



A review of technology giants' healthcare collaborations

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Contributions: (I) Conception and design: B Mesko; (II) Administrative support: B Mesko; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: G Szigetvári; (V) Data analysis and interpretation: Both authors; (VI) Manuscript writing: Both authors; (VII) Final approval of manuscript: Both authors.

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Abstract: Healthcare in the 21st century has become more dependent on technologies than ever before). The cultural transformation called digital health has brought a range of advanced technologies into the practice of medicine and the delivery of healthcare. This has led to a rise of consumerism, an approach that would put the interests of the patients on top of those of healthcare or medical professionals in general. Companies that have traditionally been involved with developing medications, medical technologies and biotech inventions, have started to turn to developing digital health-related solutions and products. This is the change in healthcare that has started to attract companies that have never been involved with this industry. Companies like Amazon, Google (and their parent company, Alphabet), Microsoft, NVIDIA, IBM, Apple and Samsung would primarily fall into this category. Technology giants have clear incentives to enter the healthcare market as patients and medical professionals turn more to technological products to obtain, access and analyze health and medical data. However, without precious healthcare data, tech giants face a challenge in developing relevant technologies that could be implemented in the clinical practice, therefore they started to collaborate with healthcare institutions that traditionally own and store such health data. We reviewed those collaborations between tech giants and healthcare institutions that have been made public to provide a picture about the nature of these collaborations and their purposes. Our goal was to shed light on the potential privacy consequences as well as the technological advantages of tech giants' collaborating with healthcare institutions. To our knowledge, this is the first review of such collaborations in the medical literature.

Keywords: Medicine; digital health; healthcare; artificial intelligence (AI); technology company

Received: 15 November 2022; Accepted: 17 February 2023; Published online: 15 March 2023.

doi: 10.21037/mhealth-22-45

View this article at: <https://dx.doi.org/10.21037/mhealth-22-45>

Introduction

Even though there were discussions about the role of devices and technology in general from the 1990s (1), healthcare in the 21st century has become more dependent on technologies than ever before (2). The cultural transformation called digital health has brought a range of advanced technologies into the practice of medicine and the delivery of healthcare (3). From wearable sensors

and direct-to-consumer genetic and laboratory tests to smartphone apps and digital therapeutics, a paradigm shift has been taking place in healthcare. In that shift, patients have started to get more engaged with their health and disease management, a process that requires data and interfaces they had no access to before (4).

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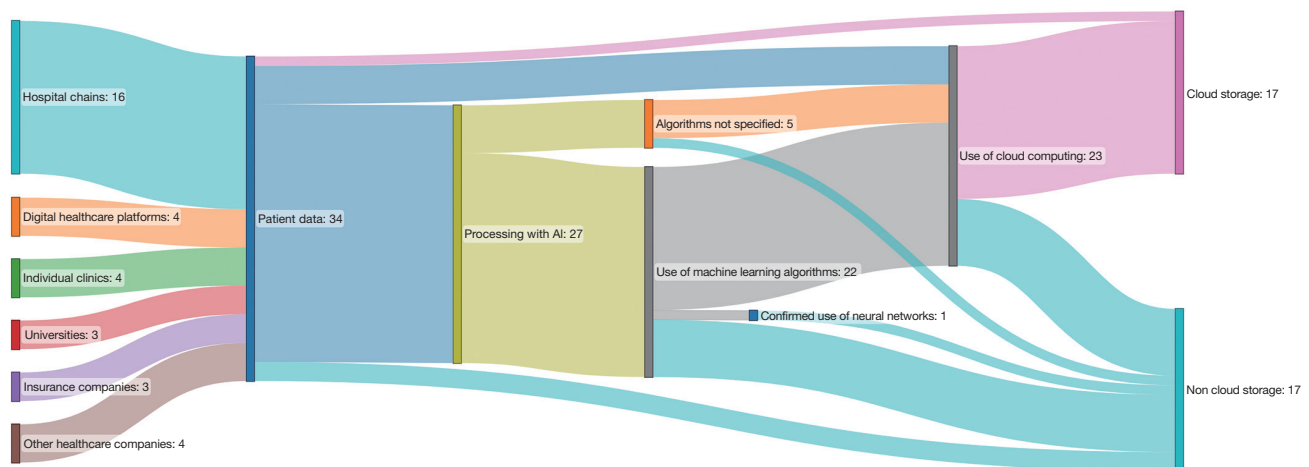


Figure 1 The figure shows the general flow of data in the examined collaborations. The sources of patient data are on the left, and the steps in the processing of such data and the ways that is stored are in the middle and on the right, respectively. The width of each connection is proportional to the number of deals belonging to that path. AI, artificial intelligence.

that have traditionally been involved with developing medications, medical technologies and biotech inventions, have started to turn to developing digital health-related solutions and products.

This is the change in healthcare that has started to attract companies that have never been involved with this industry. Examples especially include technology companies, the so-called tech giants, that have had a good track record of developing technological products, devices, social media services and software that millions of people use. From the early 21st century, discussions around privacy issues of the products and services of such technology companies have been in the spotlight (5).

Companies like Amazon, Google (and their parent company, Alphabet), Microsoft, NVIDIA, IBM, Apple and Samsung would primarily fall into this category. Technology giants have clear incentives to enter the healthcare market as patients and medical professionals turn more to technological products to obtain, access and analyze health and medical data. It is predicted the global digital health market will grow to USD 508.8 billion by the year 2027 (6). This is a lucrative business that requires more and more technological products as digital health, and the clinical evidence behind that, matures.

However, without precious healthcare data, tech giants face a challenge in developing relevant technologies that could be implemented in the clinical practice, therefore they started to collaborate with healthcare institutions that

traditionally own and store such health data.

This way, tech giants get access to data they can build technologies on; while usually the healthcare institutions taking part in such collaborations either are financially rewarded or can use the end product for free. In such an example, The Moorfields Eye Hospital in the United Kingdom (UK) provided the UK-based company, DeepMind Health, a database of retina scans of their patients. DeepMind has developed an artificial intelligence (AI) algorithm to help identify potentially blinding eye diseases (7). In exchange, Moorfields could use DeepMind's trained AI model for future non-commercial research efforts.

We reviewed those collaborations between tech giants and healthcare institutions that have been made public to provide a picture about the nature of these collaborations and their purposes. Our goal was to shed light on the potential privacy consequences as well as the technological advantages of tech giants' collaborating with healthcare institutions. To our knowledge, this is the first review of such collaborations in the medical literature (*Figure 1*).

Methods

For creating the database, we used public information, available on the internet, preferably from official press releases issued by the companies involved, and business journals such as Fierce Healthcare and Becker's Hospital

Review for smaller deals that had no related press release.

We considered including technology companies with a revenue in 2022 over 1 billion USD with any prior examples of digital health collaborations in healthcare. Regarding healthcare institutions, we considered including one that involved a collaboration with a technology company while also having access to patient data.

We analysed technology giants and their subsidiaries including Alphabet (formerly known as Google), Amazon (with its Amazon Web Services), Apple, Samsung, Microsoft, IBM and NVIDIA.

During data collection, we looked for potential entries for the database in public search engines using the following search query (e.g., Amazon AND healthcare AND collaboration). We have also collected data from press release archives using keywords such as “healthcare” or “medical research”.

Besides the number of deals that were made publicly available, we were also interested in their geographical distribution and further details about the deals such as financial background and the description of the collaboration. As the results are heavily centred around the United States, we also searched specifically for partnerships based on other countries.

We have tried to extract features from the set of collaborations that made clustering the results easier, and which may provide meaningful insights. We have categorised deals based on their use of certain technologies such as AI or cloud services; and by the type of healthcare institutes involved (*Table 1*, available online: <https://cdn.amegroups.cn/static/public/mhealth-22-45-1.xlsx>).

Results

Overview of collaborations

We have identified 34 collaborations between technology companies and healthcare institutions. Out of those, Google and its subsidiaries combined 12 entries (Verily with two and DeepMind with one) followed by Microsoft [9], Amazon (6 with its Amazon Web Services), IBM [3], NVIDIA [2], with Apple and Samsung registering a single entry.

Location and type of healthcare organizations involved

Of the collaborations, 23 have taken place in the United States, 2 in the UK and India each, and one in Australia, Singapore, Belgium, The Netherlands. The three

remaining deals reach across borders including health care providers with locations in multiple countries or in Apple’s case, multiple providers from different countries.

Various types of healthcare organisations have signed partnerships with tech giants; 17 deals have involved major organisations (Mayo clinics have 2 such deals)—which own multiple hospitals; 3 were signed by individual medical centres—mostly outside the US; while universities and insurance companies have signed 4 and 3 deals, respectively.

Four collaborations took place with companies that provide digital platforms (3 of these deals include Change Healthcare); while one was picked up by a telehealth company (Amwell) and one by an individual research lab (Jackson Laboratory). A US government agency, the Defense Innovation Unit also got involved in a collaboration with Google.

There has been one agreement that involved two healthcare collaborators while working with Google. Those were Massachusetts General Hospital (an individual clinic) and ProofPilot (a digital clinical research start-up platform). The one remaining collaboration is linked to Apple that has convinced more than 40 hospitals and countless other providers to accept the company’s digital health records.

There have been another two collaborations where one healthcare provider and two tech companies partnered up. One of these agreements included Google and Highmark’s Health that were joined by Google’s sister company, Verily after a year. In the other case, Chang Healthcare started working with Microsoft and Adobe, where Adobe provided the cloud services.

AI and cloud computing in healthcare collaborations

Out of the 34 collaborations, 27 mention the use of some sort of AI. In 22 cases, machine learning was used; and in the partnership between NVIDIA and the University of Florida even the use of neural networks has been specified.

Cloud computing is part of 23 partnerships and on 16 occasions healthcare institutes have moved their data to a cloud platform nearly all of which are operated by tech giant’s exception being the aforementioned Microsoft-Adobe-Change Healthcare deal. In the remaining deals, healthcare companies have developed solutions which are run on cloud platforms but store the data in their own databases.

Apple presents the only case where data is stored in the cloud, but no cloud computing is utilised in the traditional meaning—only digital health records are stored in iCloud

Table 1 The list of participants of the collaborations between technology giants and healthcare institutions

Name of the tech company	Name of the healthcare collaborator	When they started (year)	Country
Amazon	Fred Hutchinson	2022	USA
Amazon Web Services	Change Healthcare	2022	Global
Amazon Web Services	Radboud University Medical Center	2020	The Netherlands
Amazon Web Services	Pittsburgh Health Data Alliance	2019	USA
Amazon Web Services	Houston Methodists	2021	USA
Amazon Web Services	Tufts Medicine	2022	USA
Apple	40 different hospitals	2018	Multinational
Deepmind (Google)	Moorfields Eye Hospital NHS Foundation Trust	2016	UK
Google	Mayo Clinic	2019	USA
Google	Northwell Health	2018	USA
Google	HCA Healthcare	2021	USA
Google	Amwell	2020	USA
Google, Google Verily	Highmark Health	2020	USA
Google	Massachusetts General Hospital & ProofPilot	2020	USA
Google	Defense Innovation Unit	2020	USA
Google	Hackensack Meridian Health	2021	USA
Google Cloud	Change Healthcare	2017	Global
Google-Verily	Mayo Clinic	2021	USA
Google-Verily	Lumea	2022	USA
IBM	Groupe santé CHC	2020	Belgium
IBM	Apollo Hospitals (10 out of 64 hospitals)	2018	India
IBM	Cleveland Clinic	2021	USA
Microsoft	Swedish Health Services	2020	USA
Microsoft	Bethesda Health Care	2022	Australia
Microsoft	Apollo Hospitals	2019	India
Microsoft	Addenbrooke's Hospital in Cambridge	2020	UK
Microsoft	UCLA Health	2019	USA
Microsoft	John Hopkins Medicine	2020	USA
Microsoft	Jackson Laboratory	2019	USA
Microsoft	Humana	2019	USA
Microsoft (& Adobe)	Change Healthcare	2018	Global
NVIDIA	SingHealth	2022	Singapore
NVIDIA	The University of Florida's academic health center	2020	USA
Samsung	Centene Corporation	2020	USA

without computational power being used for manipulating or getting insights from them.

Some collaborations like Microsoft's deal with UCLA Health include cloud storage but specify that the tech giant will not gain access to patient data. This way researchers can share data through a cloud platform while complying with Health Insurance Portability and Accountability Act (HIPAA) regulations.

Discussion

With new regulations such as the European General Data Protection Regulation (GDPR), policy makers have been trying to protect the privacy of patients, as the consumers of healthcare technologies, success is limited knowing how slowly policies, regulations and general rules can follow the rate at which advanced technologies develop and become accessible (8).

Researchers and policy makers have been raising awareness about the importance of privacy in the digital age, especially when it comes to medical and healthcare technologies, however, progress is understandably slow (9,10).

While we have no reason to think that these collaborations are not based on genuinely positive ideas that would benefit patients, there are stories that highlight the importance of a deeper understanding of the long-term consequences of a tech giant working with a healthcare institution. Serious privacy-related concerns have been raised in relation to the DeepMind-Moorfields collaboration described above.

Privacy campaigners claimed that patients were not being asked to provide consent whether they wanted their data the hospital collected and stored about them to be handed over to a third-party company. Google, DeepMind's parent company, and Moorfields replied saying that since the data was anonymised, they were not obliged by the information commissioner's rules to seek permission from patients (7).

Moorfields Hospital confirmed to a reporter that any data collected from patients is assumed to be available to research projects undertaken by the hospital or its partners. Patients can opt out, this way withholding data from all research projects.

Many of the hospitals and other healthcare institutions that launched collaborations with tech giants may benefit from those by being able to use the final product such as a device, software or AI-based algorithm for free or for a reduced price. These could lead to a competitive advantage over other healthcare institutions, and clinical benefits for

patients, thus the motivation for those institutions is clear.

At the same time, technology companies aim at entering the lucrative healthcare business. It might seem to them that as healthcare has been becoming more technology-dependent, they have a place in that ecosystem, even though these companies have no experience in regulations or running clinical studies.

Advanced technologies such as AI or health sensors could provide value in care that healthcare institutions cannot neglect. However, the delicate balance those should find lies between benefiting from the products tech giants can develop and protecting patients' privacy.

But as digital health progresses, the future will probably feature more collaborations between tech giants and healthcare institutions instead of becoming competitors for them.

Limitations

The study's aim was to give an overview of the current situation in healthcare collaborations. Due to the difficulties of obtaining completeness only trends should be taken from the results as our access to information can distort the ratios between the given deals.

Given the fact that providing extensive information could decrease the competitive advantage over rival firms and institutions, the press releases were often vague and ambiguous which made comparing individual deals even harder. Our search methods were less effective outside the US as many deals received less public attention. Some deals thus only came up when searching in a specific geographical region, thus it is likely that some contributions within regions we did not inspect were missed out.

The study could be further improved by dissecting the partnerships initiated by a broader range of tech giants and by exploring more regions.

Acknowledgments

Funding: None.

Footnote

Peer Review File: Available at <https://mhealth.amegroups.com/article/view/10.21037/mhealth-22-45/prf>

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at <https://mhealth.>

amegroups.com/article/view/10.21037/mhealth-22-45/coif). BM serves as an unpaid editorial board member of *mHealth* from October 2016 to February 2025. The other author has no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/mhealth-22-45

Cite this article as: Szigetvári G, Mesko B. A review of technology giants' healthcare collaborations. *mHealth* 2023;9:17.