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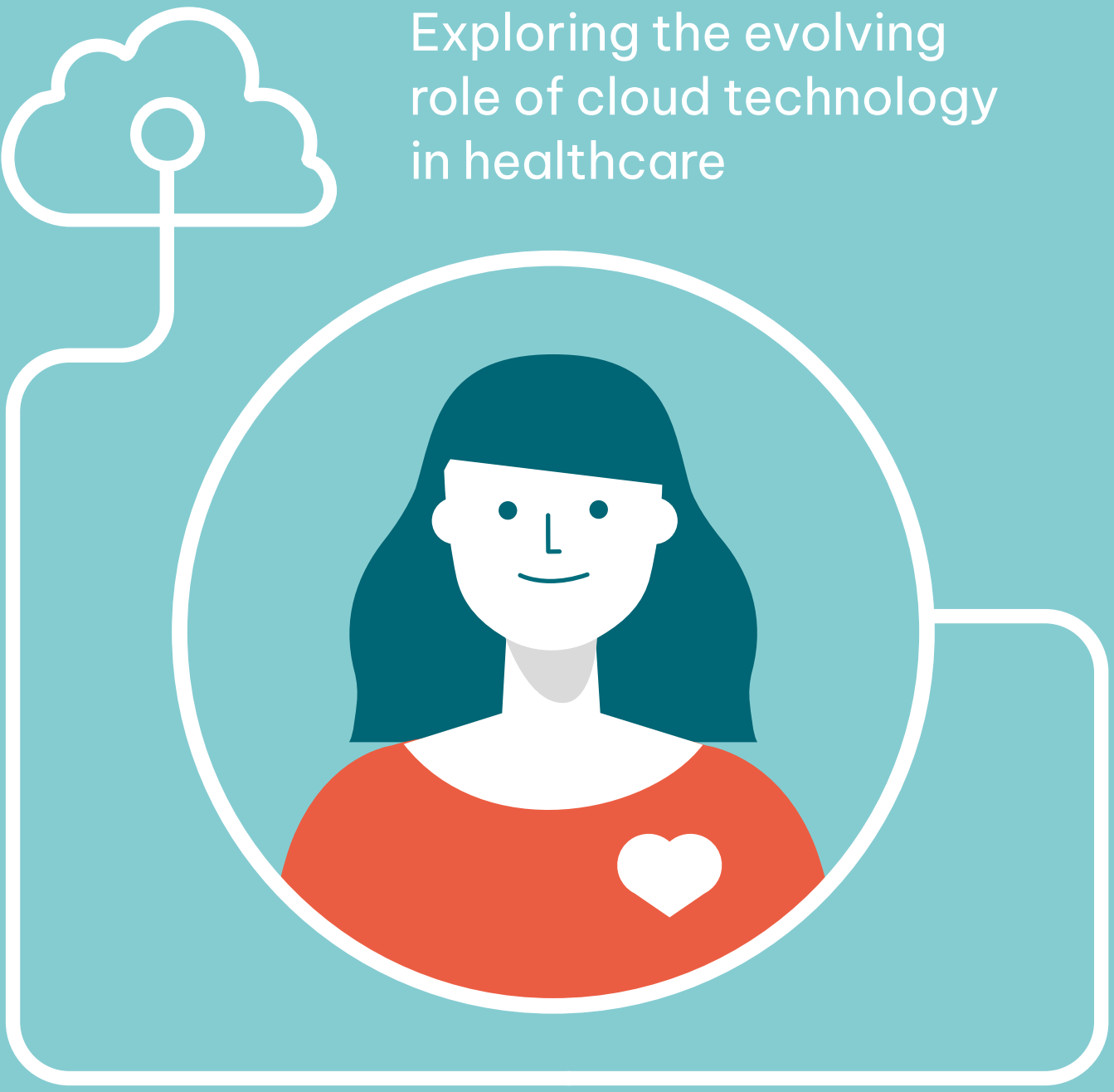
OUR HEALTH IN THE CLOUD

Exploring the evolving role of cloud technology in healthcare



The Health Policy Partnership
[research, people, action]

iHD The European Institute for Innovation through Health Data

About this report

This report was written by Catherine H. Whicher and Suzanne Wait of The Health Policy Partnership, with the support of Dipak Kalra and Nathan Lea from the European Institute for Innovation through Health Data. It was informed by desk research and expert interviews.

We would like to thank the following contributors for their insights:

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EXECUTIVE SUMMARY

Health systems around the globe are experiencing unprecedented challenges; addressing them requires an approach that is both comprehensive and data driven. Cloud technology ('the cloud') is a key enabler of this data-driven approach. Not only does it offer significantly larger amounts of virtual capacity than on-premises systems, it also allows for a flexible approach to computing and data storage, offering scalability and efficiency. This is important as both care delivery and health-related research are more data intensive and collaborative than ever, and the processes of collecting, combining, storing, analysing and exchanging these data require computational power and speed that far exceed ordinary on-premises capabilities.

> If you agree that the patient comes first, you simply need to prioritise integrated, data-driven healthcare. That needs trust and consent, but it also needs an investment in infrastructure.
>
> **Prof. Pascal Verdonck,** Ghent University, Belgian & European Association of Hospital Managers

Cloud technology is already present in our lives when we use email, social media or online banking; however, when it comes to healthcare, most people know very little about its role. In fact, the cloud has already demonstrated huge potential in healthcare, translating into tangible benefits for individual and population health in several important domains:

- more efficient and person-centred care
- a population-based approach to health
- research that drives innovation
- sustainable and resilient health systems

More efficient and person-centred care

Cloud technology can help bring all the information about a person into clinical decisions, improving continuity of care. It can also enable the deployment of artificial intelligence (AI) and machine-learning tools that speed up diagnosis and access to treatment.

A cloud-based AI system trained to read brain images interprets computed tomography (CT) scans of people suspected of having a stroke in seconds rather than hours, and with greater accuracy, offering them much more rapid access to life-saving treatment.[1]

A population-based approach to health

Cloud technology can support the application of advanced analytics to pool data to establish causality between factors. These linkages help identify opportunities to improve health equity and disseminate interventions at pace.

Public health officials used cloud technology to navigate numerous substantial data sets during the COVID-19 pandemic, in one instance building a dashboard of public health data in only nine days.[2]

> It's not really about deciding whether it's cloud or on-premises. The debate is about what we, as an ecosystem, agree on as guiding principles of trustworthiness when it comes to data storage, handling and analysis.
>
> **Prof. Liesbet M. Peeters,** Hasselt University, MS Data Alliance

Research that drives innovation

Cloud technology can offer processing powers orders of magnitude larger than conventional computing. As a result, research is democratised as organisations of all sizes may access machine-learning analytics and data insights.

Data contained in a single person's genome are equivalent to more than 100,000 photographs.[3] Before cloud technology, processing one person's molecular panel data took a lab up to 10 hours. Now, it can be completed in 15 minutes.[4 5]

Sustainable and resilient health systems

Use of the cloud can help remove inefficiencies and facilitate the smooth running of operations around the delivery of care, optimising health outcomes and allowing healthcare professionals to spend more time caring for their patients.

Database queries at a hospital which transitioned its electronic health records to cloud are now significantly faster, with tasks that once took a clinician 15–20 minutes now taking 15–20 seconds.[6]

Despite this potential, the adoption of cloud technology is at its infancy in healthcare compared with other sectors, and several barriers to optimising its use remain. Lack of general knowledge and understanding of the cloud, as well as perceived risks related to privacy and security, are important first barriers to address.

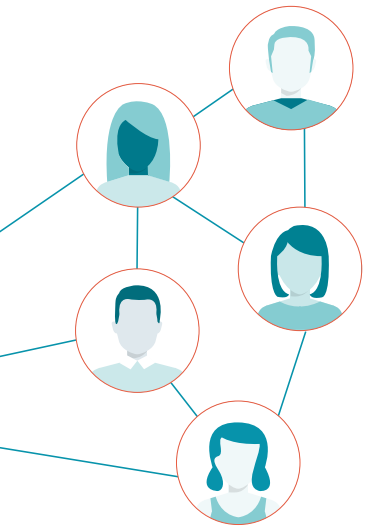
Ensuring the security and privacy of citizens' data as organisations migrate to the cloud requires a collaborative approach of shared responsibility. Cloud service providers must build robust mitigation measures into the cloud architecture; independent audits and assessments play a crucial role in demonstrating that they have adopted industry standards and certifications to do so. Health organisations must ensure they provide training to their staff and put in place appropriate data protection measures. And policymakers must implement cohesive guidance, regulatory frameworks and mechanisms to enable a consistent approach across the entire health ecosystem.

> Of course it's the future, but it's already happening, too. Patient advocates need to be aware of [the cloud] to be able to inform their communities and get involved with the discussions around its use.
>
> **Gözde Susuzlu Briggs,** 'Data Saves Lives', European Patients' Forum

Cloud technology has the potential to enable transformative change across health and health systems. Given the breadth of its applications, understanding cloud technology should not remain within the confines of IT departments; all stakeholders should be engaged in optimising its role for the benefit of individual and population health, keeping the needs of people receiving care front of mind.

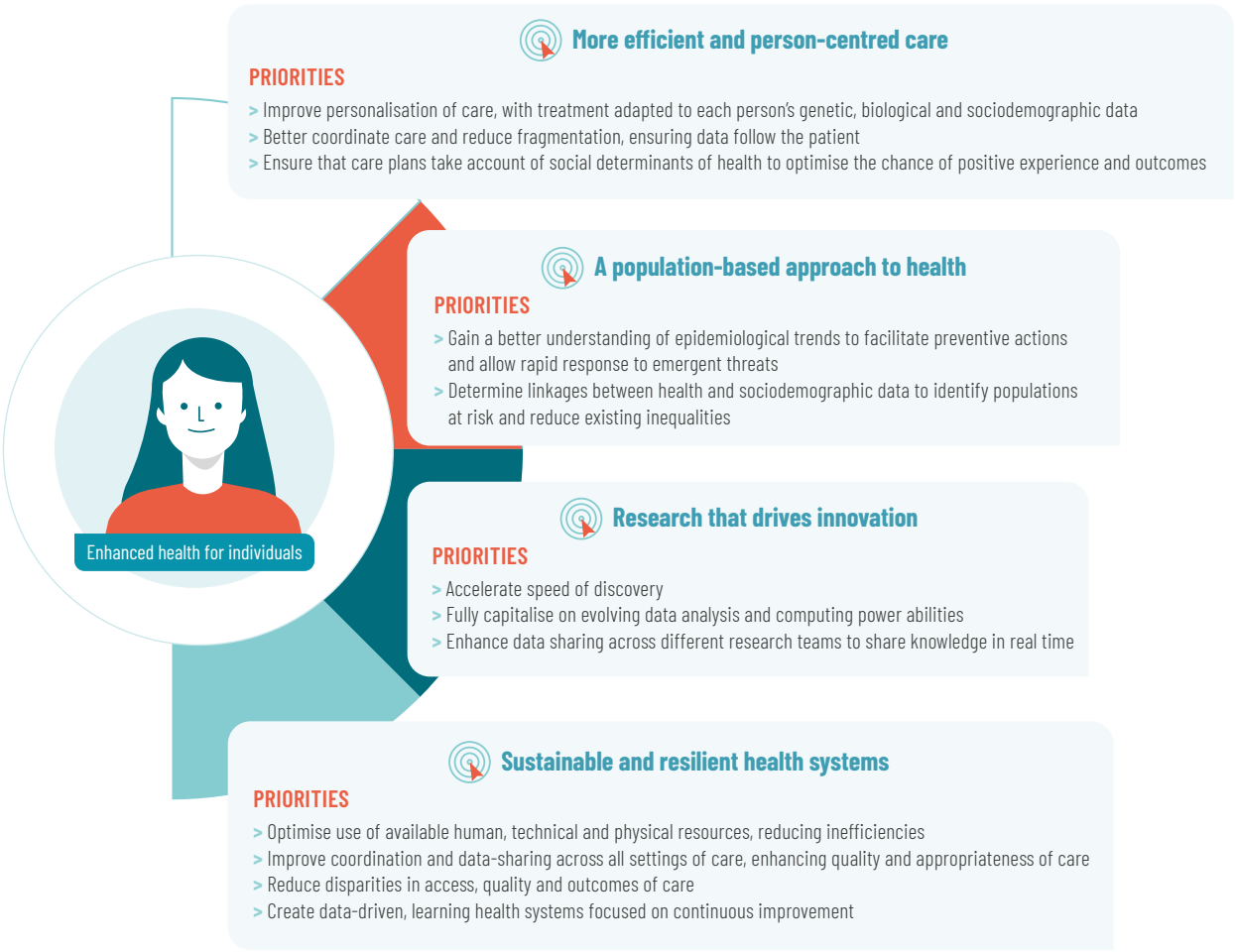
ENVISAGING THE FUTURE OF HEALTH SYSTEMS

Health systems the world over are experiencing unprecedented challenges. These include human resource shortages, financial constraints, ageing populations often living with multiple non-communicable diseases (NCDs), and rising social inequalities that cause disparities in health risks and outcomes.[7] Faced with these pressures, health system leaders are grappling with how to develop more resilient, sustainable and efficient health systems while simultaneously delivering person-centred, equitable and high-quality care to all.



Improving individual and population health requires a comprehensive and data-driven approach. Concurrent efforts are needed to optimise public health, strengthen health systems, ensure individuals receive person-centred care tailored to their needs and foster innovation through research (*Figure 1*). Achieving those priorities requires insights to be drawn from the many different sources of information on each individual in order to understand their risks and health needs and to tailor solutions accordingly (*Figure 2*). Taking such a comprehensive, data-driven approach was instrumental in mitigating the impact of the COVID-19 pandemic;[8,9] it should be emulated to support every aspect of improving health for individuals and populations.

FIGURE 1. A whole-systems view of priorities for improving health for individuals



Cloud technology is a key enabler of this data-driven vision for enhanced health and health systems. The advent of cloud technology has made it possible to pool, store and connect numerous types of data and information across multiple locations, giving all users access to a shared virtual space. Its applications, which are in theory limitless, can support the delivery of higher-quality care that is more personalised and effective,[9 10] in turn making health systems more sustainable by reducing waste and inefficiency. The cloud can also enable health systems to be more responsive to tomorrow's innovations. If integrated appropriately, it has the potential to become an indispensable tool in optimising health and research ecosystems.

FIGURE 2. The richness of data surrounding a person's health[11]

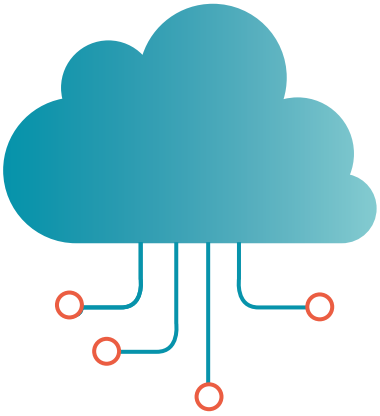
However, the use of cloud technology in health lags behind that in other sectors, and challenges persist for decision-makers wishing to adopt a cloud-first approach. Numerous organisations and countries, as well as the European Union, have developed policies that prioritise the procurement and use of IT via the cloud.[12-14] However, implementing such policies across the many layers of a health system is not a one-off exercise.[10] Appropriate preparedness, time, change management and training are all required to facilitate the transition.

Limited understanding of cloud technology also presents a barrier to its wider adoption in the health sector. Research suggests that some stakeholders have specific concerns regarding the application of cloud technology in healthcare, particularly with regard to privacy, cybersecurity and governance.[10 11 15-18] Addressing these concerns is of paramount importance: a collaborative approach fostering shared responsibility is needed between cloud service providers, organisations using their services and policymakers to ensure that cloud-enabled technologies are always applied in the best interests of the people and populations they serve.

> Transparency in the adoption of cloud is just so crucial. It's important to explain the advantages, the value to the patient, the solutions and the risks. Of course it's the future, but it's already happening, too. Patients need to be involved not because they know more but because they know different things. Lived experience is an extremely valuable part of a multi-stakeholder approach.
>
> **Gözde Susuzlu Briggs**, 'Data Saves Lives', European Patients' Forum

This report aims to demystify cloud technology in the context of health and demonstrate its potential role as a key enabler within our health systems. It provides an accessible description of what cloud technology is and draws on concrete examples of where it has already been deployed effectively. It looks at how critical issues, such as governance, cybersecurity and privacy, have been or can be addressed. Finally, it considers how decision-makers across Europe can engage all relevant stakeholders and foster the optimal adoption of cloud technology to improve population health.

UNDERSTANDING CLOUD TECHNOLOGY



WHAT IS CLOUD TECHNOLOGY?

Cloud technology is, in essence, IT infrastructure delivered as a scalable, measured service, with a cloud service provider managing the underlying network infrastructure.

Helpful terms

Cloud service provider (CSP): the entity, organisation or company providing cloud technology to the consumer.

Computational power: the ability of a computer to execute functions such as calculations, downloads or uploads.

Cybersecurity: measures used to protect digital information from being viewed, manipulated or otherwise accessed by unauthorised users.

Encryption: a way to conceal information by altering it so it is unreadable without a key.

On-premises: servers owned and operated by the user i.e. not in the cloud.

Server farm: a dedicated collection of servers; often the model used by CSPs to provide large-scale computing to consumers.

Cloud technology offers a way to capitalise on the vast amount of data and the power of analytics available in health. Probably the most well-known attribute of cloud technology is that it offers significantly larger amounts of virtual capacity than on-premises environments. This is important as both care delivery and health-related research are more data-intensive and collaborative than ever, and the processes of collecting, combining, storing, analysing and exchanging these data require computational power, cybersecurity and speed that far exceed ordinary on-site capabilities.[5 19 20] For example, the amount of data contained in just one person's genome is equivalent to more than 100,000 photographs.[3]

Cloud technology allows for a flexible approach to IT services and computing, offering greater efficiency and sustainability. The cloud is a measured service that makes it possible to use IT services and computing on a metered basis rather than paying in advance for fixed connectivity, software, hardware and associated costs of on-premises servers, such as energy and cooling (*Box 1*). The cloud service provider (CSP) takes responsibility for reliable data storage and connectivity (such as server maintenance and underlying software updates)[21] and for the implementation of appropriate cybersecurity measures at the infrastructure level.

BOX 1. The core characteristics of cloud technology[9 11 21]

CHARACTERISTIC	What does it mean?	Why this matters
 Measured service ('pay-per-use')	Computing services are metered	**Expenditure** on a per-unit basis allows cost savings for any IT resources that are not in use (e.g. due to seasonal variations in demand)
 On-demand self-service	The consumer automatically acquires computing capabilities as needed without the need for significant human interaction	**The administrator** can change their subscription with the CSP's offerings on a dedicated console (e.g. adding 'virtual hardware' tools for advanced analytics)
 Rapid scalability ('elasticity')	Computing capabilities can be scaled up and down, often automatically	**Cloud technologies** are responsive to changes in customer demand. Cost savings can be made when winding down a project, and lag is eliminated when scaling up a new initiative
 Broad network access	Cloud technology capabilities are available over a network and accessible by different devices	**Entire project** teams and organisations, regardless of physical location, can access the same data sets, analytical tools and software
 Resource pooling	The provider's resources can serve multiple consumers simultaneously, regardless of their locations	**Large teams** and organisations can access the IT services at the same time without experiencing capacity limits

As a result, hospitals and research organisations transitioning to cloud-based services can reduce costs over time, with a flexible operational expenditure that can be adjusted up or down to meet their needs.[21] Users can also choose the degree to which they embed their IT practices into cloud environments versus on-premises environments, allowing the option of a hybrid approach. CSPs with multiple server farms can also offer a choice of geographical location for the storage and processing of data, which can be helpful for compliance or disaster recovery purposes.

BENEFITS FOR HEALTH SYSTEMS, PATIENT CARE AND RESEARCH

Cloud technology's processing power and ability to pool data translate into significant benefits for health systems and individuals. Cloud technology is already present in our lives when we use email, social media, streaming services or online banking. However, when it comes to healthcare, most people know very little about the technology's role or potential value. Using the cloud, health systems can make use of data across multiple settings with less risk of duplication and inefficiency. It can support greater coordination of care, enabling the use of electronic health records and real-time interactions between healthcare practitioners, which means better continuity of care for individuals. It can also make up-to-date patient data accessible to the entire (authorised) healthcare team, enabling clinicians to monitor patients remotely and supporting patients to learn more about their condition and take a proactive role in seeking relevant responses from their care teams in real time.

Cloud technology also multiplies the speed of research several-fold and democratises it. It can offer processing powers orders of magnitude larger than conventional computing. As a result, organisations of all sizes may access machine-learning analytics and data insights. Data and computational resources from multiple settings and geographical locations can be pooled in centralised, accessible virtual spaces, such as open data registries, made available to research teams around the world for investigation.[5]

MITIGATING RISKS WITH HEALTH DATA

> People should understand that there will always be risks. We as a community should have a debate about what types of risk we are willing to cope with. It's not really about deciding whether it's cloud or on-premises. The debate is about what we, as an ecosystem, agree on as guiding principles of trustworthiness when it comes to data storage, handling and analysis.
>
> **Prof. Liesbet M. Peeters**, Hasselt University, MS Data Alliance Academic

Any platform that holds data comes with certain risks. People rightly wish to ensure that their health data are handled with caution and due diligence, and they regularly cite concerns about privacy and security as central to their decision-making around the digitisation of health data.[10 11 15-17] Risk-averse approaches to data sharing are both understandable and appropriate regardless of the data server's location, which may be in a doctor's surgery, regional hospital or dedicated storage facility or on a cloud server. Many of the concerns surrounding cloud technology actually apply to all digital health platforms and represent priorities for all digital health data handlers to address (*Box 2*).[22]

Safeguarding against risk is paramount for cloud service providers, and mitigation measures can be embedded into the underlying architecture of the cloud. Independent audits and assessments also play a crucial role in demonstrating the trustworthiness of CSPs that have adopted appropriate industry standards and certifications. All CSPs must maintain consistent and high cybersecurity requirements and uphold stringent data security strategies to help mitigate known risks around data storage and sharing.[23-25] They should also work closely with end users (e.g. hospitals or research institutes), providing them with tools and support to stay current with security requirements and build the necessary cybersecurity literacy among their workforce. This will enable users to appropriately manage vulnerabilities, including human error, across their operations.[26]

BOX 2. Priorities for the deployment of cloud technology in healthcare settings[10 11 15-19 27]

PRIORITY	Perceived **risk**	How to **manage it effectively**
 Data security	Cybersecurity, e.g. health data being accessed without authorisation (hacked)	All servers – whether on-premises or cloud based – are at risk of targeted or indiscriminate cyberattacks. Appropriate investment in data security practices, security training and contingency architecture is required to minimise this risk. Encryption techniques are increasingly important in masking data from unauthorised users
 Data privacy	Approved network users finding a way to view private individual health data without a lawful reason to do so	Systems can use varying levels of access to add extra layers of protection that operate specifically over more sensitive data (such as individual patient data) so that only specially authorised users can view or access them. System access can be audited to examine usage patterns and flag unauthorised access
 Availability and reliability	Cloud server outage leading to the corruption or loss of data	Users can choose to host data on multiple, redundant servers at separate locations to act as back-ups, reducing the likelihood of any localised server problem affecting the consumer
 Adherence to data governance	Data not always being handled in line with regulatory requirements	Cloud technology allows systems to be designed with built-in regulatory, governance and legislative standards, with users unable to override the requirements that their administrator has set

THE PATIENT PERSPECTIVE

A TUMOUR NEARLY MISSED

In a European country, Marie* consulted her gynaecologist for a routine examination. Her doctor noticed a small lump on her breast on the ultrasound but did not think it was a cause for concern. This country's health system is mainly paper-based, so the doctor could not compare the findings with previous ones unless Marie could bring a CD or physical printouts of previous scans to her appointment. She had neither of these as she had recently relocated from a Latin American country with different record-keeping practices. She was told to return for her next routine check-up in a year or two.

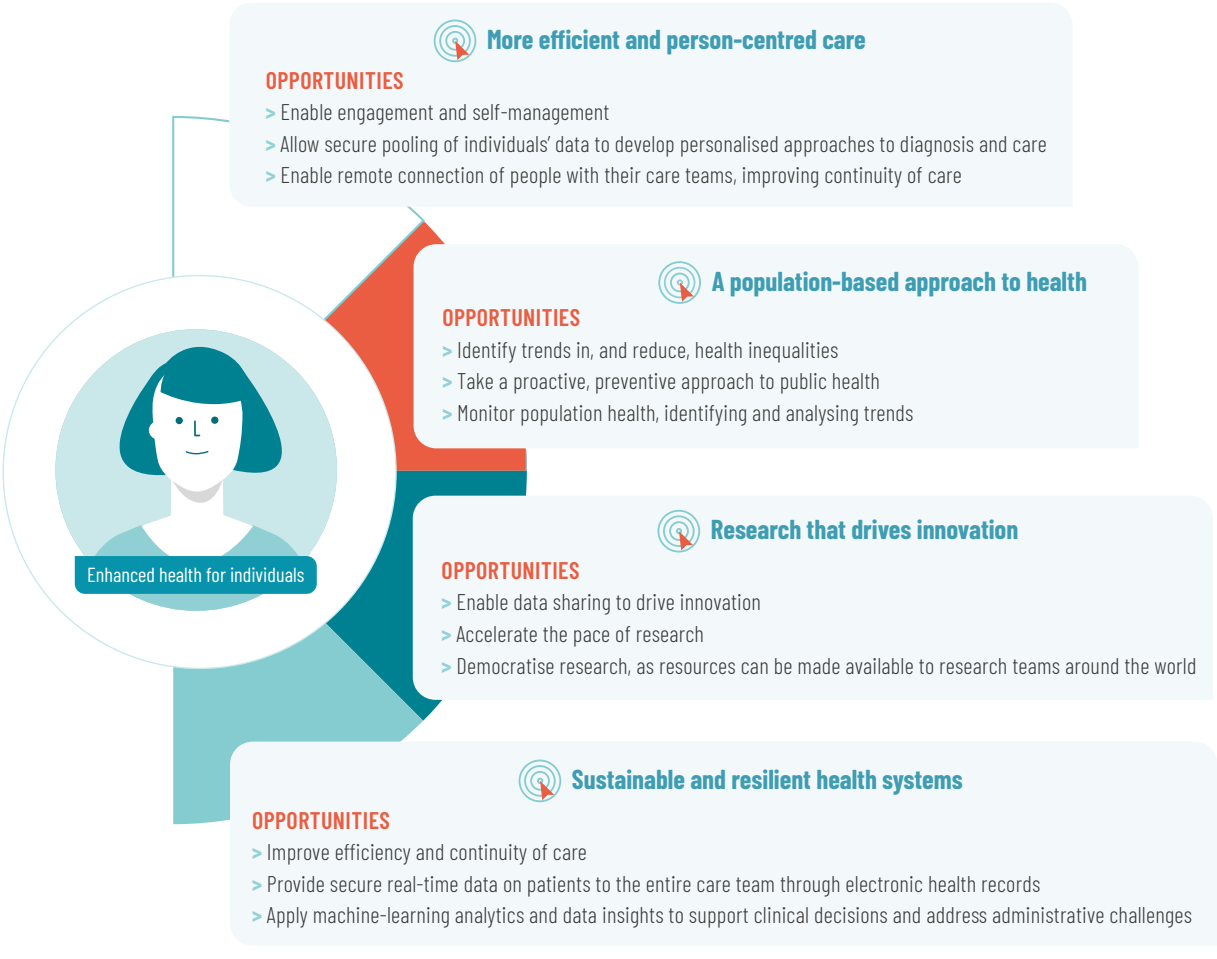
When Marie visited her family, she decided to consult her former gynaecologist for a second opinion. Her home country's health system utilises cloud technology, so with her permission to access her digital health records, the gynaecologist was able to compare the most recent findings with the results of previous scans over the past decade. Those comparisons clearly showed that the lump had doubled in size, prompting a biopsy. Marie was diagnosed with early-stage breast cancer and given immediate treatment.

** This scenario is inspired by real-life experience; the person's name has been changed to respect their anonymity.*

DRIVING CHANGE: CLOUD TECHNOLOGY IN PRACTICE

Although the adoption of cloud technology in health is in its infancy compared with other sectors, the cloud has already demonstrated huge potential across health systems, research settings and public health practice. This section presents a range of case studies that demonstrate how the characteristics of cloud technology allow it to help address some of the core challenges facing healthcare, public health and research (*Figure 3*).

FIGURE 3. How cloud technology can enable health system goals



IMPROVING HEALTH EQUITY

> When it comes to addressing the social determinants of health, we tend to underuse technology. However, it is increasingly relevant as we try to prevent non-communicable disease because [it allows you] to capture and understand significant quantities of data from different sources to inform which interventions will help achieve your population health goals and improve health equity most efficiently and effectively.
>
> **Prof. Mark Lawler**, Queen's University Belfast

Improving health equity and addressing inequalities are critical goals for all health systems. The disproportionate impact of COVID-19 on people belonging to underserved or minority ethnic groups[28] has renewed the urgency around understanding and tackling the social determinants of health. People's health is influenced by many facets of their lived realities, including their neighbourhood, income, education and ethnicity.[29] Understanding the potential impact of these different variables on health requires exploration of the data for possible links (*Case study 1*).

Cloud technology can enable the combined analysis of individual and population-level data to identify possible links between variables. This requires the computational processing of vast stores of data – beyond the capacity of a single ordinary server – and the application of advanced analytics to determine trends and causality. Such analyses can yield results that help identify inequalities in outcomes across populations.[30 31] This in turn can inform proactive interventions to address them, such as distributing resources more efficiently across the population.

Case study 1. **Identifying disparities in cancer care across Europe**[31-33]

There are significant inequalities in cancer care across Europe, both within and between countries. The European Cancer Organisation (ECO) developed the European Cancer Pulse as a tool to capture and visualise these disparities and help support healthcare professionals and patient advocates in their efforts to demand improvements in cancer care and research. The tool has collated and analysed data from 34 countries across ten areas of interest, including differences in disease burden, research spending, early detection programmes and survivorship. The data capture information on more than 120 indicators of inequalities across the European continent.

The aggregation and presentation of data such as these can empower healthcare professionals, researchers, individuals and patient associations to identify specific gaps in care and best-practice models. It also provides them with the evidence to present a compelling case for change.

TAKING A PROACTIVE APPROACH TO PUBLIC HEALTH

> Since the pandemic, people are starting to understand a bit of the data movement behind digital technologies, digitalised health and what it can really do in terms of population health outcomes, but it's still very new to them.
>
> **Gözde Susuzlu Briggs**, 'Data Saves Lives', European Patients' Forum

The ability to link different data sets can aid the development of targeted public health approaches. The COVID-19 pandemic made it clear that public health officials must be able to navigate numerous substantial data sets so that they can rapidly determine population health trends and mitigate risks through the dissemination of interventions at pace.[8] In one instance, public health officials used cloud technology to build a dashboard of public health data in only nine days.[2] However, population health management extends beyond acute responses. Cloud-based approaches can also allow for the safe combination of data captured from individuals' smartphones and wearable devices with other health data (*Case study 2*). Meaningful analyses of these data make it possible to tailor preventive approaches and connect a person with their care team in real time.[34]

Case study 2. **Promoting health lifestyles in young people with mobile tech[34]**

Physical inactivity is a major risk factor for non-communicable diseases over a person's life. A sedentary lifestyle and poor diet can lead to obesity and other serious health risks. Adolescence is a good time to intervene and introduce health-promoting habits, such as physical activity, good nutrition and high-quality sleep.

In a pilot study, researchers developed a dedicated mobile application on a cloud platform that connects with wearable tech data used by the participants. The data were analysed in the cloud and used to offer personalised interventions to each user. The system also connected the users with experts who could provide specific support and answer their questions as the study progressed. Each person's data could be securely transferred from the cloud to their national health record to support continuity of care and further monitoring of progress past the end stage of the study.

IMPROVING THE EFFICIENCY OF CARE

> It's not just diagnostics, there are many more applications of cloud in healthcare under development. Complete data around a person's health can be directly transformed into precision medicine and targeted treatment plans. This will be here quite soon.
>
> **Prof. Dr Dr Torsten Haferlach**, Munich Leukemia Laboratory

Given the financial pressures on all health systems, addressing inefficiencies around the delivery of care offers an important opportunity to ease budget constraints while improving the standard of care. Experts have estimated that up to 20% of healthcare is inefficient – that is, not contributing to better health outcomes – and that much of this inefficiency is linked to a lack of coordination within health systems.[35] This can easily be avoided. Transitioning from paper to electronic health records is one key driver of efficiency, partly because it provides the option to combine different types of data from different sources into one record.[5] These may include unstructured (text) data, as machine-learning tools available via cloud technology are now able to read handwritten forms.[36] Streamlined, data-driven processes can facilitate the smooth running of operations around the delivery of care, optimising health outcomes. Such processes can also remove inefficiencies for healthcare practitioners, administrators and ancillary staff. The use of cloud-enabled artificial intelligence to speed up diagnostic processing times is one such example (*Case study 3*).

Case study 3. **Using artificial intelligence to review brain scans in seconds[1]**

Time is critical when responding to a stroke. One of the key diagnostic steps in confirming a stroke is a computed tomography (CT) scan, which could take several hours for healthcare professionals to review, potentially delaying life-saving treatment and interventions. One research team decided to train artificial intelligence to address this bottleneck in care. Working with machine-learning specialists, the team built an algorithm that was able to read a CT scan in 30 seconds. The cloud-based system saved hours of time per scan, and its readings were more accurate than those of human experts.

These technologies enable faster life-saving care of brain injuries and free up clinicians to spend more time with their patients. They may also give smaller hospitals the same diagnostic powers as specialist centres, as the only tools needed are a CT scanner and a connection to the cloud.

DELIVERING INTEGRATED, PERSON-CENTRED CARE

> If you agree that the patient comes first, you simply need to prioritise integrated, data-driven healthcare – any challenges are secondary. That is the only way to create value in healthcare, delivering better experiences and outcomes at a lower cost. That needs trust and consent, but it also needs an investment in infrastructure.
>
> **Prof. Pascal Verdonck**, Ghent University, Belgian & European Association of Hospital Manager

Health systems have been striving for years to deliver more person-centred care. Clinical guidelines for nearly all conditions advocate a multidisciplinary approach to care to enable coordination between the different providers involved in each person's care. Cloud technology can enable safe handling and analysis of the extensive data a person can generate over their life course, streamlining communication between different healthcare professionals. This is particularly important for individuals living with several chronic conditions, who, given the siloed nature of specialist care, may have to navigate often parallel care pathways (*Case study 4*). This can be confusing, time-consuming and, if treatment is not coordinated to account for their specific medical needs, even harmful. Cloud technology can also facilitate the organisation and investigation of electronic health records, delivering insights to clinicians in real time.[6] This is a key step towards strengthening efficiencies in care, by both reducing the non-caring time of healthcare practitioners and improving reliable access to a person's full health record (*Case study 5*).

Case study 4. **Integrating care for people with multiple conditions**[37-40]

It is estimated that more than 28% of people over the age of 50 live with more than one non-communicable disease. Researchers set up pilot studies in three countries in Europe, trialling technologies built on cloud infrastructure for the joint management of congestive heart failure, diabetes, depression and renal failure. The tools automatically generated each person's care plan based on clinical best practice, as well as their medical history, medications, health goals and other data. The person and their multidisciplinary care team then reviewed and personalised the plan.

Care teams could quickly see the recommended best practice for each one of the multiple health conditions. They could engage in a more nuanced conversation centred around the proposed care plan for the person and any further customisations necessary to meet their needs and goals. Study participants appreciated the system's potential to simplify their care plan, finding that it enhanced their understanding and engagement.

Case study 5. **Drawing insights from patient data via a comprehensive data platform[6]**

One research hospital group in Belgium had significant volumes of health data digitised, but its ability to draw insights was limited as the data were distributed across different servers and locations. To make use of advanced analytical tools, the group migrated all patients' electronic health records and other relevant data to cloud infrastructure. The hospital team was then able to design a dedicated data platform with comprehensive security and analytics that met its specific needs and objectives.

Database queries are now significantly faster, with tasks that once took a clinician 15–20 minutes taking 15–20 seconds. The ability to perform more complex analyses of the data using tools built for their system means healthcare administrators can rapidly capture insights about their patients that will help them more efficiently manage each person's care delivery.

ENABLING PRECISION MEDICINE

> We have sequenced more than three petabytes of data. To put that into context, if you wanted to download a three-petabyte video, you would have to sit in front of your TV for 100 years, day and night. Without cloud, there is no way to store that much data.
>
> **Prof. Dr Dr Torsten Haferlach**, Munich Leukemia Laboratory

Precision medicine has long been heralded as the future of care, but numerous challenges have hampered its transition from research to clinical practice. Research advances, such as an improved understanding of the human genome, along with enhanced computational power and data analytics capabilities, are helping make this transition a reality.[41] Integrating precision medicine into mainstay clinical practice also relies on sophisticated IT platforms powered by cloud technology.[42] These can process genomic data at scale and in rapid time, making it possible to identify treatments suited to the genomic profile of each patient (*Case study 6*).

Case study 6. **Enabling personalised treatments for people with blood cancers**[4 5]

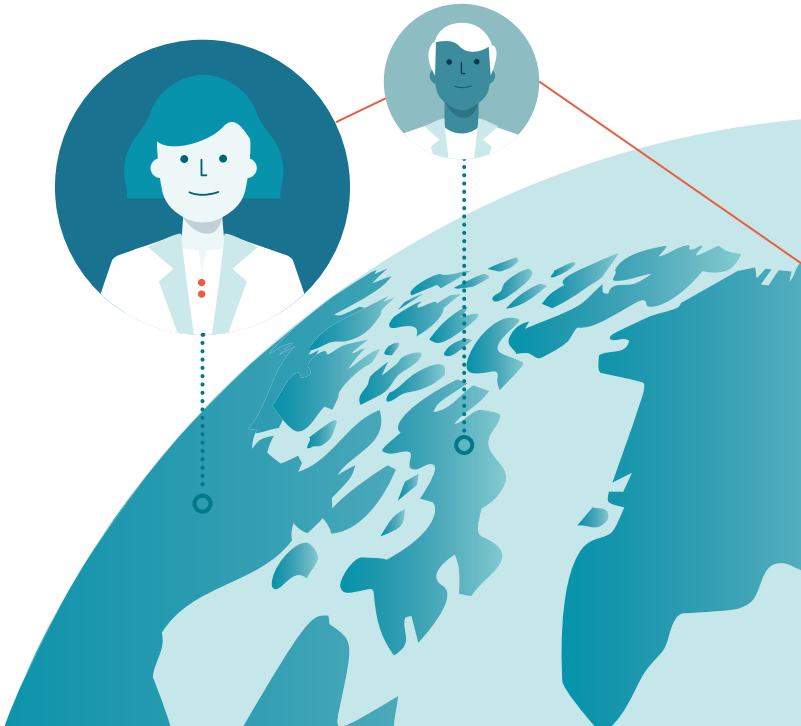
In 2020, blood cancers affected more than 250,000 people in Europe. The Munich Leukemia Laboratory (MLL) works on diagnostics and treatments for two types of blood cancer, leukaemia and lymphoma. Before access to the advanced analytical tools available with cloud technology, processing one patient's molecular panel data took up to 10 hours. Now, this task can be completed in 15 minutes, delivering the diagnosis sooner so that treatment can start more promptly. The lab's cloud environment also allows MLL to collaborate securely on these enormous data sets with research groups around the world by opening a 'tunnel' for third-party access to select data and analytical tools in its cloud. This can then be closed once the analysis is complete. In addition to gene sequencing, MLL works with imaging data in a highly automated system that can process 500 images by artificial intelligence tools in just 20 seconds. It is exploring the application of artificial intelligence to develop treatment recommendations tailored for each person.

Since its inception in 2005, MLL has operated entirely digitally, scanning any physical papers on receipt so that every piece of information related to every case is available for querying. Accreditation (ISO 15189) for all stages of the on-site and cloud-based processes has addressed questions around privacy and security from clinicians, patients and external researchers.

SHARING DATA TO DRIVE INNOVATION

> Because we are so slow in the digitalisation of healthcare and in cross-border data sharing, many urgently needed insights that could transform our health systems are not happening, or they are happening at a speed that is unacceptably slow. When it comes to innovation in healthcare, the gap between the world of medicine and the world of data science is a huge obstruction.
>
> **Prof. Liesbet M. Peeters**, Hasselt University, MS Data Alliance

Data sharing is of tremendous value to researchers and can be facilitated with cloud technology. Appropriately encrypted data that are stored on a suitable virtual platform are easy to anonymise and make available for multiple research teams to interrogate and use for various purposes. Cloud technology can enable connections between data, analytical tools, researchers and study participants to make such data sharing possible (*Case study 7*).

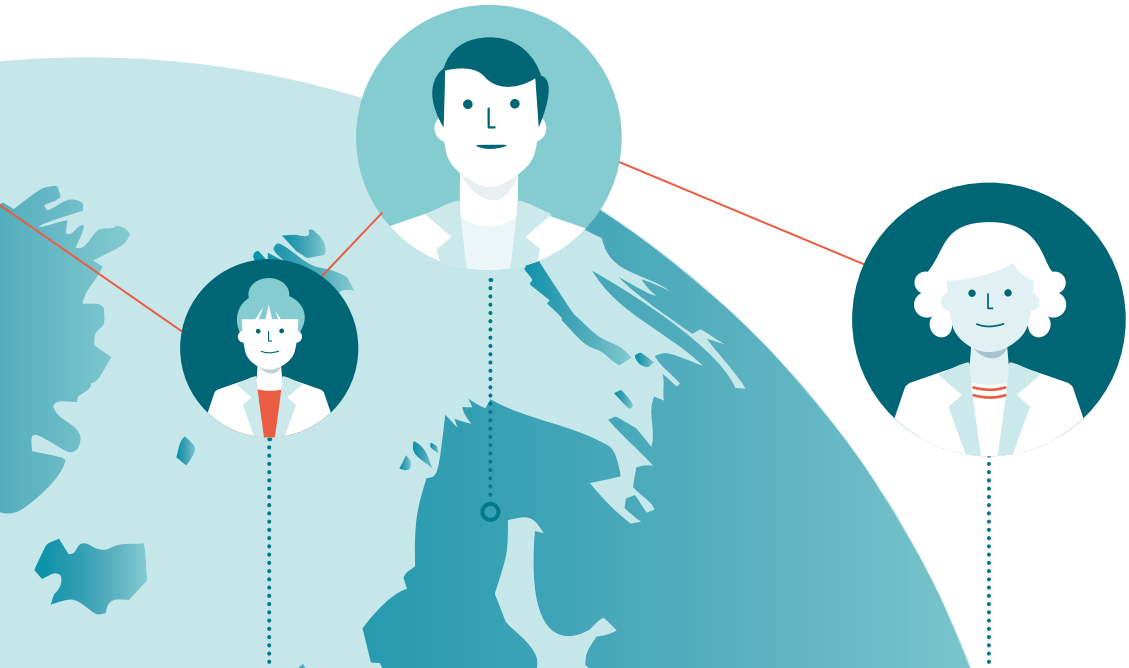


This not only democratises access to research but also multiplies the opportunities for meaningful discovery and innovation.[25] Data sharing can also enable the leveraging of existing data sets, enhancing the return on investment from data collection. Findata is one such example of reusing health and social care data. Similar to how MLL opens 'tunnels' for external researchers (*Case study 6*), the Finnish government accepts applications for researchers to analyse the data on its dedicated operating environment, Kapseli, using statistical software and computing tools to support the research.[43 44]

Case study 7. **Genomics England's 100,000 Genomes Project[45]**

Each person's genetic material is a large data set. Unravelling and understanding the information it contains, multiplied by the millions of sequenced genomes, represents a computational and analytical challenge of the highest scale. Yet these volumes of data must be analysed on a population scale to get a better understanding of rare diseases.
To process and capture this information, Genomics England partnered with several specialist organisations and tasked its CSP with delivering the underlying infrastructure and platform tools needed to build its dedicated research environment.

A total of 85,000 people were recruited for whole-genome sequencing.
Of the first 4,000 participants alone, whole-genome sequencing and analysis were able to provide 25% with new diagnoses based on the project's findings.
Results from the project, which continue to be disseminated in research, will allow for more rapid and complex analysis of the genetic information of all individuals who took part. This will, in turn, enable further breakthroughs and innovations in biomedical science, particularly in rare diseases.



THE PATIENT PERSPECTIVE

SECURING A DIAGNOSIS FOR A FAMILY WAITING NEARLY TWO DECADES FOR ANSWERS

Annabel* was born in 2003. Although she at first appeared to be a healthy baby, she demonstrated multiple developmental delays and health issues before reaching her first birthday, culminating in a diagnosis of severe autism and learning difficulties at 20 months old. Over the years that followed, Annabel underwent more tests, including genetic screening, but her family never received a clear diagnosis and her health continued to worsen. By the age of 10 years, she was experiencing seizures almost constantly; she needed a gastrostomy and became dependent on using a wheelchair, with severe scoliosis.

When Annabel was a teenager, her paediatrician suggested that she join a new study, the 100,000 Genomes Project, which was conducting unprecedented research into rare diseases. Four years later, Annabel's family finally received an answer: a unique genetic mutation. In fact, Annabel is the only known person in the world with that exact mutation.

Having a clear diagnosis has been a relief to Annabel's family, who now know that their other children are not at risk of developing similar symptoms or passing on the genetic mutation to their own children. Research is ongoing into targeted therapies that can help other children with similar conditions in the future.

** This scenario is inspired by real-life experience; the person's name has been changed to respect their anonymity.*

SUPPORTING OPTIMAL INTEGRATION OF CLOUD TECHNOLOGY INTO HEALTH SYSTEMS

Cloud technology has the potential to become a key enabler of improved individual and population health, but outdated policies and system-level barriers persist.

Complexities inherent to health systems often restrict the adoption of data-first approaches in general and may partly explain why the sector lags behind others in the area of cloud computing.[23] Additionally, some stakeholders encounter barriers during procurement[46] – for example, while shifting from acquiring IT services as a capital expenditure to doing so as an operational expenditure.[10] The initial costs of adoption and data migration may also act as a deterrent.[9 10] The most prevalent barrier, though, is limited understanding of cloud technology and the relative risks and benefits when it comes to data storage and handling.

BUILDING SOCIAL AND CULTURAL ACCEPTANCE

> Anything you do in relation to data should be of value to the patient, to the health service, to research and to industry. Individuals and institutions are much more supportive of collecting and sharing data when they see the value in doing so, both individually and collectively.
>
> **Prof. Mark Lawler**, Queen's University Belfast

Limited knowledge and understanding of cloud technology is one of the first challenges to address in building acceptance. Research suggests that general knowledge about cloud technology is often limited, sometimes even within hospital IT departments, and that there is a lack of 'user pull' for cloud technology by healthcare professionals because the potential benefits may not be understood or be visible to them.[10 22] This also extends to patients, who are often unaware of the potential benefits of new technology for their health. Some may find this technology intimidating, even if they see its potential, whereas others may not understand it or may feel it has not been developed with their interests at heart.[47]

Engaging the patient community will be key to improving knowledge and understanding of cloud technology and addressing concerns about privacy and security. Many of the concerns about cloud technology also apply to other digital platforms. Working closely with patient organisations when developing and integrating cloud-based technologies may help build a greater understanding of cloud and its potential applications, with secure and responsible management of health data. Collaborative approaches such as DATA-CAN, the UK's Health Data Research Hub for cancer, are models that patient members at all levels of governance can use to ensure that cloud technology is deployed with the needs and priorities of patients and the public in mind.[32 48] This has resulted in a true sense of ownership among involved patients.[32]

A culture shift is also needed within healthcare organisations to facilitate more widespread adoption of cloud technology. Healthcare organisation leaders must be mindful of communicating transparently about the benefits and risks of using externally hosted IT services, as well as demonstrating their ability to mitigate any risks.[10 16 23] They should view and portray the migration to cloud

technology as a business transformation, not merely a change in IT infrastructure. They also need to invest in new skills for their IT specialists and data protection officers to ensure they are fully capable of adopting and using cloud technology, and can optimise its integration into their ways of working.[10]

ADDRESSING TECHNICAL BARRIERS

> Reuse of medical data leads to much more attention being given to data quality and how data are stored. Then the insight arrives about the enormous volumes of data that are actually out there and relate to health and health outcomes. Hospital administrators are asking, 'How can we best construct our storage architecture?' and 'How can we efficiently interpret and understand all the data?'
>
> **Prof. Pascal Verdonck**, Ghent University, Belgian & European Association of Hospital Managers

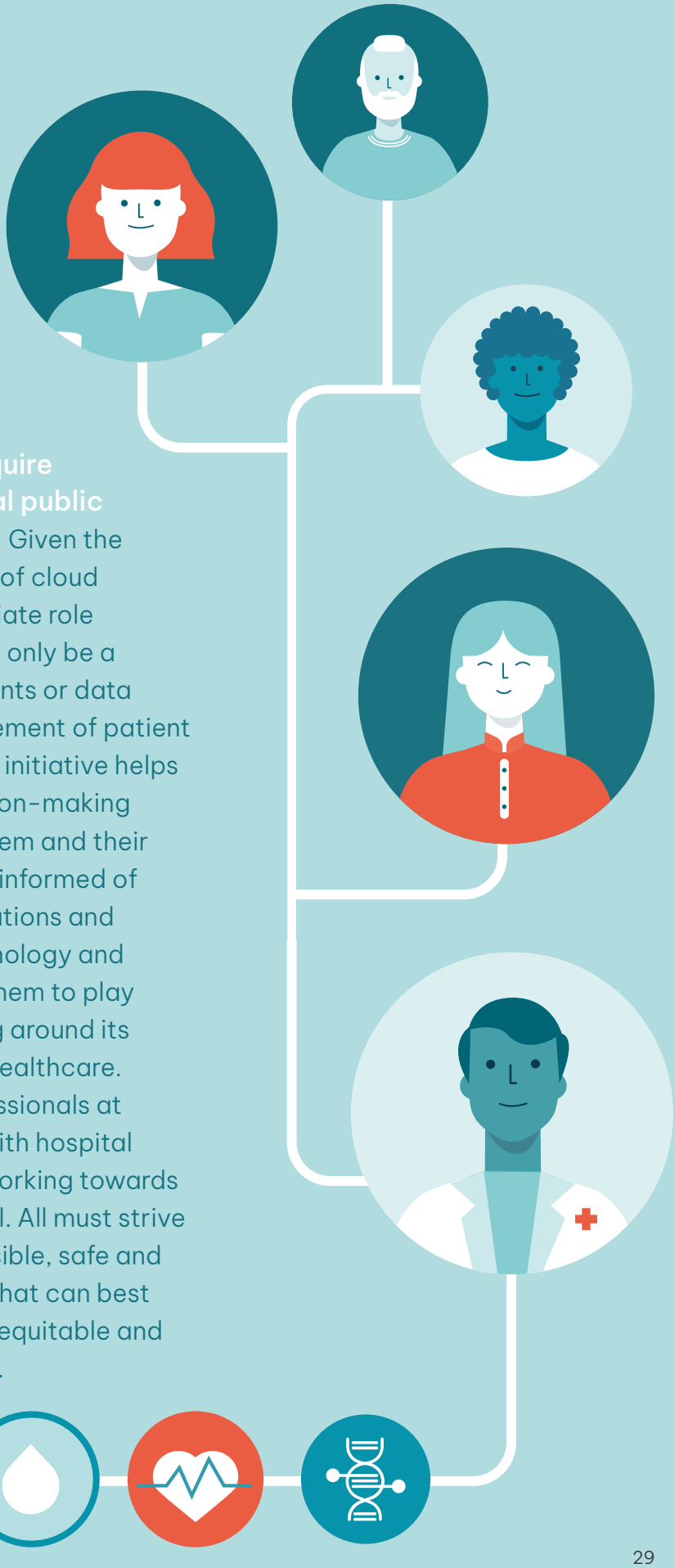
Technical challenges that are not specific to the cloud but rather to health data use in general also need to be addressed to support widespread adoption of the technology. The lack of a comprehensive framework of standards for data handling means there is a lack of clarity around the requirements for storage and no centralised regulation for data transferred between jurisdictions.[10 46] The ownership of data can also be opaque. Data handlers may struggle to balance FAIR data principles – which state that research data should be findable, accessible, interoperable and reusable – with General Data Protection Regulation (GDPR) requirements that mean adhering to the highest data governance standards to ensure security and privacy.[18] This ambiguity must be resolved not just to enable cloud technology but also to establish best practice for everyone working with digitised health data.

Ensuring interoperability between data sets is an important step to facilitate wider adoption of the cloud in healthcare. The absence of standard definitions and methodologies for health data means different data systems cannot 'talk to each other'. This holds back the adoption of cloud technology as a tool to better understand and establish linkages between different data sets.[9 11 18] Ensuring greater interoperability between data sets in the cloud as well as between different CSPs is thus urgently needed.[10 27 46 49]

ENABLING THE WAY FORWARDS

> I hope cloud technology is going to be there to help facilitate the day-to-day life of patients, to earn their acceptance and trust, and make care easier. And sometimes, without them even noticing what's happening 'behind the scenes', that they might feel it's getting easier to cope with their everyday healthcare challenges.
>
> **Gözde Susuzlu Briggs,** 'Data Saves Lives', European Patients' Forum

Cloud technology can enable transformative innovation across our health systems, but appropriate policy frameworks are needed to guide this transformation. As with any innovation, the adoption of this new technology requires system readiness – both in technical terms and through a culture shift.[10] Governments and health system decision-makers have a central role in fostering system readiness by setting the tone of embracing innovation. They must ensure that policy frameworks are adapted to reflect the growing role of cloud technology across health systems and research. Harmonised guidance and regulatory frameworks are also needed to adequately protect data governance, privacy and security and to reflect citizens' priorities for secure use of their health data. The European Health Data Space, which is a powerful example of such a comprehensive framework, can serve as a useful starting point for promoting responsible data sharing and facilitating data-driven health systems across Europe.



The appropriate adoption of cloud technology will also require engaging patients, the general public and healthcare professionals. Given the breadth of possible applications of cloud technology, securing its appropriate role across health systems should not only be a concern for hospital IT departments or data specialists. Conscientious involvement of patient communities in any data-related initiative helps place them at the heart of decision-making about the changes that affect them and their health data. They should be fully informed of the benefits, opportunities, limitations and risks associated with cloud technology and its applications, which will help them to play an active role in decision-making around its adoption and role in health and healthcare. Engagement of healthcare professionals at the frontlines of care, together with hospital managers and all stakeholders working towards improving health, is also essential. All must strive to work together to ensure a feasible, safe and promising pathway to adoption that can best advance societal goals for more equitable and efficient healthcare for everyone.

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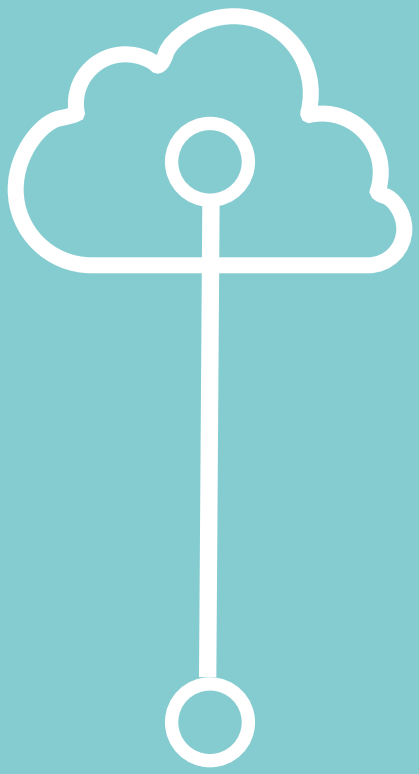

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The Health Policy Partnership
[research, people, action]

i~HD The European Institute for Innovation through Health Data