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Emerging applications of quantum computing technology in healthcare

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Conflicts of Interest

The authors declare no relevant conflicts of interest.

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Key findings

- We identified fifty-five quantum computing technologies with applications in healthcare from a combination of published literature and soft intelligence. No technologies were found in clinical trial registries

- Key areas of development include quantum computers, algorithms, artificial intelligence and software

- Molecular research, diagnostics and data analysis stand out as the most prevalent areas of application for quantum computing technologies

- Funding for quantum computing with specific application to healthcare is limited in the UK and EU

- Collaborations within industry and between industry and academia are widespread

- The quantum computing landscape is currently held back by computational problems including noise, scalability and lack of error-correction, leading to a current prevalence of hybrid quantum-classical approaches

- Many technologies are early in development and further breakthroughs in quantum computing design will be needed before a great impact can be made in healthcare

Background

Quantum computing is an emergent and rapidly accelerating field that has the potential to transform many aspects of our lives.[1] Healthcare stands out as a key area of application for quantum computing, as it offers clear benefits over classical computing in problems including molecular simulations, genomics, personalised medicine and the implementation of artificial intelligence into health systems.[2]

Quantum computing is a form of computation that is underpinned by key quantum particle behaviours including superposition, entanglement and interference. These unique properties offer computational power for quantum computers that exponentially exceeds that of classical computers.[3] Particularly important in quantum computing is superposition, which utilises quantum bits, or qubits, to facilitate computation. Unlike bits used in classical computing, qubits can exist in multiple states, i.e. 0 and 1 at the same time, which vastly increases computational potential.[3]

Industrial competition is driving a surge of recent breakthroughs in quantum computing capability. Start-up company Atom Computing announced in 2023 that it was operating the largest known quantum computer, utilising 1,180 qubits.[4] Meanwhile, larger traditional technology companies are quickly developing quantum computing capability. In December 2023, IBM showcased IBM Quantum Heron, a quantum processor, and IBM Quantum System Two, a modular quantum computer that is currently active and in use.[5] The following year, Google announced a quantum chip Willow, which focuses on solving the problem of error correction, an important hurdle that currently holds back widespread quantum computing use.[6] Additionally, in February 2025, Microsoft unveiled a quantum processor Majorana 1, the first to be designed for and powered by topological qubits.

These breakthroughs have created momentum in the field, something which is reinforced by the UK government. In March 2023, the UK government published the National Quantum Strategy for the UK, highlighting quantum computing as a vital area of growth and development and committing £2.5 billion to quantum research and development over the course of ten years from 2024.[1] More recently, the government has announced an investment of £500 million over the next four years, rising to £670 million over ten years, specifically targeted at quantum computing in the UK.[7,8] This includes secure funding for the National Quantum Computing Centre (NQCC), which hosts research and development in quantum computing.[9] Similar governmental funding approaches have been taken internationally, including the US National Quantum Initiative[10], the EU-funded Quantum Flagship[11] and China's National Laboratory for Quantum Information Sciences.[12]

The UK's 2023 National Quantum Strategy highlights healthcare as one of the areas that stands to benefit the most from the exponential increase in computational power offered by quantum

computers. Work by Durant et al. characterises the key areas of utility for quantum computing in healthcare:[2]

- Artificial intelligence (AI) and machine learning (ML)
- Genomics
- Protein folding
- Drug discovery
- Network analysis
- Cryptography

Vast increases in computational power directly underpin the utility of quantum computing in these areas, facilitated by increased calculation and optimisation speed of algorithms, enhanced accuracy of AI/ML models and enhanced search abilities in large datasets.[2,13]

While many of the use cases of quantum computing in healthcare remain theoretical for now, there are emerging examples of real-world research and benefit, often created through the collaboration of healthcare and quantum computing organisations. In the United States, IBM delivered the IBM Quantum System One (a quantum computer), to the Cleveland Clinic, an academic medical centre. The partnership allows the Cleveland Clinic to harness the computer to expedite biomedical research, including developing models to screen and optimise drugs and predict cardiovascular risk following non-cardiac surgery.[14] Additionally, biotechnology company Moderna Inc have also initiated a collaboration with IBM, allowing Moderna to utilise quantum computing for generative AI that can help researchers discover and create new therapeutics.[15] Similar models have previously been followed, such as the 2017 collaboration between Biogen, Accenture Labs and 1Qbit to accelerate drug discovery using quantum-enabled molecular comparison.[16]

Given the steadily increasing interest in the application of quantum computing technologies to healthcare, it is important that health systems and regulators are aware of the technologies in development and the novel quantum-related challenges they may pose. As a result, we set out to use horizon scanning methodologies to identify emerging quantum computing technologies that are in use or in development, that have the potential to impact healthcare settings. The findings of this scan can be used to understand which quantum computing technologies are likely to make a significant impact on health systems, what logistical challenges these novel technologies will provide and the time frame of these impacts. Additionally, regulators can use this intelligence to review and change regulatory frameworks as a result of the new approaches outlined.

Aims

- Provide a comprehensive horizon scanning overview of emerging quantum computing technologies in any stage of development for use in the healthcare sector using clinical trials, published literature and soft intelligence sources
- Identify funding granted for quantum computing in healthcare in the UK and Europe to assess the future direction of quantum computing development

- Analyse the classifications, development status and activity levels of quantum computing technologies in development
- Assess the impact quantum computing will have on health systems, policy and regulatory frameworks

Methods

This horizon scan set out to identify all quantum computing technologies that are being developed currently, or are already being used in healthcare in any setting (clinical and non-clinical). We aim to do this through a combination of data sources: clinical trials, published literature, soft intelligence and funding grants. This provides coverage of many routes of development for quantum technologies, for example those being developed through the classical clinical development pathway in trials, and those being developed privately in industry.

Data sources were eligible for inclusion in the scan if they mention at least one quantum technology that is in development or already being used in healthcare in any setting. Relevance to healthcare was determined on a case-by-case basis by individual reviewers. The quantum technologies must be directly used in healthcare (e.g. treating, preventing, diagnosing a health condition) or have specific, indirect use (e.g. biomedical and molecular research, health data processing and analysis, health wearables).

We searched for data from specified sources that had been added since our previous scan that focused on quantum sensing from January 2025[17], and used this to update our existing dataset. The full dataset used for analysis is made up of data from three Innovation Observatory horizon scans for quantum technologies in July 2024[18], January 2025[17] and the April 2025 as described below.

Clinical trials

Clinical trial searches were conducted on two registries: Clinicaltrials.gov[19] and the World Health Organisation's International Clinical Trials Registry Platform (ICTRP).[20] The following search terms were used on both registries: "quantum" OR "quantum technology" OR "quantum sensor" OR "quantum sensing" OR "quantum computing" OR "quantum image" OR "quantum encryption" OR "quantum cryptography" OR "quantum magnetic resonance" OR "quantum molecular resonance" OR QMR OR QMRT OR "quantum sonotherapy" OR "quantum spectrum radiation" OR "multimodal imaging" OR "structured light imaging" OR "structured light" OR "fluorescent imaging" OR "Quantum dot" OR "semiconductor nanocrystals" OR "semiconductor particles" OR magnetoencephalogram OR MEG OR superconducting quantum interference OR SQUID OR "optically pumped magnetometer" OR "atomic magnetometer" OR

"Silicon Nanowire Biosensor" OR SiNW OR "Photoelectrical Immunosensor" OR PEC OR "digital tomosynthesis" OR "tunnel magnetoresistance" OR "quantum tunnelling" OR "photonic integrated circuits" OR "quantum photonics" OR "quantum integrated photonics". Only clinical trials with a first posted date (Clinicaltrials.gov) or registration date (WHO ICTRP) from 18th October 2024 to 11th April 2025 were searched for.

Searches on Clinicaltrials.gov and ICTRP were conducted on 11th April 2025. The Clinicaltrials.gov search returned fifty-two trials and the ICTRP search returned twenty trials. The trials were deduplicated to create a single dataset for screening. The final screening dataset contained sixty-seven clinical trials.

The following information was extracted from the clinical trials for inclusion in our final dataset: *Trial identifier; Trial URL; Trial registry; Trial title; Technologies tested; Trial condition(s); Trial type; Trial design; Trial status; Trial start date; Trial primary completion date; Trial phase; Trial participants; Trial sponsor; Trial funder type; Trial locations (countries).*

Published literature

Published literature searches were conducted using three bibliographic databases: MEDLINE, Embase and Scopus. A detailed search strategy is available in Appendix A.

Searches on Embase and MEDLINE were conducted on 10th April 2025 and a search on Scopus was conducted on 11th April 2025. Following deduplication, we retrieved 832 articles from Embase, 232 from MEDLINE and 888 from Scopus. Articles were added to Microsoft Excel for manual screening. Four screeners single-screened all articles. Any article that mentions in the title or abstract a quantum technology or technologies, or a technology or technologies that potentially utilise quantum mechanics were eligible for inclusion. Articles must also refer to technologies that are in early development, in clinical testing, or approved for the treatment, prevention or diagnosis of a health condition.

During the screening of published literature, an alteration was made to our eligibility criteria for publications only and for this horizon scan only. In light of the large number of publications retrieved due to the inclusion of technologies that utilise quantum physics in any way, we revised our eligibility criteria so that non-novel imaging techniques being used routinely were no longer eligible. This included, but was not limited to, technologies including standalone magnetoencephalography (MEG), magnetic resonance imaging (MRI), multimodal imaging and fluorescent imaging. This edited criteria was used for the screening of all published literature, but did not apply to screening for clinical trials, soft intelligence or funding. As a result, these types of technologies are less likely to appear in this scan.

The following information was extracted from the published literature for inclusion in our final dataset: *Trial title; Abstract; Year; Authors; doi; Relevant technologies; Health conditions.*

Soft intelligence

We used the NIHR Innovation Observatory's in-house Google News retrieval tool (SCANAR) to retrieve news articles for thirty-two search queries, each time retrieving up to 100 articles published between 08/11/2024 and 03/15/2025. The following query search terms were used in the tool: *quantum medicine*, *quantum health*, *quantum technologies*, *quantum medical technology*, *quantum medical technologies*, *quantum health technology*, *quantum health technologies*, *quantum application*, *quantum applications*, *quantum computing*, *quantum computing algorithms*, *quantum computing applications*, *quantum algorithm*, *quantum algorithms*, *quantum computer*, *quantum device*, *quantum devices*, *quantum sensing*, *quantum sensors*, *quantum machine learning*, *medical quantum solutions*, *healthcare quantum solutions*, *medical quantum applications*, *healthcare quantum applications*, *quantum computing software*, *quantum computing hardware*, *quantum artificial intelligence*, *quantum AI*, *quantum diagnostic*, *quantum diagnostics*, *quantum dot*, *quantum dots*.

SCANAR's core functionality is to automate the retrieval, de-duplication, full text scraping, self-supervised relevancy-ranking, and data export for systematic news article searches. The tool implements an unsupervised ranking algorithm that orders likely relevant articles to the top based on how many keywords were identified, how many times an article was retrieved in the search, and if they were among the first articles retrieved by each Google search. The tool has been validated across different IO projects for effectiveness, though requires further empirical assessments in less controlled scenarios.

We retrieved 620 articles, which were single screened manually by three reviewers. During screening, we read titles and skimmed article full texts as retrieved by the tool, including 108 articles per the initial title and description screening. In rare cases the tool was unable to retrieve the full text, then we followed article links to view the news articles online.

The following information was extracted from the soft intelligence news retrieval tool for inclusion in our final dataset: T*itle; Description; Media; URL link; Date of publication; Full text; Number of Appearances.*

Funding

Funding searches were conducted on CORDIS, a database maintained by the European Commission containing information on European Union (EU) research and development projects[21] and the UK Research and Innovation (UKRI) funding gateway.[22] Funding searches were limited to two databases in the UK and EU as they are the most geographically relevant to this horizon scan. Further databases and regions were not included due to resource constraints.

Keywords used in the searches are presented in Appendix B. CORDIS was searched for funding grants published between 18th October 2024 and 11th April 2025. UKRI was searched for funding grants published anytime in 2024. We retrieved five funding records from CORDIS

and five hundred and sixty-two from UKRI, which were manually single screened for relevance to quantum technologies in healthcare using objective, title and keywords fields.

Data extraction

Following our searches, data regarding the technologies identified in any one of clinical trial, published literature, soft intelligence or funding were added to our existing dataset of all technologies. Data was collected for technologies independently by four researchers from information sources including developer websites and soft intelligence articles. In case of disagreement between researchers during review and extraction, a third researcher was able to resolve the query.

The following information was extracted or collected for technologies: *Name of technology; Developer name; Developer website URL; Technology utility classification; Technology quantum application; Potential health conditions; Country of development; AI component?; Intended use/setting; Overall regulatory approval?; Number of clinical trials; Associated clinical trials; Number of journal articles; Associated journal articles; Number of soft intelligence articles; Associated soft intelligence articles; Total identifications of technology*.

Based on understanding from the literature and technologies identified in the scan, we created two bespoke classifications to inform our data analysis of quantum computing technologies: technology type and utility classification. Technology type groups different applications of quantum computing as one of: Algorithms, Artificial intelligence, Quantum computer, Software, Software development platform. Utility classification categorises the intended application of the technology in a biomedical setting as one of: Data processing and analysis, Diagnostics, molecular research or Multiple. The Multiple categorisation is used when the quantum computing technology is being applied in more than one of the categories.

Quantum Algorithm Maturity Classification

To assess the maturity of quantum computing applications in healthcare, we developed a simplified Application Development Level (ADL) framework for early-stage innovations. This approach was adopted due to the limitations of traditional Technology Readiness Levels (TRLs), which are often hardware-centric and insufficiently granular for early-stage, algorithm-driven innovations.

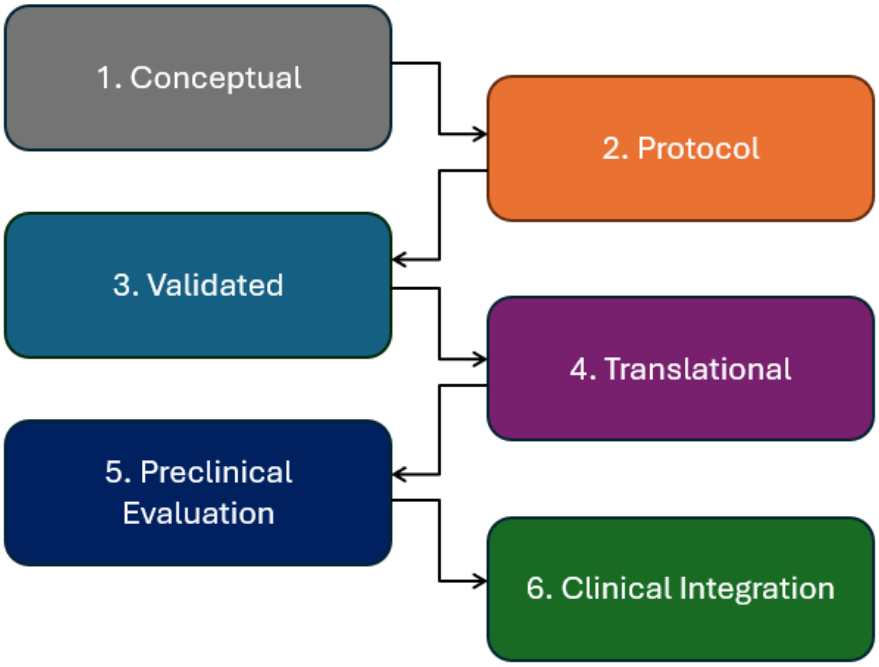

Figure 1 – Flow chart showing the Application Development Levels (ADL)

The ADL model used in this report draws from three complementary sources. Firstly, the DECIDE-AI framework[23], which provides structured guidance for the early-stage clinical evaluation of AI-based decision support systems. Secondly, the Quantum Technology Readiness Level (QTRL) model developed by the Jülich Supercomputing Centre[24] offers a quantum-specific adaptation of TRLs, recognising the interdependence of quantum hardware and software maturity. Additionally, there were elements incorporated from the recent proposal for standard quantum technology readiness levels and quantum commercial readiness levels (QCRLs), which proposes a framework for evaluating the commercial viability and market readiness of quantum technologies.[25]

The combination of these frameworks informed the simplified model outlined below (Table 1), creating a six-stage framework tailored to include quantum computers, applications and algorithms in the healthcare context that are early in the development pipeline. This model was used to classify the technologies identified and support a comparative analysis across the different application types.

Table 1 - Application Development Levels for Quantum Applications in Healthcare

	Stage	Description	Example

1	**Conceptual**	Theoretical application proposed; no implementation yet	*Quantum algorithms that could be used to predict drug-responses through molecular stimulation*
2	**Prototype**	Application implemented and tested on simulated data or small-scale quantum hardware	*Quantum Support Vector Machines (SVM) that have been developed for IBM quantum computing software (Qiskit)*
3	**Validated**	Application tested on real-world datasets or benchmarked against classical methods	*Quantum SVM used on publicly available clinical trial datasets for cancer classifications, with performance compared with classical computing methods*
4	**Translational**	Application adapted for healthcare-specific use cases (e.g. drug discovery, diagnostics)	*Adaptation of quantum annealing techniques to model protein folding for disease-specific contexts (such as Alzheimer's)*
5	**Preclinical Evaluation**	Application tested in silico or in lab settings with healthcare partners	*Quantum sensors tested in lab settings for biomarker detections at low concentrations*
6	**Clinical Integration**	Application embedded in clinical workflows or decision support tools	*Quantum-enhanced support tools embedded in hospital systems to inform clinical decision making*

Results

Our scan identified fifty-five quantum computing technologies that have current or potential applications in healthcare. Thirty-six of the technologies were identified only from soft intelligence sources and eleven technologies were identified only in published journal articles, with the remaining eight identified in a combination of both sources. No technologies were identified from clinical trial registries. The proportion of technologies being developed by industry companies and academia is similar, with some technologies also being developed in collaborations of the two. (Table 2)

Table 2- selected characteristics for all identified quantum computing technologies

Technology	Developer	Technology classification	Utility classification	ADL Stage
AQbiosim	SandboxAQ	Software	Molecular research	2 – Prototype
Aqumen Seeker	Quantum Circuits	Quantum computer	Molecular research	2 – Prototype
Aurora	Algorithmiq	Software	Molecular research	3 – Validation
Contracted Quantum Eigensolver	N/A	Algorithms	Molecular research	2 – Prototype
Cuda-Q	Nvidia	Software development platform	Multiple	2 – Prototype
Generative Quantum Artificial Intelligence Framework	Quantinuum	Artificial intelligence	Molecular research	2 – Prototype
Grover's Algorithm	N/A	Algorithms	Data processing and analysis	1 – Conceptual
Harrow-Hassidim-Lloyd Algorithm	N/A	Algorithms	Data processing and analysis	1 – Conceptual
Hybrid Quantum Neural Network	Terra Quantum	Artificial intelligence	Diagnostics	4 – Translational
Hybrid Quantum-Classical Machine Learning	Gero	Artificial intelligence	Molecular research	2 – Prototype
Hybrid ZFnet-Quantum Neural Network	Gachon University	Artificial intelligence	Diagnostics	3 - Validation
IBM Quantum System One	IBM	Quantum computer	Multiple	3 – Validation
IBM Quantum System Two	IBM	Quantum computer	Molecular research	2 – Prototype
ID4	XtalPi, Pfizer	Software	Molecular research	2 – Prototype
IonQ Forte	IonQ	Quantum computer	Molecular research	3 – Validation
Molecular simulation Quantum Artificial Intelligence	Quantistry	Artificial intelligence	Molecular research	2 – Prototype
Nvidia Quantum Cloud	Nvidia	Software development platform	Multiple	2 – Prototype
Origin Wukong	Origin Quantum	Quantum computer	Multiple	2 – Prototype
Pegasos QSVC	Toyota Technological Insitute at Chicago	Artificial intelligence	Diagnostics	3 – Validation
PennyLane Quantum Programming Software	Xanadu	Software development platform	Multiple	2 – Prototype
PT-2	Orca	Quantum computer	Molecular research	2 – Prototype
Q-BGWO-SQSVM	Hainan Normal University	Algorithms	Diagnostics	2 – Prototype
QSMOTEN	Sichuan University	Algorithms	Data processing and analysis	3 – Validation
QuADro	ParityQC	Algorithms	Molecular research	3 – Validation
Quantum Algorithim	Infleqtion	Algorithms	Data processing and analysis	2 – Prototype

Quantum Annealing-Based Algorithm	D-Wave Quantum Inc	Quantum computer	Multiple	2 – Prototype
Quantum Approximate Optimization Algorithms	Multiple	Algorithms	Data processing and analysis	3 – Validation
Quantum Artificial Intelligence	Multiple	Artificial intelligence	Multiple	4 – Translational
Quantum Circuit Born Machine	University of Toronto	Artificial intelligence	Molecular research	3 – Validation
Quantum Computing Integrated Classical Computational Fluid Dynamics	IonQ	Algorithms	Molecular research	4 – Translational
Quantum Computing-Inspired Bald Eagle Search Optimisation	Noida Institute of Engineering and Technology	Algorithms	Diagnostics	2 – Prototype
Quantum Denoising	Kobe University Hospital	Algorithms	Diagnostics	2 – Prototype
Quantum Enabled Cell-Centric Therapeutics	IBM	Algorithms	Molecular research	3 – Validation
Quantum Feature Mapping	Kipu Quantum	Artificial intelligence	Molecular research	3 – Validation
Quantum Gene Regulatory Networks	Texas A&M University	Algorithms	Molecular research	2 – Prototype
Quantum Hybrid Classical Convolutional Neural Network	Multiple	Artificial intelligence	Diagnostics	3 – Validation
Quantum Machine Learning	Multiple	Artificial intelligence	Multiple	4 – Translational
Quantum Medical Data Simulation Computation Model	Minjiang University	Algorithms	Data processing and analysis	3 – Validation
Quantum Neural Network	Multiple	Artificial intelligence	Multiple	2 – Prototype
Quantum Parallel Processing	Picture Health	Algorithms	Diagnostics	3 – Validation
Quantum Software For Drug Discovery	Qradle Inc	Software	Molecular research	2 - Prototype
Quantum Support Vector Machine	UC Davis	Artificial intelligence	Diagnostics	2 – Prototype
Quantum-Assisted Federated Intelligent Diagnosis Algorithm	Federal University of Lavras	Algorithms	Diagnostics	2 – Prototype
Quantum-Enhanced Artificial Intelligence	Zapata Computing, Insilico Medicine, University of Toronto	Artificial intelligence	Molecular research	2 – Prototype
Quantum-Inspired Algorithms	Merck, HQS Quantum Simulations	Algorithms	Molecular research	4 – Translational
Quanvolutional Neural Network	Rigetti	Artificial intelligence	Diagnostics	2 – Prototype
Quest-Admet	Classiq, Quantum Intelligence Corp	Software	Molecular research	3 – Validation
Secretary Bird Optimization Algorithm	Chengdu University	Algorithms	Diagnostics	2 – Prototype
SmartCADD	Southern Methodist University	Software	Molecular research	2 – Prototype
Tensor Train Optimisation	Terra Quantum	Algorithms	Molecular research	2 – Prototype

The Menten Platform	Menten AI	Artificial intelligence	Molecular research	2 – Prototype
Variational Quantum Classifier	N/A	Artificial intelligence	Diagnostics	2 – Prototype
Variational Quantum Eigensolver	N/A	Algorithms	Molecular research	3 – Validation
Vehicle Routing Problem Assembler	BGI Research	Algorithms	Molecular research	2 – Prototype
Walsh Imaging	MITRE	Software	Diagnostics	2 – Prototype

Of the fifty-five quantum computing technologies identified, the most common technology type classification was algorithms (n=21, 38%), followed by artificial intelligence (n=17, 31%). The technology type identified the least were software development platforms (n=3, 5%). We identified broad utility, with many types of technologies being applied to different areas of healthcare. The only group targeting data processing and analysis tasks were algorithms, with 29% of algorithms primarily being used for this task. Additionally, we found that diagnostics were concentrated in algorithms and artificial intelligence, which made up thirteen out of fourteen identified diagnostic technologies. The most common utility of technology was molecular research, with 47% of technologies being applied to this category which consists of genetic studies and drug discovery research (Figure 1).

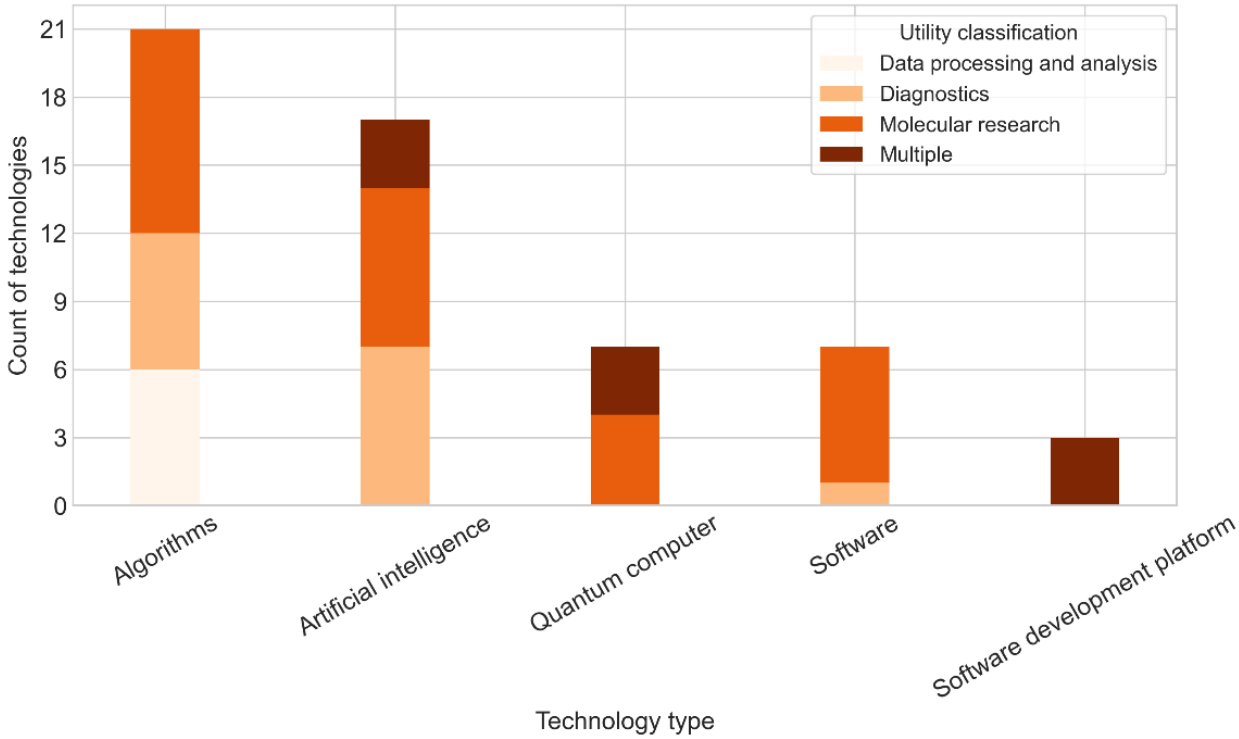

Figure 1 - Count of technologies by technology type, stratified by utility classification

Most of the technologies (n = 32; 58%) were classified in the prototype stage, indicating early testing on simulated or synthetic data. Additionally, 16 technologies (29%) reached the validation stage and were identified through peer-reviewed publications or were utilising real-word datasets. Only 5 (9%) technologies were considered translational, having been adapted for real-world healthcare use cases, and no technologies were identified at the preclinical and clinical integration stages (Figure 2).

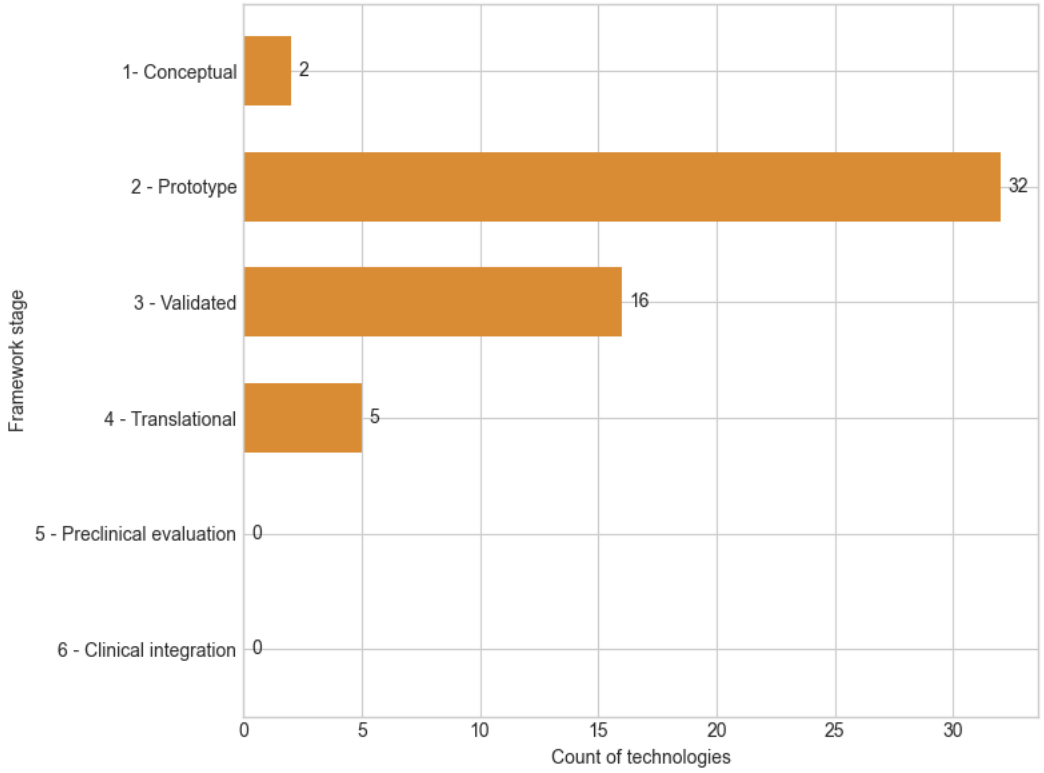

Figure 2 - Count of technologies by application development levels (ADL)

Funding

In our searches of funding portals CORDIS and UKRI, we identified only one funding grant where quantum computing was to be applied to healthcare. The grant, listed on CORDIS, is for the development of the Center for Artificial Intelligence and Quantum Computing in System Brain Research under the umbrella of the CLARA project. The project is led by the International Neurodegenerative Disorders Research Center (INDRC) located in Czechia and is funded with €14,999,782.50 from the European Commission. The research center will utilise quantum computing and artificial intelligence to enable the processing of large scale biological and clinical data, enabling better research into neurodegenerative disorders.[26]

Quantum computers

Table 3 - characteristics of identified quantum computers

Name of Technology	Developer	Computing type
Quantum Annealing-Based Computer	D-Wave Quantum Inc	Annealing
PT-2	Orca	Photonic
IBM Quantum System One	IBM	Superconducting
Origin Wukong	Origin Quantum	Superconducting

Aqumen Seeker	Quantum Circuits	Superconducting
IBM Quantum System Two	IBM	Superconducting
IonQ Forte	IonQ	Trapped-ion

Our scan identified seven quantum computers or quantum processing units that are being used or have outlined plans to be used in healthcare. Based on categorisations outlined by TechTarget[27] describing the type of physical hardware used in computation, we identified four superconducting quantum computers and one of each annealing, quantum dot, photonic and trapped-ion quantum computers.

In March 2023, IBM and the Cleveland Clinic announced a ten-year collaboration which saw IBM deliver quantum computer the IBM Quantum System One to Cleveland Clinic, marking the installation of the first quantum computer to be dedicated solely to healthcare research.[14] Since installing the computer, research utilising the quantum hardware has already begun. Researchers from both organisations collaborated on a study in May 2024 presenting a framework for systematically selecting protein structure prediction problems for in silico structure prediction.[28] Cleveland Clinic has since initiated further collaborations that leverage the IBM Quantum System One. This includes projects with the CAS (a division of the American Chemical Society) on drug discovery for Alzheimer's disease[29] and with UK-based digital technologies organisation Hartree Centre, working on predicting surgical response in epilepsy patients.[30] IBM have recently partnered with Japanese research institute RIKEN to deploy the first Quantum System Two, the successor to the Quantum System One computer.[31] While the Quantum System Two is not currently being used in healthcare, the Quantum System One's ongoing use provides a framework to utilise to the greater computational power provided by the Quantum System Two.

In early 2025, China-based Origin Quantum reported the launch of a 72-qubit superconducting computer named Origin Wukong.[32] Origin Wukong is available for cloud-based computing and the company report that it has completed 339,000 quantum computing tasks for users in 139 countries.[33] In a collaboration with Bengbu Medical University, Origin Quantum stated that they have carried out work to improve molybdenum target detection for breast cancer diseases.[34] Additional work in molecular research and drug design utilising a quantum-classical hybrid approach has also been undertaken, although detailed information is limited.[35]

Another application of superconducting quantum computing is seen in an industry collaboration between Algorithmiq and Quantum Circuits.[36] Algorithmiq have used Quantum Circuits full-stack quantum computing system, Aqumen Seeker, to optimise quantum algorithms which improve simulation accuracy for drug discovery research.[37] Aqumen seeker utilises a unique dual-rail qubit design, which allows for a "correct first, then scale" approach. This approach allows the computer to bypass lengthy brute-force techniques and reduces the need for error correction in calculation.[38]

Trapped-ion quantum computers represent an alternative approach to computation, offering long coherence times, high gate fidelity and a clear path to error correction, all of which allow for enhanced computing systems.[39] One such computer being used in healthcare currently is the IonQ Forte computer. Together with computer-aided engineering company Ansys, IonQ

have used the Forte computer to simulate blood pump dynamics and analyse fluid interactions. These simulations allowed Ansys to optimise the design of medical devices, increasing processing power by up to twelve percent compared to classical computing.[40]

Additionally, there are other types of quantum computers that are being applied to healthcare. ORCA Computing recently released PT-2, a photonic quantum computer that is developed to integrate with existing classical high-performance computing. ORCA's collaborators are using PT-2 in molecular and peptide vaccine design.[41] D-Wave Quantum's annealing quantum computers have been used by Korean researchers at Yonsei University to gain novel insights from a dataset of student's mental health during the COVID-19 pandemic[42] and used in collaboration with Japan Tobacco's pharmaceutical division alongside artificial intelligence to discover new molecules quicker than classical approaches.[43]

Hybrid quantum-classical algorithms

To realise the full potential of quantum computers, the development of quantum algorithms that can harness quantum mechanics are required.[44] Some algorithms integrate existing classical computing with quantum, creating hybrid quantum-classical algorithms which provide quantum advantage through algorithms that can be used on classical hardware.[45] This can be achieved by using classical algorithms and enhancing computational performance by executing code on quantum computers using parallelism, or by simultaneously utilising classical and quantum computing and combining the outputs.[46] One such example of this is the quantum approximate optimisation algorithm (QAOA), designed for combinatorial optimisation problems.[47] Recently, QAOA has been applied to the enhancement of rehabilitation devices for patients by integrating exoskeletons and aquatic therapy.[48] Additionally, QAOA has been explored as a theoretical option for optimisation of clinical trial design, aiming to improve site selection, patient identification and limit delays and trial failure.[49]

IBM have described algorithm discovery as the domain that will take the field into quantum advantage. On the back of this, they have created five working groups to facilitate novel algorithm development, including one focused on healthcare and life sciences. This working group has created an algorithmic framework known as Quantum Enabled Cell-Centric Therapeutics, which utilises quantum neural networks, hybrid quantum-classical algorithms and topological data analysis to understand the behaviours of cells in diseased tissue. It is hoped that this approach can lead to better drug discovery methods in the future.[50] A similar framework has also been created through collaboration between ParityQC and the University of Hamburg, who have begun work on the Quantum Algorithms for Drug Repurposing (QuADro) project, aiming to create hybrid quantum-classical algorithms for drug development and personalised medicine.[51]

Software

Quantum computers rely on specialised quantum software to achieve their practical applications.[52] Quantum software refers to the programming tools, firmware and runtimes needed to translate quantum mechanics into practical applications of quantum computing.[53,54] One example is the Aurora software, developed by Finnish company Algorithmiq. The Aurora software combined with quantum algorithms, is accelerating drug discovery by reducing errors

and solving complex calculations. The Aurora software allows researchers to conduct advanced quantum chemistry simulations, thereby overcoming issues in drug discovery associated with classical computing software.[36,55]

To fully realise the potential of quantum computers and quantum computing software, the right software environments are required.[56] PennyLane is a quantum software development kit (SDK) and programming language.[57] Written in python, PennyLane is an SDK for development, testing and troubleshooting of quantum circuits. It can be used with artificial intelligence quantum algorithms and is also able to co-ordinate with other platforms such as IBM's Qiskit.[56,58] Another SDK identified in our horizon scan was Nvidia's CUDA-Q. CUDA-Q is a hybrid programming model, which combines multiple processors into a single quantum program.[59] CUDA-Q uses multiple quantum processing unit architectures, which increases simulation speed and provides greater computation power, which is required for training of quantum neural networks and machine learning algorithms.[60] The CUDA-Q is an example of an SDK which provides a platform to enable practical application of quantum machine learning models and other quantum software.

Quantum artificial intelligence

Quantum computing and artificial intelligence are two of the largest domains of growth in computing right now. The two synergise effectively – artificial intelligence is being used to optimise qubit control and enhance error correction, while quantum computing's computational performance is leading to better machine learning models that require less training data.[61] This crossover domain is now being applied to healthcare problems. Researchers from the University of Toronto, Insilico Medicine and Zapata AI have recently collaborated in the creation of a quantum-classical generative model for small molecule design. This model was used to search for drugs targeting the KRAS protein, which has previously been difficult to target using classical approaches. Their novel model proposed 15 molecules, two of which hold promise for future drug development.[62,63]

Quantum neural networks are also being applied to diagnostic imaging analysis problems. Quantum technology company Terra Quantum reported in 2024 the use of a hybrid classical-quantum neural network model that was able to use diagnostic images to identify moderate and severe non-alcoholic fatty liver disease, now also referred to as metabolic dysfunction-associated steatotic liver disease. The model classified the disease with an accuracy of 97%, an improvement of 1.8% on current methods.[64] California-based company Rigetti Computing have also applied quantum neural networks to diagnostics by combining convolutional neural networks, a classical machine learning method, with quantum algorithms to create a 'quanvolutional neural network'. This model, named RANet, has demonstrated potential in automated diagnosis of rheumatoid arthritis from hand thermal imaging.[65,66]

Implications and Recommendations

Our horizon scan

Our horizon scan identified fifty-five quantum computing technologies utilised in different fields including molecular research, data processing and analysis and diagnostics. Areas of significant technology development emerged, including quantum computers, algorithms, artificial intelligence and software.

All technologies were identified through published research or soft intelligence articles, with none being found via clinical trial registries worldwide. This is reflective of the nature of many of the identified technologies, most of which are not being used to treat or diagnose patients directly, but are instead used in biomedical and molecular research, data analysis, or to enhance existing diagnostic methodologies. As a result, clinical trials would not be required for these technologies, as direct clinical evidence and regulatory approval is not always necessary. Additionally, as the majority of technologies were classified in the Prototype and Validation stages, it may be indicative of the early maturity of the field, which is consistent with previous assessments of quantum readiness in healthcare and life sciences. Despite increasing efforts of investment and academic interest, the absence of technologies in Preclinical and Clinical Integration stages shows that there remains a translational gap between quantum application or algorithm development and clinical deployment. There may be several barriers and limitations that contribute to this gap such as:

- Hardware limitations (such as high error rates, limited qubit counts etc) due to most algorithms being developed on noisy intermediate-scale quantum (NISQ) devices which can lack stability and have issues with scalability to clinical-scale applications
- Lack of clinically validated frameworks that are tailored to the development of novel quantum technologies
- Limited interdisciplinary collaboration between quantum computing researchers and healthcare stakeholders, limiting the co-design of relevant pilot studies
- Infrastructure or integration related challenges due to NHS systems not being equipped to fully support hybrid quantum-classical tools or implement novel quantum technologies

There remains a notable gap in robust validation frameworks and tailored policy guidance to support the early-stage application of quantum technologies, particularly in the context of public health, where there is a high importance for safety, equity and effectiveness. The Information Technology Industry Council (ITI) has published quantum technology policy guidance that offers more strategic principles for governments and industry in this context. The ITI emphasises the need for collaborative policy development, further investment in research and skills, and the development of more harmonised evaluation standards. It highlights the importance of cross-sector engagement and the need for anticipatory governance to address both the risks and opportunities posed by the emergence of quantum technologies in different specialised sectors.[67]

Furthermore, the UK government's response to the Regulatory Horizons Council (RHC) advocates for the development of flexible guidance, best practice documents and recognises the need for standardisation in regulating quantum computing applications to support innovation while safeguarding public interests. There is also an emphasis on adaptive regulation using Technology Readiness Levels (TRLs), by ensuring the Department for Science, Innovation and Technology (DSIT) work with regulators consistently to assess how emerging technology applications impact existing frameworks and work on additional measures if needed. Additionally, the RHC supports the development of sandboxes and testbeds for early-stage technologies that include regulatory components and ensure proactive integration of governance insights for future regulatory decisions.[68]

As quantum technologies and applications rapidly emerge within the healthcare sector, it is becoming increasingly evident that there is a lack of regulatory pathways or systems of approval that can accelerate the adoption of these innovations, leading to delays in clinical adoption. Additionally, quantum computing resources are currently quite expensive to implement and concentrated in a few global centres, limiting access to NHS researchers, clinicians and innovators. Furthermore, quantum computing applications are yet to outperform classical solutions in most healthcare applications. However, they offer theoretical advantages in terms of efficiency (such as QAOA) that can perform computational intensive tasks more effectively, which may become complementary tools in areas where classical methods may plateau.

Quantum computers, algorithms and software alone are not likely to directly or indirectly interface with patients. Instead, we see they are being utilised often in drug discovery, molecular research and data analysis, domains for which it would not be appropriate to conduct clinical trials. In addition, many of the applications of our technologies being conducted outside of traditional clinical pathways in industry. Many technologies, particularly quantum computers, are not solely relevant to healthcare, and instead provide platforms which can be applied to many areas. As a result, while the computers may be readily available, the application in healthcare by third parties remains in early stages of development.

Only a single funding grant, a brain research centre for AI and quantum computing led by the INDRC in Czechia, was identified in our horizon scan. This single finding demonstrates a lack of funding activity for quantum computing in healthcare in the UK and EU, albeit with a limited search time frame for the UKRI registry. The absence of funding activity is likely explained by the funding models currently employed for quantum computing, currently dominated by large scale governmental projects which are not specific to healthcare. The UK's governmental funding[7,8] and the EU Quantum Flagship[11] project are high-level, cross-sector initiatives, meaning that individual funding grants for healthcare have not yet materialised. Additionally, while the UK now has the Quantum Biomedical Sensing Research Hub (Q-BIOMED)[69] to catalyse funding for quantum sensing in healthcare, a similar healthcare-specific quantum computing organisation does not exist, limiting the sectors ability to create an effective funding ecosystem.

Quantum computing landscape

The current state of quantum computing development and research is often framed in eras. It is mostly accepted that we are currently in an era known as noisy intermediate-scale quantum (NISQ), a term coined by quantum researcher John Preskill in 2018. In practice, this means that quantum computers are of intermediate size (approximately containing between fifty and a few hundred qubits) and their widespread uptake remains constrained by noise and problems with error correction.[70] Future milestones are difficult to define, but may involve concepts such as quantum utility,[71] practical quantum advantage over classical computing or completely fault-tolerant quantum computing.[72]

It is because those milestones have not yet been reached that our scan identifies many instances of hybrid quantum-classical algorithms, where researchers look for near-term benefits of quantum computing in the NISQ era by combining classical hardware and quantum algorithms to provide quantum advantage in specific problems.[45] Application of these algorithms in healthcare settings is narrow and remains limited to early work in drug discovery research and diagnostic imaging enhancements. A recently published systematic review by Gupta et al. examining quantum machine learning algorithms, many of which are hybrid quantum-classical, reported little empirical difference in the utility of these algorithms compared to classical-only counterparts. The primary reason for this finding was that many studies were not carried out in realistic operating conditions reflecting real-world experiences.[73] However, some examples of hybrid quantum-classical algorithms having an immediate impact do exist. The collaboration between the University of Toronto, Insilico Medicine and Zapata AI demonstrated that combining artificial intelligence with quantum algorithms in a hybrid approach could be successful, by producing two KRAS inhibitor candidates which could be studied for use in cancer patients.[62,63] While this example highlights promise, it is clear that much of this work remains theoretical and any currently realised benefit to the health system is small.

Our horizon scan identifies algorithms as the largest area of quantum computing development. As with all computers, algorithms are required for quantum computers to be programmed and function as intended. Quantum algorithms are necessary to enable quantum computing to harness quantum particle behaviours including superposition, entanglement and interference, allowing for a route to quantum advantage over classical computing.[74] As quantum computing remains in the NISQ era, research and development efforts are heavily focused on algorithms as they, along with hardware, represent the best approach to overcoming the current barriers to quantum advantage.

One area of utility that stands out as especially prevalent in this scan is molecular research, where quantum computers, algorithms and artificial intelligence are being applied to simulations of molecular dynamics, computational chemistry and biological systems.[75-77] Molecular research is uniquely positioned as an area of health research that can benefit most from quantum computing, as the molecules that need to be simulated obey quantum mechanics themselves. This makes classical approaches exceptionally computationally intensive and make quantum approaches a natural fit.[78]

The majority of molecular research applications we identified focus on drug discovery and development, a domain that costs the pharmaceutical industry significant and ever-growing time and resource. Quantum systems can outperform classical approaches to quantum-chemistry calculations, allowing companies to replace labour intensive processes and accelerate bringing novel drugs to patients who need them.[79] However, current efforts utilising quantum computing remain mostly in the proof-of-concept stage and may not reflect real-world drug discovery challenges, limiting potential near-term benefits.[80]

Collaborations between quantum developers in industry and researchers appear often in our scan. Many commercial companies are currently focused solely on developing capacity in hardware and algorithm development, meaning that most of the healthcare-related ventures are done in collaboration with health researchers. One collaboration that stands out is the pioneering partnership between IBM and the Cleveland Clinic, which positioned the first quantum computer that is completely dedicated to health research.[14] This, coupled with positive research findings[28] already emerging from the collaboration, signal to the broader ecosystem that quantum capability in healthcare is possible and can have immediate, short-term benefits alongside revolutionary visions for the future.

Barriers to uptake

We identify a significant pipeline of quantum computing technologies being applied to healthcare, however their utility is currently shallow and mostly experimental. Many barriers still exist that are limiting the development and uptake of quantum computing in healthcare. This includes the high cost of quantum hardware, driven by the need for highly specialised cryogenic or vacuum operating conditions that would require bespoke purchase and set up in medical settings.[81] Research is ongoing in cryogenic control techniques, including cryogenic integrated circuits, which may mitigate these issues and enhance scalability.[82]Additionally, different modalities of quantum computers already in use can overcome these problems by requiring less resource-intensive cooling (trapped ion, neutral atom) or require no cooling at all (photonic).[27,83]

Uptake is slow in the NISQ era due to problems with decoherence and noise in computation, meaning that quantum computing is unreliable, something which is of particular detriment in clinical settings. Similarly, increasing the computational power of quantum computers is not as straightforward as adding extra processors, as is true classically. Adding additional qubits increases the complexity of systems exponentially, meaning that organisations will find it difficult to scale computers to meet their needs.[84] Research to improve error correction and increase scalability is underway and is formed of many different approaches. These include quantum error correction codes[85], dynamical decoupling for qudit-based systems[86], decoherence-free subspaces[87] and topological architectures.[88]

Regulatory challenges

Quantum computing faces significant regulatory challenges in the UK, EU, USA and globally, particularly in the areas of data security, ethical concerns, and the lack of standardized frameworks.

Data Security

Quantum computing's ability to process vast datasets raises concerns about data security, particularly in healthcare, where sensitive patient information is involved. Quantum computers could potentially break traditional encryption methods, exposing healthcare systems to data breaches. The UK's National Health Service (NHS)[89] and the EU's General Data Protection Regulation (GDPR)[90] mandate strict data protection protocols, but these frameworks are not yet equipped to handle quantum-specific threats. In the USA, the Health Insurance Portability and Accountability Act (HIPAA)[91] similarly lacks quantum-specific provisions, creating regulatory gaps that must be addressed to ensure patient data confidentiality.

Ethical Concerns

The application of quantum computing in healthcare also raises ethical issues, particularly regarding the potential misuse of advanced data analytics. For example, quantum-enabled algorithms could inadvertently perpetuate biases in medical decision-making if training datasets are not representative. In the EU, the European Commission's Ethics Guidelines for Trustworthy AI[92] emphasize the importance of fairness and transparency, but these principles are challenging to enforce in quantum applications due to their complexity. Similarly, the UK's Data Ethics Framework[93] and the USA's ethical guidelines for AI in healthcare do not yet fully address the unique ethical dilemmas posed by quantum computing.

Lack of Standardized Frameworks

A significant barrier to quantum computing in healthcare is the absence of standardized regulatory frameworks. Unlike traditional computing, quantum technology is still in its infancy, and there are no universally accepted standards for its development or deployment in healthcare. The World Health Organization (WHO)[94] and the International Organization for Standardization (ISO)[95] have initiated discussions on quantum standards, but these efforts are still in early stages. In the UK, the Medicines and Healthcare products Regulatory Agency (MHRA) is working on adapting its regulatory approach, while the EU's Medical Device Regulation (MDR) and the USA's Food and Drug Administration (FDA) are also exploring ways to incorporate quantum-specific regulations.

Global Perspective

Globally, there is a lack of harmonization in quantum computing regulations, which complicates international collaboration in healthcare innovation. Countries like China and Japan are making significant strides in quantum technology[96,97], but their regulatory approaches differ from those in the West, creating challenges for cross-border data sharing and research. The lack of a cohesive global strategy for quantum computing in healthcare could hinder its potential to address global health challenges.

While quantum computing promises significant benefits for healthcare, its adoption is impeded by regulatory hurdles such as data security vulnerabilities, ethical concerns, and the absence of standardized frameworks. Addressing these challenges requires coordinated efforts among regulators, industry stakeholders, and international organizations to establish robust and adaptable regulatory systems.

UK perspectives

While many of the developers and associated organisations identified in this horizon scan are concentrated in North America and Asia, some activity also points to the UK being in a strong position to progress quantum computing in healthcare. Underscoring the UK's commitment to quantum computing in healthcare is the continued emphasis given to it by policy[1] and support through governmental funding. This has helped the UK rank second globally for the number of quantum companies and levels of private investment.[98]

Two companies identified as working on quantum algorithms applied to healthcare and with a footprint in the UK are Quantinuum[99] and Infleqtion. Infleqtion announced in 2025 the launch of the largest neural atom array in the UK, which they say will pave the way for fault-tolerant quantum computing in the country.[100] This was done in collaboration with the UK's National Quantum Computing Centre[9], a national lab for quantum computing, reinforcing the UK's strong position in the field. These collaborations, in combination with the continued backing and funding announcements from the UK government[7,8], position the UK well to harness the power of quantum computing in healthcare.

Limitations

A recent study conducted by the Massachusetts Institute of Technology found over 200 existing quantum computers or processing units, contrasting with the seven identified in this horizon scan.[101] This is because our scan necessitated clear context of an application of healthcare to be presented in the data source. While it is likely all quantum computers could be applied to healthcare problems, we only present here those that meet our eligibility criteria of being applied to healthcare. Future research could map out the entire quantum computers landscape and assess the impacts of some or all computers being applied to healthcare.

Our horizon scan may be limited by the systematic searching methods used, specifically in clinical trials, publications and soft intelligence searches. The searches rely heavily on identifying 'quantum' and quantum-adjacent keywords and phrases in our data sources. However, not all sources will use the word quantum specifically when describing quantum computing technologies and developers that use quantum technology. As a result, these documents may not be retrieved in our searches. Future work should look to expand the set of keywords utilised and implement intelligent searching and screening methods. One potential approach could utilise generative artificial intelligence and large language models to lessen researchers resource constraints and assess a wider range of data sources.

Conclusions

This horizon scan has revealed a strong pipeline of emerging quantum computing technologies with the potential to be used in healthcare. The pipeline is narrow in scope, focusing on a few key areas including quantum artificial intelligence to enhance diagnostics, quantum computers for drug discovery and development and data processing and analysis to enable greater insights from patient data. Quantum computing technology is not yet mature enough to provide clear quantum advantage over classical computing, but development is rapid and backed by

governmental and industrial funding and interest. Developers are turning to hybrid quantum-classical approaches to realise some forms of quantum advantage in the near term.

Many of the applications identified in this scan are still under development and remain in the proof-of-concept stage, limiting quantum computing's real-world impact in healthcare settings for now. Future development will be heavily tied to the continued development of quantum computers by some of the industry leaders identified in this scan, including IBM, IonQ, D-Wave and more. If the challenges of the NISQ era can be overcome, quantum computers will be able to fully utilise quantum algorithms, artificial intelligence and software. Quantum computers would then be better positioned to have a revolutionary impact on healthcare diagnostics, data analytics and molecular research.

To accelerate the adoption of quantum computing in healthcare, researchers, developers and policymakers must work together to overcome the challenges of the NISQ era and enable quantum advantage to improve the health of patients. Additional funding and creation of institutions in the UK, as already seen in quantum sensing, can help to focus on key challenges. Health systems should prepare for the challenges quantum computers bring, including high cost, specialised operating conditions and technologies that do not follow traditional clinical development pathways.

Appendix A – Published literature search strategy

Embase (Run 10-04-25)

<1974 to 2025 April 09>

1 (Quantum adj (comput* or sens* or resonance or imag* or encrypt* or therap* or cryptograp* or sonotherap* or electrotherap* or electro*)).ti. 1313

2 (quantum dot* adj3 (drug* or diagnos* or therap* or medic*)).ti,ab,kw. 453

3 (multimodal adj (imag* or therap* or microscop*)).ti. 4471

4 (structured light adj (imag* or therap* or microscop*)).ti. 23

5 (fluorescen* adj (imag* or therap* or microscop*)).ti. 10538

6 quantum molecular resonance.ti,ab,kw. 49

7 (QMR or QMRT).ti,ab,kw. 262

8 (semi?conductor adj (nanocrystals or particles)).ti,ab,kw. 1290

9 (Magnetoencephalogra* adj MEG).ti,ab,kw. 6608

10 superconducting quantum interference.ti,ab,kw. 1078

11 (superconducting quantum interference adj SQUID).ti,ab,kw. 5

12 (optically?pumped magnetometer or atomic magnetometers).ti,ab,kw. 159

13 Silicon Nanowire Biosensor.ti,ab,kw. 24

14 SiNW.ti,ab,kw.395

15 photoelectrochemical immunosensor.ti,ab,kw. 134

16 PEC?Immunosensor.ti,ab,kw. 10

17 or/1-16 26583

18 (digital adj2 tomosynthesis).ti,ab,kw. 2434

19 tunnel magnetoresistance.ti,ab,kw. 96

20 (quantum adj2 (tunnel or tunnelling)).ti,ab,kw. 297

21 photonic integrated circuits.ti,ab,kw. 640

22 (quantum adj2 photonics).ti,ab,kw. 244

23 (quantum adj2 (integrated or photonics)).ti,ab,kw. 539

24 or/18-23 3970

25 limit 17 to dd=20241015-20250409 952

26 limit 24 to dd=20241015-20250409 200

27 conference abstract.pt. 5438205

28 "review".pt. 3340207

29 27 or 28 8778412

30 25 not 29 771

31 26 not 29 178

32 30 or 31 949

33 (rat or rats or mouse or mice or swine or porcine or murine or sheep or lambs or pigs or piglets or rabbit or rabbits or cat or cats or dog or dogs or cattle or bovine or monkey or monkeys or trout or marmoset$1).ti. and animal experiment/ 1295371

34 animal experiment/ not (human experiment/ or human/) 2730283

35 33 or 34 2810988

36 32 not 35 893

37 limit 36 to english language 877

Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations (Run 10-04-25)

<1946 to April 09, 2025>

#	Query	Results from 10 Apr 2025
1	(Quantum adj (comput* or sens* or resonance or imag* or encrypt* or therap* or cryptograp* or sonotherap* or electrotherap* or electro*)).ti.	1,877
2	(quantum dot* adj3 (drug* or diagnos* or therap* or medic*)).ti,ab,kw.	373
3	(multimodal adj (imag* or therap* or microscop*)).ti.	3,460
4	(structured light adj (imag* or therap* or microscop*)).ti.	23
5	(fluorescen* adj (imag* or therap* or microscop*)).ti.	10,315

6	quantum molecular resonance.ti,ab,kw.	38
7	(QMR or QMRT).ti,ab,kw.	173
8	(semi?conductor adj (nanocrystals or particles)).ti,ab,kw.	1,633
9	(Magnetoencephalogra* adj MEG).ti,ab,kw.	5,098
10	superconducting quantum interference.ti,ab,kw.	1,192
11	(superconducting quantum interference adj SQUID).ti,ab,kw.	3
12	(optically?pumped magnetometer or atomic magnetometers).ti,ab,kw.	172
13	Silicon Nanowire Biosensor.ti,ab,kw.	21
14	SiNW.ti,ab,kw.	562
15	photoelectrochemical immunosensor.ti,ab,kw.	135
16	PEC?Immunosensor.ti,ab,kw.	10
17	or/1-16	24,893
18	(digital adj2 tomosynthesis).ti,ab,kw.	1,928
19	tunnel magnetoresistance.ti,ab,kw.	167
20	(quantum adj2 (tunnel or tunnelling)).ti,ab,kw.	372
21	photonic integrated circuits.ti,ab,kw.	923
22	(quantum adj2 photonics).ti,ab,kw.	331
23	(quantum adj2 (integrated or photonics)).ti,ab,kw.	709
24	or/18-23	4,047
25	limit 17 to dt=20241015-20250409	710

26	limit 24 to dt=20241015-20250409	237
27	conference abstract.pt.	0
28	"review".pt.	3,408,256
29	27 or 28	3,408,256
30	25 not 29	628
31	26 not 29	211
32	30 or 31	837
33	exp animals/ or exp animal experimentation/ or exp animal experiment/ or exp models animal/ or nonhuman/ or exp vertebrate/ or exp vertebrates/	27,948,757
34	exp humans/ or exp human experimentation/ or exp human experiment/	22,625,383
35	33 not 34	5,324,002
36	32 not 35	815
37	limit 36 to english language	813

Scopus (Run 11-04-25)

#	String	Results
1	TITLE (Multimodal W/1 (imag* OR therap* OR microscopy)) OR	5263
2	TITLE (structured light W/1 (imag* OR therap* OR microscopy)) OR	183
3	TITLE (fluorescen* W/1 (imag* OR therap* OR microscopy) W/3 (drug* OR diagnos* OR therap* OR medi*)) OR	1044
4	TITLE-ABS ("Quantum dot" W/3 (drug* OR diagnos* OR therap* OR medi*)) OR	1607

5	TITLE-ABS ("quantum molecular resonance" OR QMR OR QMRT) OR	573
6	TITLE-ABS (semiconductor W/1 (nanocrystals OR particles)) W/3 (drug* OR diagnos* OR therap* OR medi*)) OR	6,422
7	TITLE-ABS-KEY(Magnetoencephalogram W/1 MEG) OR	426
8	TITLE-ABS-KEY ("superconducting quantum interference" W/1 SQUID) OR	4520
9	TITLE-ABS-KEY("optically pumped magnetometer" OR "optically-pumped magnetometer" OR "atomic magnetometer") OR	1697
10	TITLE-ABS-KEY("Silicon Nanowire Biosensor" OR SiNW) OR	2132
11	TITLE-ABS-KEY ("Photoelectrical Immunosensor") OR	1
12	TITLE-ABS-KEY (PEC w/1 Immunosensor) OR	227
13	TITLE-ABS-KEY (digital W/2 tomosynthesis)	4328
14	TITLE-ABS-KEY ("tunnel magnetoresistance")	2001
15	TITLE-ABS-KEY (quantum W/2 (tunnel or tunnelling))	2588
16	TITLE ("photonic integrated circuits") OR	2061
17	TITLE-ABS-KEY (quantum W/2 photonics) OR	2449
18	TITLE-ABS-KEY (quantum w/2 (integrated or photonics)) OR	4962
19	OR/1-19	59949
20	AND ORIG-LOAD-DATE > 20241017	2267
21	Limited to English	2200
22	Limited to Document Type: Journal	1309

TITLE (multimodal W/1 (imag* OR therap* OR microscopy)) OR TITLE ("structured light" W/1 (imag* OR therap* OR microscopy)) OR TITLE (fluorescen* W/1 (imag* OR therap* OR microscopy) W/3 (drug* OR diagnos* OR therap* OR medi*)) OR TITLE-ABS ("Quantum dot" W/3 (drug* OR diagnos* OR therap* OR medi*)) OR TITLE-ABS-KEY ("quantum molecular resonance" OR qmr OR qmrt) OR TITLE-ABS-KEY (semiconductor W/1 (nanocrystals OR particles)) OR TITLE-ABS-KEY (magnetoencephalogram W/1 meg) OR TITLE-ABS-KEY ("superconducting quantum interference" W/1 squid) OR TITLE-ABS-KEY ("optically pumped magnetometer" OR "optically-pumped magnetometer" OR "atomic magnetometer") OR TITLE-ABS-KEY ("Silicon Nanowire Biosensor" OR sinw) OR TITLE-ABS-KEY ("Photoelectrical Immunosensor") OR TITLE-ABS-KEY (pec W/1 immunosensor) OR TITLE-ABS-KEY (digital W/2 tomosynthesis) OR TITLE-ABS-KEY ("tunnel magnetoresistance") OR TITLE-ABS-KEY (quantum W/2 (tunnel OR tunnelling))

OR TITLE ("photonic integrated circuits") OR TITLE-ABS-KEY (quantum W/2 photonics) OR TITLE-ABS-KEY (quantum W/2 (integrated OR photonics)) AND ORIG-LOAD-DATE > 20241017 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))

Appendix B – Funding grant database search strategy

CORDIS

(quantum OR "quantum technology" OR "quantum sensor" OR "quantum sensing" OR "quantum computing" OR "quantum image" OR "quantum encryption" OR "quantum cryptography" OR "quantum magnetic resonance" OR "quantum molecular resonance" OR QMR OR QMRT OR "quantum sonotherapy" OR "quantum spectrum radiation" OR "multimodal imaging" OR "structured light imaging" OR "structured light" OR "fluorescent imaging" OR "Quantum dot" OR "semiconductor nanocrystals" OR "semiconductor particles" OR magnetoencephalogram OR MEG OR "superconducting quantum interference" OR SQUID OR "optically pumped magnetometer" OR "atomic magnetometer" OR "Silicon Nanowire Biosensor" OR SiNW OR "Photoelectrical Immunosensor" OR PEC OR "digital tomosynthesis" OR "tunnel magnetoresistance" OR "quantum tunnelling" OR "photonic integrated circuits" OR "quantum photonics" OR "quantum integrated photonics")

Limit to Domain: Health

Limit Start Date (From): 2024-10-18 to Start date (To): 2025-04-11

Results 5

UKRI

(quantum OR "quantum technology" OR "quantum sensor" OR "quantum sensing" OR "quantum computing" OR "quantum image" OR "quantum encryption" OR "quantum cryptography" OR "quantum magnetic resonance" OR "quantum molecular resonance" OR QMR OR QMRT OR "quantum sonotherapy" OR "quantum spectrum radiation" OR "multimodal imaging" OR "structured light imaging" OR "structured light" OR "fluorescent imaging" OR "Quantum dot" OR "semiconductor nanocrystals" OR "semiconductor particles" OR magnetoencephalogram OR MEG OR "superconducting quantum interference" OR SQUID OR "optically pumped magnetometer" OR "atomic magnetometer" OR "Silicon Nanowire Biosensor" OR SiNW OR "Photoelectrical Immunosensor" OR PEC OR "digital tomosynthesis" OR "tunnel magnetoresistance" OR "quantum tunnelling" OR "photonic integrated circuits" OR "quantum photonics" OR "quantum integrated photonics")

Filter by year: 2024-2025

Results: 562

Appendix C – Technologies and developers identified outside of our searches

The following table presents quantum computing technologies or developers that are developing products for healthcare applications. These were not discovered through clinical trials, publications, soft intelligence, or funding searches but were identified through discussions and feedback with stakeholders. Their firsthand experiences and perspectives helped to identify promising innovations that might not yet be widely recognised.

Name of technology	Commercial developer	Source(s)
Quantum Computing for Covalent Inhibitors in Drug Discovery	QuEra, Phasecraft	https://www.quera.com/press-releases/two-projects-powered-by-quera-computing-contributions-move-to-phase-three-of-wellcome-leaps-quantum-for-bio-challenge-focused-on-healthcare-and-biology-applications
Drug Discovery using Programmable Quantum Simulation	QuEra	https://www.quera.com/press-releases/two-projects-powered-by-quera-computing-contributions-move-to-phase-three-of-wellcome-leaps-quantum-for-bio-challenge-focused-on-healthcare-and-biology-applications
Quantum Pangenomics	Wellcome Sanger Institute	https://www.sanger.ac.uk/collaboration/quantum-pangenomics/
The Novo Nordisk Foundation Quantum Computing Programme	Novo Nordisk	https://nqcp.ku.dk
Using Quantum Machine Learning to Improve Early Detection of Cancer	Applied Quantum Computing	https://www.nqcc.ac.uk/wp-content/uploads/2025/06/NQCC-Quantum-Computing-Use-Case-Compendium-web.pdf
Quantum Machine Learning for Clustering Multi-Omics Data in Cancer Research	Infleqtion	https://www.nqcc.ac.uk/wp-content/uploads/2025/06/NQCC-Quantum-Computing-Use-Case-Compendium-web.pdf
Using Quantum Optimisation Techniques to Improve Operational Healthcare	Applied Quantum Computing	https://www.nqcc.ac.uk/wp-content/uploads/2025/06/NQCC-Quantum-Computing-Use-Case-Compendium-web.pdf

A Next-generation Quantum Computing Based Approach to Enzyme Targeted Drug Discovery	Kuano	https://www.nqcc.ac.uk/wp-content/uploads/2025/06/NQCC-Quantum-Computing-Use-Case-Compendium-web.pdf
Security-first Federated Quantum Machine Learning for Genomics	Zaiku Group	https://www.nqcc.ac.uk/wp-content/uploads/2025/06/NQCC-Quantum-Computing-Use-Case-Compendium-web.pdf

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