum-AI systems might also generate a trust crisis, if not developed with a responsible approach. Multidisciplinary teams are needed, therefore, to study the long-term implications of this frontier technology from every possible angle.

The World Economic Forum is actively engaged via the Quantum Economy Network and the Digital Healthcare Transformation Initiative in promoting dialogue among creators, deliverers and enablers, helping to prioritize the necessary steps to scale the ecosystem and connect investors with quantum start-ups to promote a culture of innovation. As testament to the Forum's willingness to contribute to this agenda, UpLink and the Quantum Economy Network launched the Quantum for Society Challenge[12] in November 2024 to find impactful, scalable quantum solutions to secure a sustainable and healthy future.

Quantum can become a powerful force for a more personalized, patient-centric healthcare system. To accomplish this goal, organizations will need to put in place clear and actionable roadmaps, assessing both the opportunities and risks of action and inertia. Companies and health institutions that do not start their quantum journey soon will be at a significant market disadvantage, unable to match the capabilities of leaders who use quantum technology for cost efficiency and growth.

Appendices

A1 Inventory

TABLE 13 **Creator use cases – solutions detailed in Table 6 span across other health ecosystem roles**

Use case	Deliverers	Enablers
mRNA secondary structure prediction		
Molecular dynamics simulation		
Protein folding prediction		
Photodynamic property modelling	✓	
High-throughput ligand–protein interaction simulation		
Bio-silico peptide screening		
Predictive toxicology modelling	✓	
Biological response simulation	✓	
Cohort selection optimization		✓
Quantum photonic particle sensing for inline bioprocess control		
Quantum diamond sensors for high-throughput magnetic bioassays		✓

TABLE 14 **Deliverer use cases – solutions detailed in Table 11 span across other health ecosystem roles**

Use case	Creators	Enablers
Wearable OPM-MEG for pediatric/neurology diagnostics		
Quantum biomarker algorithms for multimodal cancer data	✓	
Early lung cancer detection using hybrid quantum-classical biomarker modelling	✓	✓
Low-dose, high-contrast quantum biomedical imaging		
Quantum neural networks for surgical risk prediction		
Bedside/portable MCG		
Low-dose continuous biomedical imaging		✓
Operating room (OR) block scheduling and use optimization		
Quantum-secure hospital data links		✓
Continuum of quantum-secure healthcare networks		✓

TABLE 15 | **Enabler strategic actions – action points detailed in Table 12 have implications across other health ecosystem roles**

Use case	Creators	Deliverers
Run mission-driven quantum-for-health challenges	✓	
Co-fund continental secure network build-out for health		✓
Adopt NIST post-quantum cryptography in health IT baselines		✓
Reference QKD evaluation standards in procurement and assurance		✓
Create hospital-to-hospital QKD links		✓
Use OPENQKD healthcare testbeds to harden operations and report KPIs		✓
Scale towards EuroQCI health-sector infrastructure		✓
Provide healthcare-grade quantum access via cloud/HPC platforms	✓	
Deploy on-site hospital quantum testbeds		✓
Integrate HPC and quantum in national supercomputers	✓	
Use OPENQKD and partner sites for healthcare pilots and published metrics		✓
Create joint provider–industry testbeds for secure data exchange and clinical pipelines		✓
Launch quantum-for-health talent pipelines	✓	✓
Fund national QIST workforce development programmes	✓	

A2 Explanation of other indicators

Indicators	Explanation
Maturity	How developed and reliable the technology is, based on existing use cases
Learning curve	Ease and speed of learning to use the technology
Implementation time and cost	Resources needed to deploy the technology
Scalability	Ability to grow and handle increased demand
Risks	A "risk" evaluates the potential negative outcomes associated with adopting, not adopting, or poorly adopting quantum technologies. This includes financial losses, technological uncertainties, security vulnerabilities and competitive disadvantages. The "risk" indicator is also shaped by a conjunction of the first four indicators: maturity, learning curve, implementation and scalability.

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