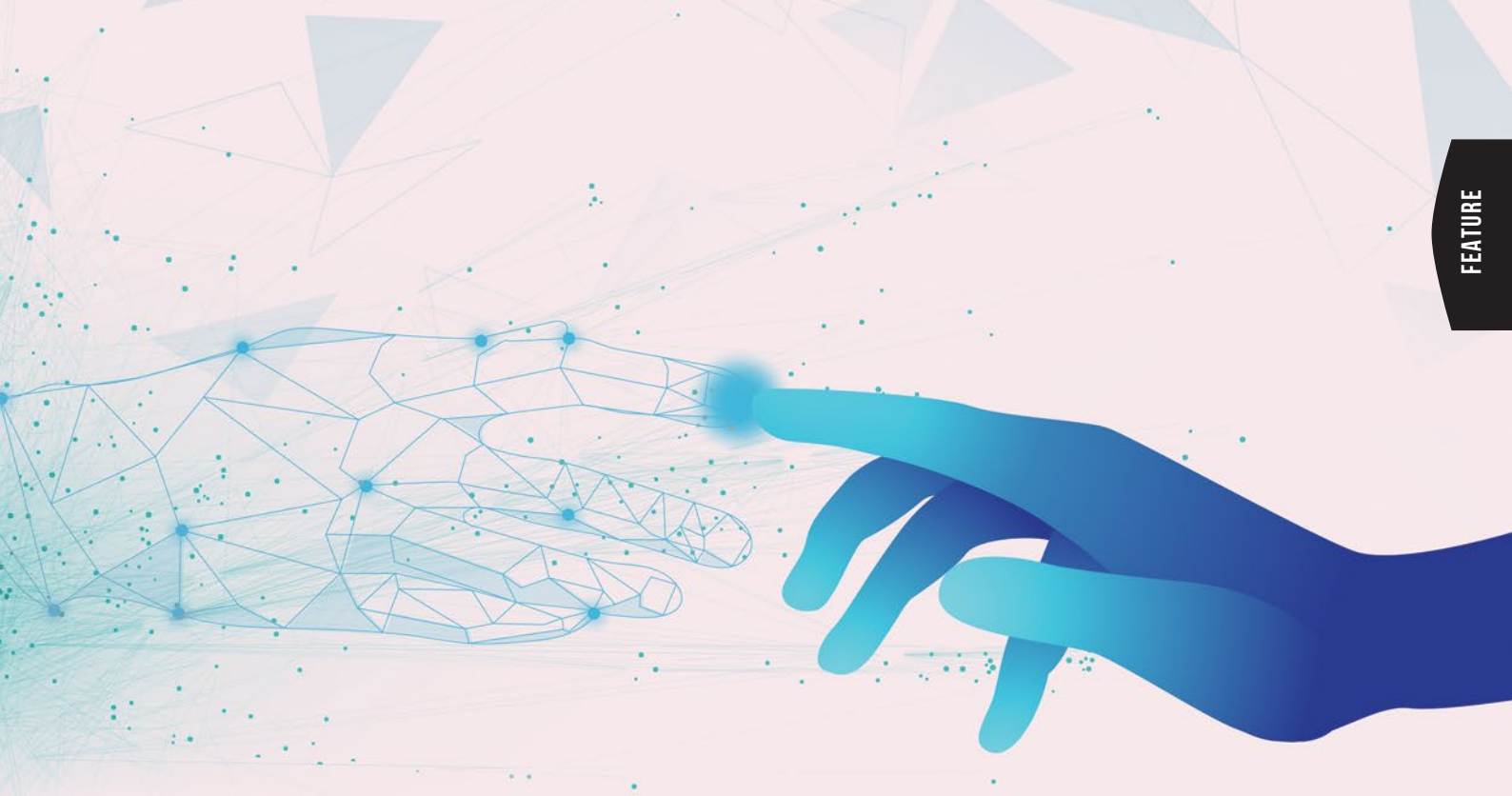

A DAY IN THE FUTURE OF HEALTHCARE

Opportunities and Challenges for Big Data and the Internet of Things

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Big data and the Internet of Things (IoT) are some of the disruptive technologies set to transform healthcare. Big data is defined by its three "Vs" – volume (data with much more observations/variables than previously), velocity (data updated very frequently or at real-time, often automatically) and variety (combining different types of data from multiple sources into a single dataset for analysis).[1] IoT refers to the interconnection of devices (or "things") via the Internet, enabling them to interact and exchange data. An IoT network consists of sensors that collect data, which are processed and synthesised by servers in the cloud, and linked to actuators that respond appropriately.[2] In the imagined scenario below, the state of development of big data and IoT is much more mature than what it currently is.

A day in the future of healthcare

Mr Lim awakens to prepare breakfast. Immediately, his smart home IoT assistant displays a list of recommended meals, based on current stock in his fridge and blood glucose readings from his wearable biosensor. He chooses chicken omelette and is guided along the recipe by the assistant, and adds just the right amount of seasoning for a healthy meal. Mr Lim has not taken his RFID-tagged medications and insulin injections yet, and the assistant reminds him to do so, while titrating his morning insulin dose based on the meal he is about to have and his usual physical activity profile.

After breakfast, Mr Lim has his regular follow-up teleconsultation with his GP, Dr Wong. He speaks to Dr Wong on his smart television and together, they review blood glucose and other charts generated by Mr Lim's cloud health assistant. Mr Lim's diabetes is well controlled, but his blood pressure is still suboptimal. Based on Mr Lim's genetic data and the response profiles of millions of other similar patients, the clinical decision support recommends switching Mr Lim's antihypertensive drug. Mr Lim agrees and orders the new medication via an online pharmacy. The entire teleconsultation is documented by an artificial intelligence (AI) scribe.

As Mr Lim is about to watch a movie, the cloud health assistant gently notifies him that he has fallen behind his friends in overall exercise rates for the week. Determined to get the rebates offered by his medical insurer for reaching the next tier of activity, he quickly gears up for a jog at the nearby park. While jogging, his smart watch sounds an alert notifying him of a transient arrhythmia. He answers a few simple questions about his symptoms via a mobile app. The health assistant determines his condition to be non-urgent and advises him to stop exercising for now. With Mr Lim's permission, it arranges for a cardiologist assessment the next day and shares his medical records, including the ECG tracings from his smart watch, with the relevant hospital department.

On his way home, Mr Lim receives another alert – this time a community call for help at a nearby location. Guided by an augmented reality map, he rushes to the scene to find a collapsed elderly man. He begins to perform CPR as guided by the mobile app, while a drone dispatched by the neighbourhood polyclinic arrives at their exact spot carrying an AED. He removes the AED from the drone and attaches it to the man. Just then, paramedics, having been activated automatically by the man's fall monitor, appear and take over. Mr Lim watches as the ambulance carrying the man whisks away, with the traffic control system pausing vehicular traffic at each junction to allow the ambulance quick and safe passage.

Obstacles to opportunities

As illustrated, big data and IoT have the potential to benefit patient safety, compliance, behaviour modification, navigation of the healthcare system, the practice of evidence-based and precision medicine, and much more. However, before these opportunities can be realised, several key challenges must be addressed.[3]

Firstly, fragmented systems need to be integrated. Pieces of the data systems and technologies described in the scenario already exist today. The next step is to connect them into a network that can generate value. The difficulty lies in integrating the rapidly increasing number of systems and in curating useful data from noise. Not only are current data sources in silos, but analytic efforts are also largely fragmented. Most of our current analytics projects are ground-up initiatives addressing individual use cases. We need an overarching strategy and architecture to build cross-linkages and synergy across these disparate threads.

One related roadblock is "territorialism" – the notion that data must be jealously guarded and hoarded by its owner. But to whom does the data really belong? While healthcare institutions are custodians of clinical data, we argue that they belong ultimately to the patients, and any insights that can be gained belong to society as a whole. Therefore, we have a duty to work together to unlock the full potential of these data.

Secondly, we need to build the culture of a "data-driven organisation" in our healthcare system.[4] This means the entire enterprise embracing data as a strategic asset for improving patient care. Many of the current analytics projects end in research publications and are not translated clinically. We must not be afraid to "trial and fail", as adoption ultimately depends on clinical impact on both patients and providers. In line with a "start small, act fast" mentality, we should develop mechanisms to rapidly test and evaluate new ideas and prototypes. Some physicians may worry that these technologies will replace them, but this is unlikely. Having big data will not eliminate, but will in fact increase, uncertainty. The value of doctors will lie in the greyscale space, and in explaining to patients their data and supporting them in decision-making through uncertainty.

Thirdly, privacy and ethical questions need to be answered. Cybersecurity will always be hard because it is a negative goal. We have to consider all possible ways an adversary might compromise

our system, and there are infinite ways. Perhaps a mindset shift could alleviate our need for complete security. After all, our email and social media accounts often contain more private information about us than our health records. This is not to say that we should abandon security, but rather adopt a more open attitude towards sharing medical data, especially if doing so contributes to our collective wisdom and may benefit population health in ways we cannot yet foresee. Beyond privacy, there are other ethical quandaries, such as who is accountable for wrong recommendations and decisions? How do we train a machine to act with fairness and sensitivity when human bias is inherent in the data? As different societies have different views, we need to debate these questions before we can accept and harness these technologies.

Concluding words

Disruptive technologies such as big data and IoT will improve access and timeliness to healthcare. However, issues relating to fragmented systems, data literacy and ethical concerns must be tackled. We must also be prepared that the interface of healthcare will change, from one that is currently human touchpoint-centric, to one that is more virtual. Future populations will need to adjust their expectations of how care is communicated and delivered. ◆

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