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Case studies on China, IBM, Nvidia and Google

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"Once you know a population's genetic make-up and health concerns it is a threat opportunity for rival countries"

Solomon Assefa of IBM

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Editorial

Healthcare finally turns to AI

> Livongo exit validates CVC thinking on AI
> Biohacking makes politicians cautious
> Industry will remain polarised between China and US

James Mawson
Editor-in-chief

Wow, what a difference a year makes. In August, Teladoc agreed to acquire health monitoring platform Livongo, which provides services for managing chronic conditions for $18.5bn.

Livongo was a leader of the corporate-backed digital health companies that started an IPO surge last summer with corporate venturing portfolio companies first through the exit doors.

The surge followed a fairly barren three years for the digital health sector in the public markets but that 2019 interest has exploded since the coronavirus shut down people's movements and pushed more reliance on technology.

Livongo's about eightfold rise since its initial public offering has validated the corporate venture capitalists and venture capitalists' forward-thinking on the broader demographics and societal needs as well as how artificial intelligence (AI) and other technologies could combine to offer improved service.

Callum Cyrus's main feature tackles the healthcare areas AI is already supporting, such as telemedicine, diagnostics and drug development.

But with healthcare already on the watch list for geopolitical considerations – biohacking tends to make politicians more than usually cautious and once you know a population's genetic make-up and health concerns it is a threat opportunity for rival countries – expect the sector to remain polarised between the US and China.

Microsoft might be able to buy out the US customers of Bytedance's Tiktok video application but without the algorithm its value is diminished. Imagine the same scenario for a government suddenly afraid of who owns their population healthcare data and how they could tailor a disease or virus that can target their specific genetic code.

Third-party nations, however, such as in Africa, are, for now, more open to technology from the AI giants coming out of China and the US.

But this can also undermine industries outside those two poles. There are very few healthtech unicorns in Europe for example, such as Benevolent AI, and compared with financial services, another large and heavily-regulated sector, AI usage is low. Some AI startups that began focusing on healthcare have pivoted to financial services to stay alive.

But the tech skills to manage AI in one field could be transferred back to healthcare. The fundamental hardware – as described in our first-quarter AI supplement – or software and operating systems – covered in the second quarter report – means the platform players, whether Nvidia, Google or Apple in the west or Tencent, Alibaba, SoftBank and Baidu in the east, have core advantages.

Feature

A revolution in the making: health and AI

> Pandemic has boosted venture dollars across health AI
> AI telemedicine and diagnostic tools race to scale up successfully
> Big pharma eyes strategic gains but data collection remains an issue

Callum Cyrus
Reporter

Most people have read the Wizard of Oz or watched the film but few go as far as to remember every line. Now it is possible to have it literally woven into your DNA as the Esperanto-language version of Frank Baum's 1900 classic just received a novel re-release. All 150 pages have been imprinted into a double strand of DNA.

Where DNA strands become damaged, University of Texas at Austin's algorithm is trained to retrieve the text from other areas of code, demonstrating how models could learn to fix gaps in medical information.

And so society is poised to advance, by harnessing the connection between biotech and data-driven artificial intelligence (AI). If there is a coronavirus vaccine unearthed at breakneck speed, then here too AI will have been crucial.

As Covid-19 ensnared China, it was AI from internet group Baidu that allowed its secondary RNA sequences to be predicted 120 times faster than conventional RNA analysis. (The two main types of nucleic acids are DNA, which provides the code for the cell's activities, and RNA, which converts that code into proteins to carry out cellular functions.)

Later, the US government asked ImmunityBio, an immunotherapy company, to work on Covid-19 after its AI supercomputer, powered by Nvidia and Microsoft hardware, put together a model of the Sars Cov-2 spike protein.

It is arguably AI's biggest test to date, and the world now awaits with suspense news from the potential vaccines it has helped devise.

A stampede of coronavirus-related startups have emerged, including at Nvidia Inception, the virtual AI-focused accelerator of Nvidia. Renee Yao, the company's global lead for healthcare AI startups, says more than 200 of Inception's 900-plus health-focused members claim to have technologies useful in tackling or managing the disease.

AI may have even discerned the scale of the threat before it was discovered by global health officials. BlueDot, a Canada-based infectious disease forecasting platform, says it found unusual pneumonia cases in Wuhan in late December 2019 and flagged the cluster as significant, according to broadcaster CNBC.

This forecasting has also strengthened the arsenal of developing nations least equipped to tackle infectious disease.

For example, technology group IBM told GCV it had helped implement a Covid-19 forecasting dashboard for the South African province of Gauteng, using AI to recognise existing clusters and factors likely to influence the virus's future spread. Having reported 500,000 cases by August 2020, South Africa is the African nation most affected by Covid-19, with Gauteng accounting for about 21% of its diagnoses in June according to IBM.

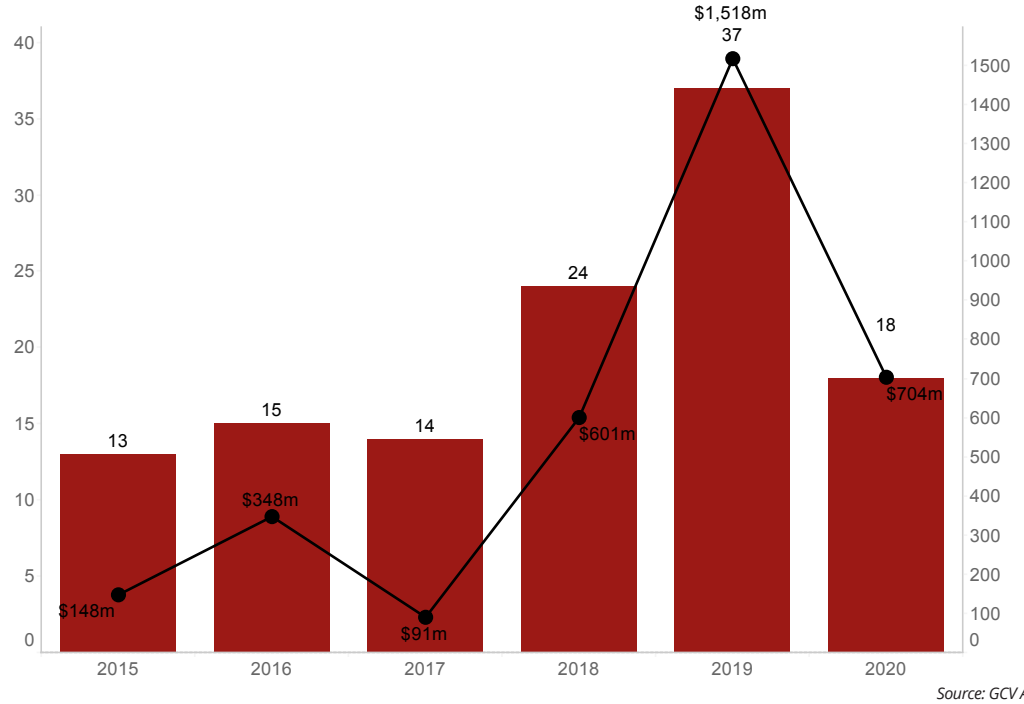
Fighting coronavirus has demonstrated deep algorithmic potential in all areas of medicine, with the greatest benefits arguably still to come.

With models already capable of digesting compound structures and genetic code, we are potentially on the cusp of an age where deep AI sparks revolutionary medical insights.

GCV Analytics indicates there were 37 corporate-backed rounds for explicitly AI or machine learning-driven health applications in 2019, almost three times the number in 2015. Collectively, the deals hauled in $1.5bn compared with $601m year-on-year.

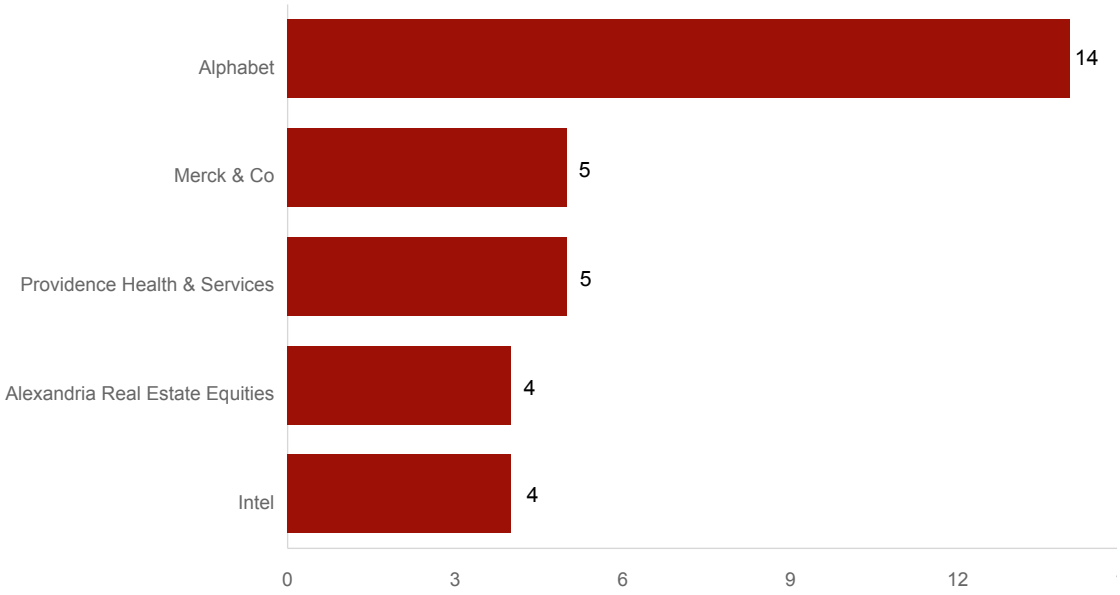
The dollar tally for 2020 has surpassed 2018 already, with $704m from 18 deals

Health artificial intelligence or machine learning corporate-backed deals



Source: GCV Analytics

Top investors in healthcare artifical intelligence, 2015-2020



Source: GCV Analytics

as of early July, despite the economic situation.

Deal values continue to rise although the number of exits for AI health companies may have stalled, according to Anand Kamannavar, global head of Applied Ventures, the corporate venturing arm of semiconductor technology producer Applied Materials.

Kamannavar said: "From the [trade body] National Venture Capital Association's data and our experiences investing, we are seeing a surge in late-stage deal values and outsized deals are pushing the average higher."

Alphabet heads the league table of CVC investors since 2015 in terms of deal numbers, underscoring the importance of the space.

Telemedicine

Telemedicine has seen more attention during Covid-19 as strict stay-at-home orders left healthcare providers facing a conundrum: how to continue treatments without risking infections.

Telemedicine is not new. An early case for using the telephone to reduce doctor's visits appears in 1879, in The Lancet, the medical profession's journal of record. Successive technologies have borne out the 19th century prophecy but crucially, with Covid-19, patients' resistance to remote consultation has diminished.

Major backing for the sector came with the $550m series C round for UK-based Babylon Health, developers of an AI-assisted telemedical consultation app used by some 4.3 million people globally.

Conversations can only reveal so much about medical symptoms and, while connected devices such as blood glucose meters have some data functionality, AI could provide more holistic feedback.

Bradley Thompson, a member of law firm Epstein Becker Green, writing an opinion piece for Mobi Health News, said that AI-assisted telemedicine would soon be prioritised by Food and Drug Administration (FDA), the US healthcare regulator for which he conducts advisory work.

For Thompson, AI will bring telemedicine to almost any patient by making user interfaces easier to operate and understand. At that stage, some

Top 5 deals in healthcare artificial intelligence since 2015

Portfolio Company	Location	Round	Round Size ($m)	Co Particpant List
Babylon Health	UK	C	550	Centene Corporation | Kingdom of Saudi Arabia | Kinnevik | Munich Re Ventures | Vostok New Ventures
Tempus	USA	E and beyond	200	Baillie Gifford | Franklin Templeton | New Enterprise Associates | Novo | Revolution | T Rowe Price
iCarbonX	China	A	154	Tencent | Vcanbio Cell and Gene Engineering
Insitro	USA	B	143	Alexandria Real Estate Equities | Alphabet | Andreessen Horowitz | Arch Venture Partners | BlackRock | Canada Pension Plan | Casdin Capital | Foresite Capital | Hof Capital | T Rowe Price | Third Rock Ventures | Two Sigma Investments | WuXi AppTec
BenevolentAI	UK	Undisclosed	115	Undisclosed strategic investors | Woodford Investment Management

Source: GCV Analytics

conditions could be managed with fewer in-person visits.

Nvidia's Yao endorsed the thrust of Thompson's argument, predicting: "Telehealth and telemedicine that enable patients to see their doctors will be prevalent and a standard for medical care two or three years from now."

Tech corporates are signposting telemedicine during Covid-19. At Google Health, remote care services now reside neatly within business profiles on its parent's search and map portals, which are often first port of call for anyone checking potential symptoms.

Zeenat Patrawala

Zeenat Patrawala, who spoke to GCV when she was a founding team member at Google, and has since left to join diagnostics company Onc.AI, said:

"[Google Health's] virtual care launch has been key to the support we are providing in enabling end-consumers given that the pandemic has caused people to be at home.

"It is about trying to change the model in how you engage with medical care and your physician appointments, and our engagement has been through virtual care to get people to use telemedicine."

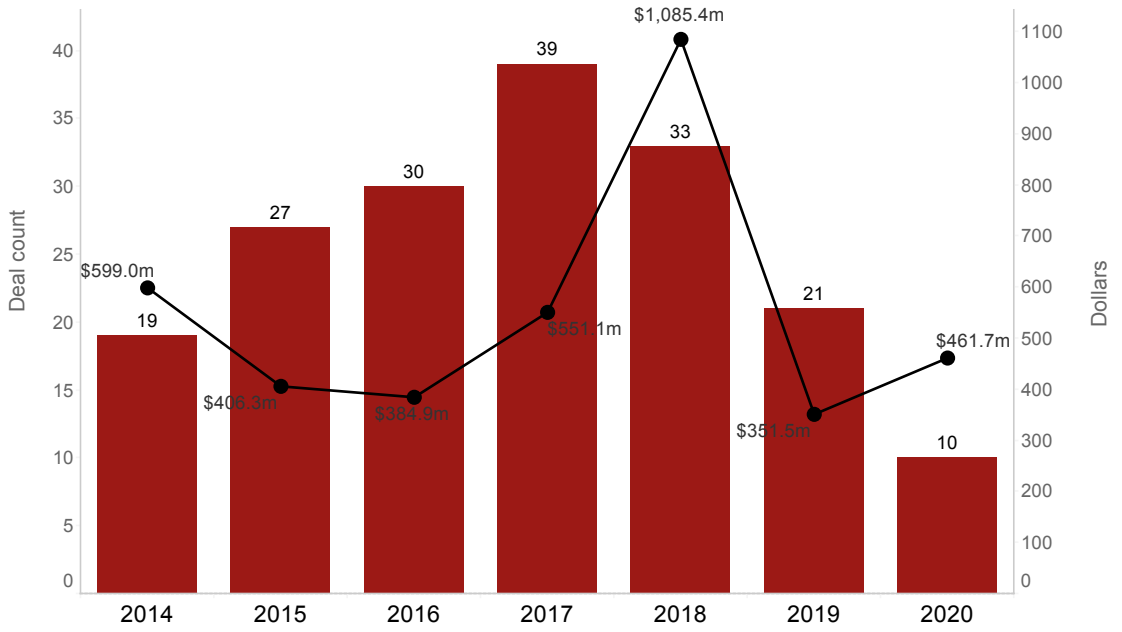
The adoption of telemedicine adds real value for CVCs investing in the space, as data from GCV Analytics demonstrates. As of July 2020, 10 CVC-backed deals for digital health companies had raised $462m, up 31.3% on $352m across 21 deals for the whole of FY2019.

Now digital health startups are showcasing how AI telemedicine could substantially reduce traditional doctor's check-ups. GCV spoke to Phillip Alvelda, chief executive of Brainworks, which will soon launch an intelligent medicine service that tracks consumers' vital signs using mobile phones, tablets and computers.

The systems were designed to mimic human senses to ambiently read the user's biometrics and update their records accordingly. Alvelda suggests this will enable an expansion of telemedicine services, and, one day, a wider shift towards preventive medicine.

Alvelda came up with the concept while working on a brain-machine interface for blind and deaf people at

Corporate-backed deals in digital health



Source: GCV Analytics

the US government's Defense Advanced Research Projects Agency and has early interest in his startup from unnamed agencies seeking to tackle coronavirus.

He said: "The immediate need for preventative healthcare is becoming quite apparent to many, and where you have super contagious diseases like the coronavirus, the idea of remote assessment without the risk of contagion at centralised hospitals becomes very attractive."

While bio-inspired AI lights up one end of telemedicine, short-term gains will also come through automation that helps lower the cost of specialised telehealth services. One exciting application is using automation to extend the provision of genetic tests.

Gene testing represents top-tier medical care. Deaths are prevented by providing clarity on the patient's susceptibility to inheritable and severe diseases, prompting lifestyle changes.

But for most the advantages remain out of reach. Costs can range above $2,000, or higher when multiple genetic tests are needed, according to the Genetics Home Reference of the US National Library of Medicine.

Francis Ho, senior vice-president, managing director and co-head of Samsung Catalyst Fund, a corporate venturing fund for consumer electronics firm Samsung Electronics, said few clinicians sufficiently comprehend genomic health to confidently select, interpret and respond to the 75,000 or so tests available on the market.

The doctor might need guidance on the readout from each test, for instance, or the likely cost for the patient's insurance provider. Samsung Catalyst Fund recently invested in the space to back Genome Medical, a telehealth service that exploits AI to recommend genetic tests to clinicians.

Ho said: "It is remotely driven and very-data centric, and everything can be virtualised. The AI can identify which patients clinicians need to focus on, and then for those who do need more help the question is what kind of genetic tests would be required, given the rapidly changing and dynamic landscape of genomic testing."

AI and drug development

Big pharma had seen the potential of AI long before coronavirus to cope with soaring development costs and frequent project failures.

Generally, computational methods were run at the earliest stages of drug projects, for instance modelling the structure of molecules so they could be examined by human researchers.

But what is underway now is far more ambitious. Often termed "in silico" drug design, AI is becoming increasingly proactive, enacting advanced parts of investigations within algorithm-led simulations.

As Abraham Heifets, co-inventor of the neural net for AI drug design company Atomwise, told journal Future Science: "It is insufficient [for AI] to predict yesterday's weather. You have to predict tomorrow's weather and get it right over and over again."

In-silico drug design represents a grand leap toward exploring chemical space – the term for the estimated 10^{60} pharmacological active molecules from which drug-like compounds could potentially be identified.

Early deep learning models such as recurrent neural networks learned to target specific parts of chemical space based on common characteristics but it has proven trickier for AI to natively understand the impact of each molecule.

In 2014, deep learning visionary Alex Zhavoronkov, founder of automated drug design company Insilico Medicine, pioneered use of generative adversarial networks (GANs) to design drug-like molecules from scratch, playing off two neural nets against one another to appraise and reinforce in silico analysis.

The approach was an early example of transfer learning, a technique enabling algorithms imported from other sectors in medicine to cluster and discern molecular features without human assistance.

GANs had automatically designed objects such as synthetic faces before Zhavoronkov decided to apply the same concept to health, according to SingularityHub.

Yao said: "With transfer learning techniques, healthcare industries learn from many other industries and make horizontal solutions vertical to fit healthcare use cases."

"It means taking an AI algorithm that is pretrained for a different task where there is ample labelled data available and transferring that knowledge to a different application for which there is little data."

Renee Yao

Biopharma is upbeat about the scope for reduced costs, lead times and failures. Healthcare outsourcing firm Icon, in a recent survey of 326 biotech executives, said almost 80% used AI at their companies already or planned to do so.

But success is not guaranteed. In 2019, technology group IBM reportedly discontinued sales of its AI drug development platform due to poor financial performance.

Major drug firms leverage CVC to smooth the trajectory of

implementation, actively tracking AI-focused startups as a cost-effective alternative to new technology developed internally. One of the biggest CVC-backed names is UK-based drug discovery software developer Benevolent AI, reportedly valued at $1bn when Singaporean investment firm Temasek put up $90m toward the middle of last year.

Benevolent AI relies on text recognition to analyse biological datasets, extrapolating graphs that summarise how billions of chemical compounds interact with each other. The approach adds real firepower, applying true big data ethos to mining the chemical space.

Investors Lundbeck and Upsher-Smith Laboratories were vindicated when Benevolent AI identified a potential Covid-19 oral drug candidate, repurposing a rheumatoid arthritis medicine called baricitinib thought to counter the coronavirus-induced cytokine storm, according to Sifted.

There is clamour for AI's ability to drill into phenotypes in a bid to discover more drugs. Phenotype drug screening identifies substances cellular attributes expressed by genes and proteins in a disease, as opposed to specific molecular targets identified through hypothesis.

Paul Andrews, director of operations at the UK's National Phenotypic Screening Centre, told LabTube in 2017 that phenotypic research had historically led to more small molecule drugs than target-driven programs, despite the latter being more common in recent years.

Automated phenotypic screening spinout Exscientia has secured seven big pharma collaborations for programmes based on its technology, with Novo and Celgene both investing. The company was founded within shooting distance of NSPC's hub at the University of Dundee. Celgene has strategic access to three of Exscientia's AI-derived candidates under a collaboration deal, while Roche has commissioned the underlying technology for its internal preclinical pipeline.

AI and DNA sequencing

DNA sequencing technologies have revolutionised precision medicine but it remains difficult to translate raw sequence data into action, which is driving AI-related research and innovation. New technologies for DNA sequencing often leverage the technology to measure genetic data with increased speed and lower cost.

Francis Ho

Startups working in the space include Apton Biosystems, a DNA sequencing technology company backed by Samsung Catalyst Fund, which has built high-resolution optical technology for extracting details of many genomic sequences in parallel. Once extracted, the data is ingested by Apton's computer vision algorithm to interpret the raw images and classify them into one of four DNA nucleotides: A, C G or T.

Ho said: "A quick analogy would be taking a telephone book or novel and putting it through a shedder. If I get back this jumble of letters, all scrambled, how can I get back to the original text? To fit the

pieces together so that they make sense is analogous to solving a jigsaw puzzle."

Far more genetic data is available today than when the first commercial high-throughput sequencers arrived in the 2000s – with gene-editing tools such as Crispr also allowing parts of the human genome to be remoulded.

But the raw output from conventional sequencers does not provide a full indication of the whole human genome under analysis, requiring each sequence to be manually distinguished through a time-consuming process known as variant calling.

100

Bases detected by conventional sequencers, out of 3bn in the human genome

Neural network-driven image recognition will help by discerning patterns in genetic coding to quickly classify or transcribe recurrent sequences. To give some idea of the potential efficiencies, each sequencing readout typically contains only 100 of 3 billion bases that make up the human genome, with errors in each ranging from 0.1% to 10%, according to Google Health.

Moreover, efforts are underway to reduce the cost of genetic sequencing storage and analysis by executing more functions from the cloud. Genomic technology Illumina made headlines in June 2020 by purchasing Netherlands-based BlueBee, which offers cloud genomic analysis tools including machine learning. The software is now being incorporated to handle data from Illumina's 15,000 sequencing machines.

Patients, data and diagnostics

Look ahead a couple of months and you will probably envision the worst-case scenario. Summer in the northern hemisphere has faded, but the virus has not dissipated. Healthcare providers risk a fresh crisis compounded by the spread of seasonal flu.

The situation is desperate but has improved versus the first lockdown in one key area. Thanks to AI-driven medical imaging tools, clinicians can make a sure-fire prognosis as to the disease's severity, before deciding intensive treatment is needed.

Doctors would be able to quickly distinguish the patient's condition based on visual biomarkers applied to scans such as chest X-rays, quickly identifying the type of coronavirus along with mortality risk in a format intended to be instantly interpretable.

Given the heap of AI medical imaging tools that have already reached the market, it is no surprise to see many pivoting to address Covid-19, often with support from strategic partners. These would not only help patients but also potentially give public health officials more understanding of how the disease works.

Telus Ventures, a subsidiary of telecommunications firm Telus, recently backed AI radiology scan technology startup Zebra Medical Vision – also a Nvidia portfolio company – after Zebra adapted its technology for Covid-19 detection and progression tracking. Telus plans now to help Zebra expand across its home market of Canada, aided by its healthcare division Telus Health.

Similarly, Spain-based Quibim – based on International Cancer Imaging Society and Medical Research Institute Hospital La Fe research – sealed a $8m seed round in July 2020 on the heels of launching its biomarker-driven AI coronavirus analysis.

Zeenat Patrawala welcomed a coming of age for AI diagnostics and argued we should now expect the technology to mature quickly.

Patrawala said: "With the pandemic, the path might be accelerated by streamlining the operational and regulatory timelines surrounding implementation."

"Looking at the venture dollars and how the community here in Silicon Valley [has backed] the space over the past few years, and my sense is that diagnostics is already a priority from a development and investment perspective."

"The fact is that AI is already being implemented in diagnostics – it is a key area and you can find a load of use-cases and tools that are being utilised in the system that have AI or machine learning embedded within them."

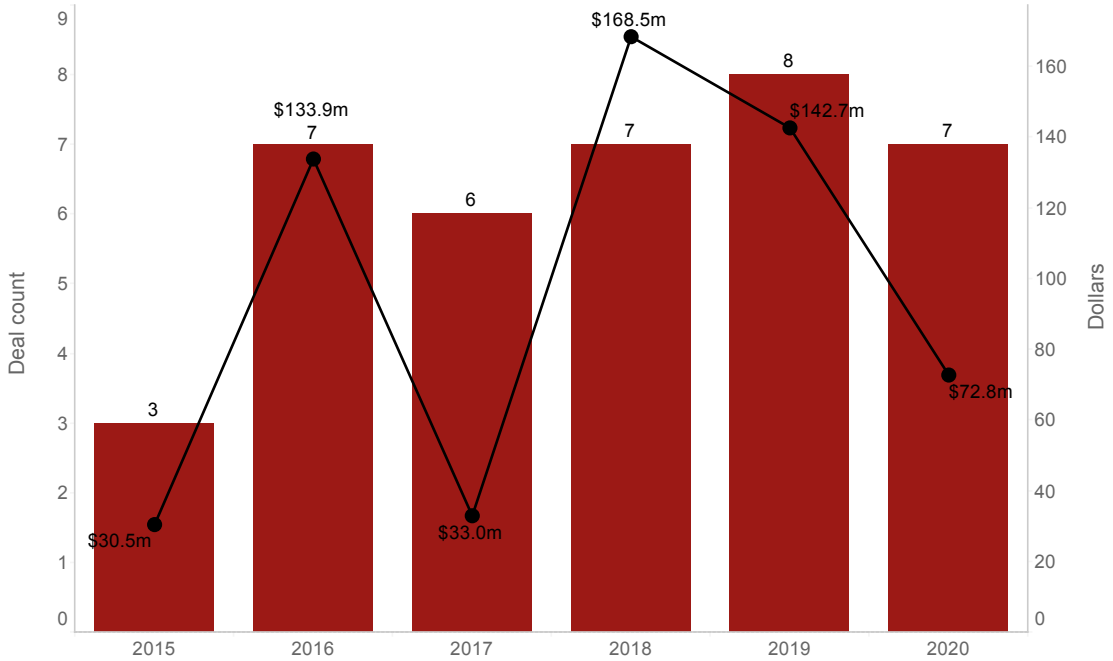
GCV Analytics data suggests that last year, $143m was raised in corporate-backed rounds for machine learning-driven diagnostics and medical device products, up from $30.5m in 2015. AI functionality is not always billed, but, nevertheless, the five year-trajectory is upward.

AI diagnostics had been complicated by difficulties in collecting patient data for modelling. For one, sourcing information must adhere to privacy regulations. Where data is available, it may lay across disparate health systems, each with different record-keeping. There are also dangers explaining AI to society at large, given the maze of tracing decisions made by complex neural nets, and a need for hardware that limits interference during data processing.

Applied Ventures' Kamannavar explained privacy had discouraged processing of patient data in the cloud, adding: "We are looking at piezoelectric and imaging sensors to get better data, and using AI edge processors like that of our portfolio company Syntiant, which are capable of processing data in an energy-efficient and secure manner at the edge."

Great strides are being made, however, and medical providers have become less reticent in light of the potential to improve outcomes for their patients.

Diagnostics & medical devices AI/ML sector corporate-backed deals



Source: GCV Analytics

Google's DeepMind and the UK's National Health Service have partnered for a digital therapeutics app based on patient data at the world's second-largest single-payer health system, also aligned to data projects at drug firms such as Roche and Biogen.

It is now largely accepted AI diagnostics should support rather than replace clinicians, and there is better communication about its effectiveness from industry to clients.

Samsung Catalyst Fund's Ho pointed to connected electrocardiogram (ECG) patches, worn by increasing numbers of heart patients. Their heartbeat can be tracked by time-series based AI models, inferring patterns indicative of irregularities such as atrial fibrillation.

"All of the data is collected and with every beat of the heart, it is going into the cloud where AI can extract information and look for anomalies," Ho said, "This is a case where the problem was collecting and interpreting the data at scale and it was resolved by combining ECG patch devices with learning algorithms running in the cloud."

"You can now conveniently gather highly accurate ECG data from people, and that is happening for health data across many domains, whether it is your heart signal, or ultrasound scans."

Race for market share

With several AI diagnostics products already on sale, the race is now on to secure market share. Success will largely depend on three factors: acquiring enough patient data, identifying the right market-fit and convincing enough doctors to embrace digital technology.

Nvidia's Yao observed: "From a diagnostics-in-imaging perspective, the greatest activity is [currently] the productisation of solutions.

"Evaluating specific parts of what AI promises to deliver – for example basic classification and segmentation tasks to aid radiologist and clinician decision-making and their workflows – has already undergone a journey: through the Gartner Hyper Cycle [the methodology relating to adoption of new technology] and peak of inflated expectations, and surviving a trough of disillusionment."

"We are currently in the 'slope of enlightenment' phase, where meaningful activities to make this technology production-ready will lead us to the 'plateau of productivity'."

Within this "productivity plateau", cancer pathology labs occupy fertile ground for several reasons including staff shortages and the need to screen ageing populations in many western countries. While AI will never replace specialist pathology, it can reduce the workload and bolster its diagnostic capacity.

Paige's AI pathology viewer

One interesting case study is Paige, a Memorial Sloan Kettering Cancer Center spinout developing AI-powered software modules for cancer pathology. The company is rapidly accruing funding, raising $70m of series B capital over the past nine months, and hopes to ride the coronavirus-driven wave for digital diagnostics.

Paige's core tech depends on convolutional image recognition, as trained on a catalogue of different cancer subtypes and occurrences. The last point is particularly important as, according to Paige's chief executive, Leo

Grady, around half of human cancers arise from less common variants.

"AI can help standardise and quantify cancer more effectively," Grady declared, "Thinking longer term, this technology affords new diagnostic tools that will allow us to extract more information from tissue structures and give doctors new information about diagnosis or cancer recurrence that enables to select the right treatment. It will almost be like a new diagnostic modality."

Working through Memorial Kettering's medical repository gave Paige an edge in acquiring pathology data for its models. The company already has one pathology-oriented digital diagnostic cleared for EU distribution, as well as its pathology scan viewing tool – FullFocus, which is also approved by the FDA in the US.

But Paige still faces a considerable battle to tempt pathologists from analogue working practices. Some French doctors told a white paper co-sponsored by business school Insead that, doubtful of AI's immediate clinical purpose, they had excluded it altogether.

7.1%

Percentage of Covid-19 research papers that cited AI between January and June

To address the digitisation roadblock, Paige has teamed up with electronics and healthcare technology producer Philips to execute its software from the latter's computational pathology platform.

Its heft will be crucial as Paige works to overcome that negative feedback loop: development requires a path to steady revenue, but hospitals shy from purchasing until there are meaningful benefits.

Marlon Thompson, business leader of digital and computational pathology at Philips, said: "[Since 2017] we have continued to successfully help several customers transition from an analogue to fully-digital workflow. We think we understand the path to digitally transforming pathology labs, and that enables us to be an effective partner for Paige to enable commercialisation of their solutions.

"In particular, we have experience with computational pathology having developed our own solutions in the past and partnered others to onboard their solutions in our platform. So we think we understand how to effectively commercialise digital and computational pathology, and how to bring that value to customers."

Much has been made of AI's role in fighting Covid-19, but it has been under-represented on the whole. Around 7.1% of Covid-19 research papers cited AI between January and June 2020, compared with 12% for non-coronavirus studies, according to research charity Nesta.

AI long ago conquered data-laden sectors such as online media but the trajectory in health has been frustratingly sluggish by comparison.

Less than one-fifth of 354 health start-ups surveyed by consultancy Early Metrics reported using AI, and those that did had often diversified or pivoted from the sector.

In fairness, health AI developers have traditionally faced a steeper path to funding than their peers, but Covid-19 is changing that. As regulators dash to adapt their rules to cope with the virus, efforts to implement AI in healthcare settings will be looked on favourably, so long as they are safe and effective. More regulatory latitude is likely to mean more

interest from venturing investors, helping more startups scale up successfully.

For the industry to truly to capitalise, however, there must be a more joined-up approach to gathering medical data. Pharmaceutical firms, healthcare providers and startups must align their resources as the Early Metrics white paper pointed out, perhaps taking cues from counterparts in other regulated sectors.

China makes strong advances in biotech and AI

The US must assiduously monitor global bio-economic trends to keep pace with China in the race toward artificial intelligence-equipped biotechnologies, according to Tara O'Toole, executive vice-president at In-Q-Tel, the venturing unit for the US intelligence community.

Major advances such as DNA synthesis and gene editing are being turbocharged in China by the expertise of local AI developers, warned O'Toole, who was speaking to trade paper National Defense.

"Biotechnologies, including synthetic biology, are going to be foundational to the 21st century economy and they are also going to be a critical arena for global competition in the geopolitical realm," O'Toole argued.

Without an adequate US response, Beijing could press home its advantage to seize the initiative. In the early 1980s, China began to develop research in the field of artificial intelligence (AI) in healthcare with half an eye on its rapidly aging population, the increase in the chronic diseases, the shortage of quality medical resources and rising public medical expenses.

Investment in AI in the healthcare industry in China is first in the world, and the quality of research is among the top three, according to Daxue Consulting.

For every blockbuster biotech exit in the West, China keeps firmly on its tail. Case in point was the $487m initial public offering for cellular therapy developer Legend Biotech, a spinout of local biotech firm Genscript Biotech, in June 2020, which priced shares around 15% above the top of its range.

Underscoring the attractiveness to western pharma CVCs, Johnson & Johnson has invested and is collaborating with Legend Biotech on its lead candidate, indicated for the bone marrow cancer multiple myeloma. Lilly Asia Ventures, the Asia-focused venturing unit of Eli Lilly, has also supplied funding.

> *"Biotechnologies, including synthetic biology, are going to be foundational to the 21st century economy and they are also going to be a critical arena for global competition in the geopolitical realm"*
>
> **Tara O'Toole**

China's proficiency in AI-driven biotech is reinforced by its ability to gather data cheaply and efficiently.

Digital health apps amass large batches of patient data to be ingested by machine algorithms. Popular services in the country include GoodDoctor from health insurance group Ping An, AliHealth, the consumer health-focused arm of e-commerce firm Alibaba, and Tencent, which led the development of

computer vision for medical diagnosis when China announced its initial team of national artificial intelligence champions in 2017.

Soon after, Tencent launched an AI medical imaging platform capable of diagnosing a broad list of illnesses, and a cloud-based ecosystem for sharing and collaboration between domestic health care AI companies.

AliHealth, meanwhile, has been increasing its portfolio with partnerships to digitise operations at Chinese hospitals, and through a pharmacy delivery service in multiple urban centres, all likely to serve as robust sources of additional data.

Elsewhere, a prediction model developed by Ping An Technology is helping healthcare authorities in Chongqing and Shenzhen predict outbreaks of flu ahead of time with accuracy rates of more than 90%, according to the report.

Diagnosis is the focus of most AI initiatives in China's healthcare sector, given the "sizeable opportunity" presented by the large number of patients and the data they generate, according to South China Morning Post's China AI Report.

China is currently mulling a data privacy law for the first time, but even so AI is far more prevalent in its public space than most liberal democracies.

Its command has again been illustrated during coronavirus. Aside from Baidu's genetic analysis tool, AI from Alibaba subsidiary Damo Academy has purportedly been trained to diagnose coronavirus from chest scans within 20 seconds at up to 96% accuracy. This augurs well for Beijing's capacity to respond to future outbreaks of disease.

The West will have been irked by China's momentum – in June 2020 it emerged the US had belatedly joined an international forum on AI ethics, the Global Partnership on Artificial Intelligence, in spite of President Donald Trump's isolationist tendencies. The partnership's founding members include 14 countries plus the EU, but China is notably absent.

If China can win O'Toole's biorevolution, its knowledge sector will reap the rewards at a time of heightened economic distress. In the race to write, read and edit our genetic wiring to unprecedented effect, yet another source of US-China enmity looks set to emerge.

IBM puts AI to work in African public health

Artificial intelligence (AI) is starting to change the face of public health planning in Africa, driven by industry players such as technology group IBM.

Traditionally, an array of manual processes and reports – as well as the need to extract data in multiple languages – have hindered efforts to understand disease across many African countries.

That is despite the great wealth of historical medical data available from sources like censuses and multilateral aid agencies. Getting to grips with machine learning means these inputs could be leveraged more effectively.

Solomon Assefa, vice-president of IBM Research for Africa and Emerging Market Solutions, said: "You can use machine learning to look at

that historic data to understand the underlying medical vulnerabilities. For example, to understand whether the infant mortality rate is affected by how many siblings or head of households are in a family.

"If we had not applied these types of highly-specialised AI techniques, we would not have been able to have further understanding about these vulnerabilities or the triggers for these vulnerabilities."

Solomon Assefa (right) demonstrates the tech

Early successes are being registered in key African markets. In Kenya and Uganda, IBM has begun implementing an AI-driven model for predicting the risk of malaria, developed alongside the University of Oxford and based on an open-source computational simulation called Open Malaria.

Every 30 seconds, an African child dies from malaria, according to Unicef. The mosquito-borne disease is difficult to diagnose and prevent without sufficient contextual information. Uganda and Kenya are big and rural, making it harder to plan a response.

While the WHO says malaria controls such as blood tests have slashed mortality in Uganda by 29% since 2010, the disease remains the country's biggest killer, and the median age was just 15.9 in 2015, according to the UN.

IBM's algorithms aim to build a clearer picture of malaria's trajectory as too often a lack of modelling has led to simplistic measures. Models imported from the US or other places fail to account for Uganda specifically, often reflecting outdated situations or unrelated climates.

Assefa said: "There are so many different types of models from different groups – many of them from the US. But ultimately what happens is policymakers look at the model and pick just one intervention – they say for the whole of Uganda, we will just use an anti-mosquito spray for the next few years.

"They cannot go down into a specific region or district because it is too complicated, but with AI you can actually help them manoeuvre through that space by having AI agents look through interventions to come up with the most cost-effective and regionalised approach for policymakers."

Assefa argued navigating African public health's idiosyncrasies had been crucial to the project's success.

Governments needed convinced of AI's benefits and wanted to be assured it would not create more problems than it solved. They preferred basic machine learning such as decision trees over complex neural networks, so the forecasts could be adequately explained.

"In Africa, when you work with the partners – especially in the public sector, you have to really work with them to help them understand AI is not an abstract concept," Assefa noted.

Comparable activity by IBM is underway in South Africa to limit the lag in reporting unstructured pathology data for cancer diagnoses and in informing the government's response to Covid-19.

Nvidia clutches health AI opportunity

Nvidia believes it has the computational solution for bringing AI into healthcare settings in the form of its Clara application framework.

Models built through Clara can be tailored to a range of biomedical data inputs, including imaging devices, genomics and drug discovery, while also tying with other development tools for graphical processing units – Nvidia's flagship hardware stack.

Clara supports the open-source Kubernetes protocol and software containers, helping tools operate with other AI frameworks more effectively.

Renee Yao, lead for global healthcare AI startups at Nvidia, said: "Today's medical devices are producing more biomedical data than ever in human history.

"Nvidia Clara domain-specific AI application frameworks in imaging, genomics, patient monitoring and drug discovery are accelerating the industry development and deployment of AI-powered applications."

Clara is available free of charge to scientific research and healthcare businesses, lining up with Nvidia's policy of engaging the whole AI ecosystem, in a sector where early-stage funding can be harder to come by.

Through its Inception accelerator, the corporate also aims to help health AI by connecting startups to its corporate venturing unit, Inception GPU Ventures, and other VC players.

Yao said: "As a corporate investor with deep ties throughout the AI ecosystem, Inception GPU Ventures further amplifies AI startups through equity investments, strategic guidance and direct introductions to Nvidia's vast global network of technology decision-makers."

In a summer where Nvidia overtook Intel to become the world's third-biggest chip firm by market cap, it will find further encouragement in the host of AI biotech businesses using its hardware. Among them is Oxford Nanopore, a genetic sequencing technology spinout of the University of Oxford that will employ the Nvidia AGX chip in a handheld version of its system.

The company uses nanopore sequencing, a technique where ionic currents enter protein nanopores and enable researchers to investigate longer DNA sequences than usual, as they are pushed through the newly-charged cavities.

Nanopore technology is garnering considerable excitement. A nanopore-driven supercomputer built at the

A University of Oxford spinout, Oxford Nanopore, will use the Nvidia AGX chip in its system

National Human Genome Research Institute in the US recently fully sequenced the human X chromosome, deciphering 3.1 million base pairs of previously intractable code.

Yao adds that Oxford Nanopore, which has raised about $692m of equity funding, is one of many to have pivoted to tackle coronavirus, employing nanopore sequencers for early-detection and tracking.

The fruits of its labour became clear as this report was going to press, underpinning a 90-minute test in the UK intended to distinguish Covid-19 from other seasonal illnesses.

But, like many healthcare companies, Oxford Nanopore is also eyeing other applications to help spread commercial risk, looking toward environmental monitoring, food inspection and microgravity biology.

Asked about the biggest roadblocks to AI in healthcare, Yao cited data as the biggest issue, followed by finding effective infrastructure to process tens of thousands of diagnoses detectable in medical images.

The third challenge was translating health AI's promise into tangible medical benefit. Yao concluded: "It is clear that everyone wants AI, but few can define what that specifically is. Clinicians and informaticists alike need to be able to clearly articulate what its they want on product roadmaps, and this needs to be achievable, implementable, safe, effective and interoperable within their medical imaging ecosystems."

Insights from Google Health

Google Health has come to the aid of national governments and healthcare providers beleaguered by the logistics of responding to the coronavirus crisis.

The unit's research and development campaign operates across two frontlines according to former Google Health partner Zeenat Patrawala: one delivering healthcare tools for medical care units, and another mandate for consumer health services. (Patrawala left in June to launch Onc. AI.)

Between the campaigns, Patrawala says Google has launched more than 200 technological instruments to combat coronavirus and put up $100m in grants for projects focused around information, support and recovery for communities.

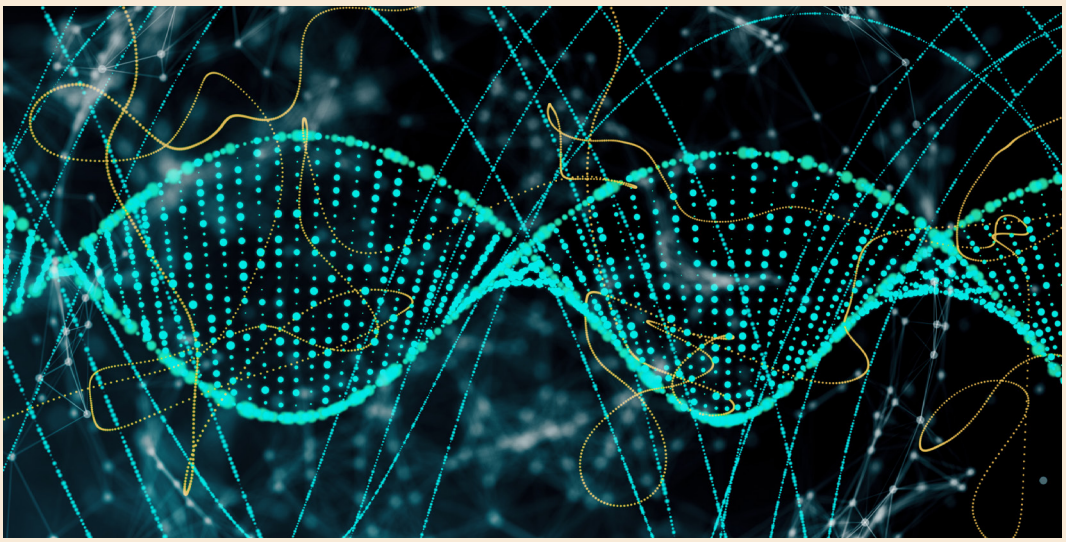
Google's partnership with Apple to build Bluetooth mobile contact tracing for coronavirus containment, now in use by many nations, may well go down in history.

With time, the plan is for the tracing technology to be supported in the core of both Apple and Android operating systems, removing the need for people to install a standalone app.

Google also provides mobility reports to 130 national authorities, applying AI and geospatial expertise to visualise disease spread and rate of infection.

"That mobility information and geolocator information as an aggregate is pretty important as we think about the next pockets of this virus will be emerging," Patrawala added.

David Feinberg, who became vice-president of Google Health in January 2019, demonstrated his enthusiasm



for the job by declaring Google was already a "health company", citing its work on medical data across cloud and AI technologies.

Patrawala said Feinberg had settled in well, merging Google Health's precursor research teams into a single unit. He certainly has the background – he led healthcare providers UCLA Health and Geisinger from 1994 until 2015.

In its non-coronavirus research portfolio, Google Health's DeepVariant software package is breaking new ground by accelerating DNA variant calling, using trained convolutional neural nets to estimate and classify the context of individual gene sequences.

DeepVariant's algorithmic prowess lies in extending the short DNA constructs produced by next-generation sequencers. The process usually requires countless lab hours to establish the sample's wider genomic context.

Google's software, now installed on Google Cloud for remote access, was lauded for its work in 2016 in a next-generation DNA sequencing contest run by US regulator Food and Drug Administration.

It catalyses research undertaken in partnership with Verily Life Sciences, the healthcare-focused Alphabet corporate venturing unit that has been increasingly active in deal terms.

As a tech group Alphabet has some of the finest data scientists, so it is unsurprising Google Health is diligently pursuing numerous AI-driven health applications.

The pipeline is teeming with potential advances in the field of AI-driven diagnostics, including a lung cancer prediction technology billed as improving detection rates by 5%.

Another Google Health model has shown how data pulled from a patient's electronic health record, fed to AI, could accurately forecast their medical requirements within 24 hours of hospital admission.

Google Health also has eye disease in its sights with its automated retinal disease assessment tool, which aims to screen more than 50 vision-endangering conditions just as accurately as human doctors.

Taken as a whole, the research is a bellwether of how deep learning could improve diagnostics in optimal conditions, although few organisations have Google's technical resources.

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