People, process and technology: A model for digital transformation of healthcare

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Abstract COVID-19 has brought forward unprecedented challenges for healthcare systems worldwide. As healthcare moves into a state of COVID-19 recovery, we must reflect on lessons learned from the COVID-19 pandemic to create a more resilient future. One of the most critical outcomes this pandemic has highlighted, is the role of digital technology and digital health in transforming health care services. We suggest that by focusing on people, processes and technologies, healthcare systems can not only recover from the impact of COVID-19, but also transform healthcare from the traditional disease management system of today into the post pandemic health system of tomorrow, one

that is modernised to align with the needs of the populations that health systems serve. Currently, health care systems are predominantly transactional, delivering care focused on disease management to restore health and/or manage acute health conditions. A digital health ecosystem offers a strategy to realise the full health potential of every human everywhere, from the smallest village to the most complex health care environments in health systems. Digital health ecosystems identify and track progress towards health goals, tracking outcomes and health risks at the individual and population level, which informs care approaches that are personalised to people and populations and are focused on mitigating risks in order to support and sustain health and wellness. The sustainability of healthcare systems and the health of global populations will be influenced by the rate of adoption and scalability of digital health. This paper will examine digital health transformation as a strategy to overcome the challenges health systems are facing and to advance the sustainability of health systems globally.

KEYWORDS: Digital transformation, digital health framework, leadership strategy, digital health

CHALLENGES TO HEALTH SYSTEM SUSTAINABILITY

Global health systems are facing significant challenges that threaten the sustainability of care delivery, best illustrated by five challenges that every health system is facing. The first is the 'silver tsunami' rapidly ageing populations that are increasingly relying on health services to manage high prevalence rates of chronic conditions. The combination of these populations living longer and the high chronic disease burden is placing significant pressure on health systems to manage the demands for care. Currently, chronic conditions cost the U.S. health system over US $3.8 trillion annually.[1] As these populations continue to age, demand for care will increase, along with pressures on fiscal resources to fund the growing demands for care for these populations. In 2018, 16.2 per cent of the Canadian population over aged 65 accounted for 45.7 per cent of total health expenditure. This population is projected to increase to 23.4 per cent by 2040 and will account for 71.4 per cent of health expenditures.[2] Similarly in the US, 60 per cent of the adult population have at least one chronic condition, and 81 per cent of adults over aged 65 have multiple chronic conditions. As the population ages, rates of multiple chronic conditions increase and so too do expenditures. Adults with five or more chronic conditions account for 12 per cent of the US population, yet also account for 41 per cent of health system spending.[3] In both 2018 and 2019, healthcare expenditures grew by 4.6 and 4.7 per cent respectively. The faster growth in spending in 2019 was accounted for by hospital care, physician and clinical services, and retail purchases of prescription drugs, which together accounted for 61 percent of total national health spending in the USA.[4]

A second challenge is geographic displacement. This challenge refers to the ability of people to access health care. Geographical displacement extends well beyond access to care among rural versus urban populations. Just one example is those inner city communities with high rates of homelessness, addiction and mental health challenges that are located in the shadow of some of the most advanced hospitals in the world, in cities such as New York, Chicago, Toronto, Vancouver, London and Sydney. Yet, residents of those communities have no access to the cutting edge care those centres offer. Geographic displacement challenges must consider access to care for every individual, everywhere. As the realities of post-pandemic

economic challenges unfold, homelessness, disparities in health conditions, access to care, and variations in the quality of care remain significant within the context of growing fiscal challenges.

The third challenge for every health system worldwide is the current funding models, which are clearly unsustainable. Health system spending continues to grow at a rate that far exceeds the annual gross domestic product (GDP) growth among developed countries.[5] There still remains much greater demand for care than there is funding available to meet care demands. This funding challenge is common to virtually every country in the world. Health system spending today is unsustainable, and, coupled with an ageing population and the increasing prevalence of chronic conditions, healthcare systems will have to make significant changes to either service delivery and/or funding models in order to become fiscally sustainable in the future.

The fourth challenge—which is also an opportunity—is the rapid emergence of the educated and demanding healthcare consumer. With the rise of the internet, 'Dr. Google', and online health social networks, consumers have access to more healthcare information, health services, and health and wellness applications than ever before. With the closure of health services in the early waves of the pandemic, consumers had few other options but to seek online information independently from their care providers and access telehealth services from a variety of online programmes and resources. Formal health systems, however, have had limited capacity or digital infrastructure through which to engage consumers in digital societies and offer them safe and evidence based digital services from trusted providers. By comparison, virtually every other business sector has far outpaced health systems in delivering digitally enabled services and informationly at consumers' fingertips. Industries such as travel and finance provide actionable information and access to services that are not widely available in healthcare, which does not offer consumers actionable information or decision-making tools. Consumers now have access to unprecedented sources of information, and alternative approaches to health services using a variety of digital tools and software applications. Consumers have few options, however, to engage their health providers using digital tools to support self-management of their health and wellness. Moreover, sharing personal health data between consumers and formal health providers (eg, primary care, community clinics), using a variety of consumer tools and devices (eg, smart phone applications, smart watch, wearables, online health services), introduces significant challenges for the privacy and security of health information—challenges that have yet to be overcome.

The fifth challenge that health systems are facing is substantial health workforce shortages worldwide. Current projections anticipate a shortage of up to 122,000 physicians across health systems in the US by 2032.[6] Workforce sustainability is a challenge that is continuing to grow, particularly given the devastating impact that COVID-19 has had on the global health workforce. Primary care alone will be losing a significant number of physicians over the next 15 years, and medical schools are unable to educate enough physicians to overcome these shortages. Currently, the World Health Organization (WHO) recognises that we are about 8 million individuals short of what we need to take care of our current populations, and, by 2035, that number will reach a 14 million person gap. The WHO indicates that 18 million more healthcare workers will be needed in order to achieve Universal Health Coverage goals by 2030.[7]

MOVING BEYOND VISIT-CENTRIC MEDICINE

The adoption of telehealth early in the COVID-19 pandemic skyrocketed across many

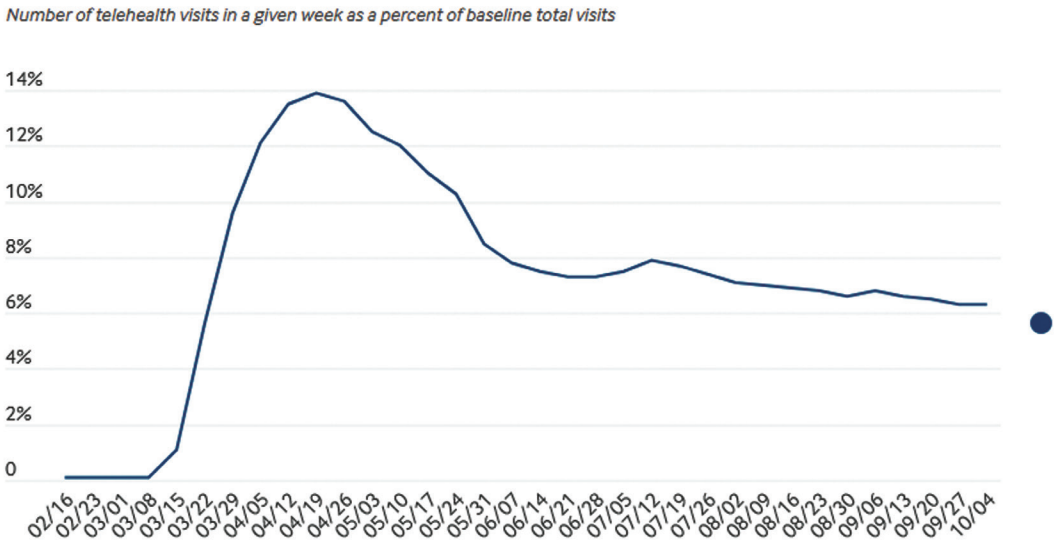

Figure 1 Number of telehealth visits in a given week as a percent age of baseline total visits

global health systems. Seemingly overnight, telehealth visits increased exponentially, from approximately 0.5 per cent of patient visits to 14 per cent of visits (Figure 1).[8]

Many hospital chief medical information officers (CMIOs) described scaling telehealth visits from 2000 telehealth visits a year to just over 2000 telehealth visits per week. Currently, the prevalence of telehealth visits remains high in the majority of health systems, although the number of visits has levelled off at approximately 6 per cent of total patient visits. This dramatic and rapid shift towards telehealth visits reflects the reality that the consumer-driven paradigm has not been fully embraced by health systems to date, although the sustained level of telehealth visits signals a shift towards new digitally enabled care delivery models, which is likely driven by consumer demand.

In the fall of 2020, when the pandemic had been escalating during the second wave, a survey revealed further insights into willingness of consumers to seek and access telehealth services in the post pandemic future.[9] Most consumers reported high levels of willingness to engage and use varying digital health technologies:

- 77 per cent expressed willingness to use some form of telehealth, an increase from just 57 per cent the previous year.
- 84 per cent reported a desire to continue with office visits, a more traditional encounter paradigm.
- 63 per cent of respondents were willing to use secure messaging.
- 71 per cent were willing to use telephone visits.
- 66 per cent were willing to use video enabled visits.

Consumer demand for new models of digitally enabled care delivery, such as telehealth visits and secure messaging, have increased significantly, and many health system leaders anticipate this demand will continue well into the post pandemic future.

EMERGENCE OF PERSONALISED HEALTH CARE

An important perspective health systems must re-examine as the post-pandemic future unfolds was described historically by Hippocrates:

> *It is more important to know what sort of patient has a disease, than to know what sort of disease a patient has. (Hippocrates)*

Individuals want to have confidence that their provider teams fully understand who they are, what their needs are, and how to meaningfully engage as partners in health and wellness care. This notion of person-centric care has been a cornerstone of care delivery for decades, implemented primarily through in-person appointments and procedural transactions in formalised health systems. This in-person care delivery model will never go away. But, as digital technologies, the internet of things, and smart devices continue to be adopted in health systems, greater access to care can be achieved for more people, and offering people choices in how care is delivered can support more personalised approaches.

The shift towards more personalised health care delivery, fueled by consumer demand and growing expectations require health systems to contemplate a number of critical questions:

- What is the knowledge foundation that, using the many digital tools and information systems that constantly capture data, can inform care delivery and translate that data into knowledge and insights to inform providers' and patients' decisions?
- Do provider teams have fulsome and accurate knowledge of every patient receiving care?
- Are scheduling decisions informed by the knowledge of a patient's personal life circumstances, which would make it either possible or impossible for the patient to attend provider appointments or access telehealth visits?
- Do care decisions consider financial resources (eg, employment concerns, billing requirements, insurance verification, access to the internet) that make it possible for an individual to be successful in seeking care?
- Do they consider equity within the context of patient socio-economic elements and all of the aforementioned variables such as age, geography, employment, and housing?

If health systems are to "know the what sort of person has a disease", then our care delivery models and processes of clinical care must be designed and individualised to reassure every individual that their provider knows and understands who they are and what their health needs are. This way of knowing must be supported by information systems that enable personalised flow of information and data sharing (Figure 2). In such a system, a patient undergoing chemotherapy for breast cancer would never receive a routine notification to book an annual mammography appointment.

There are many 'ways of knowing' that are highly relevant to health care delivery. There is the *Knowledge Foundation* stage, which is the tools and capabilities to gather, evaluate and understand consumer insights and needs. Then there is the *Know Everyone* stage, which refers to the essential capabilities for meeting baseline consumer needs, such as convenient scheduling, and insurance verification. Next, there is the *Know Us* stage, where data and analytics are used to meet the distinct needs of population segments. Lastly, there is the *Know Me* stage, which entails personalised healthcare that focuses on individual needs, goals, and wellness. As a result of inadequate

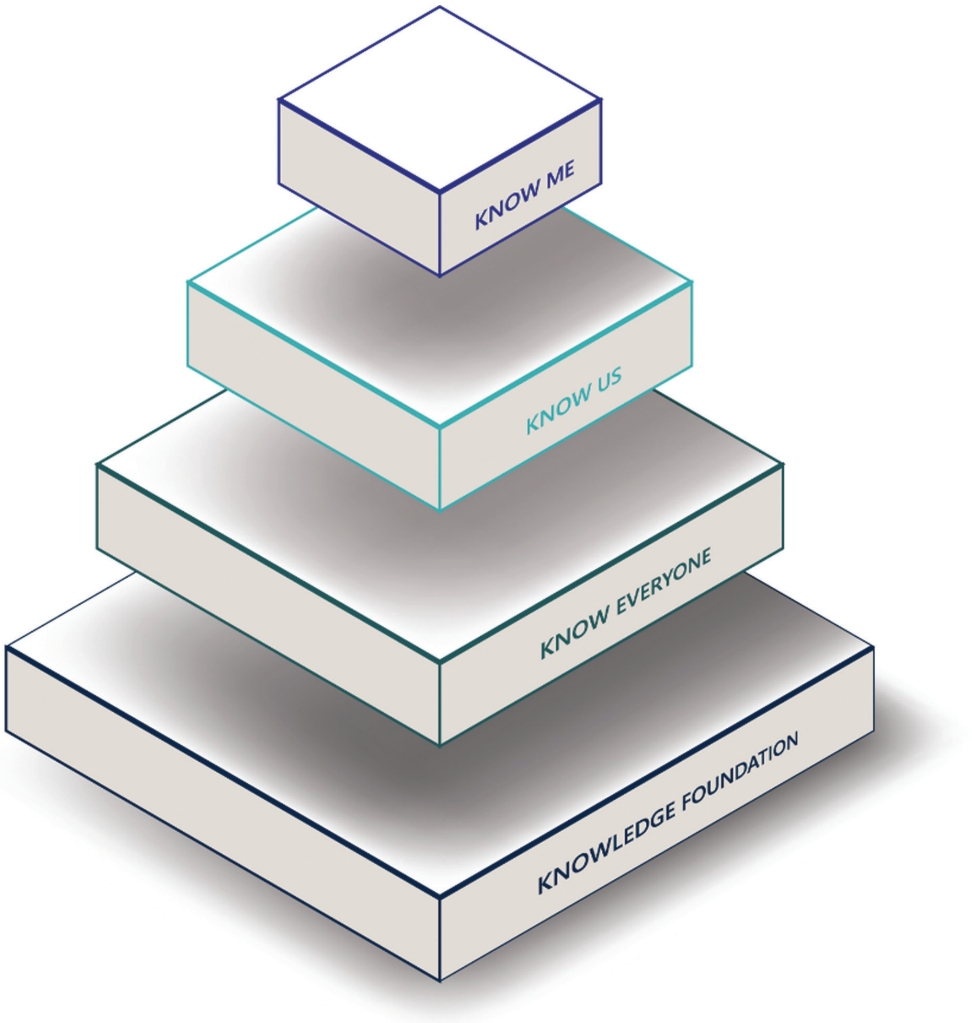

Figure 2 Personalisation informed by ways of knowing

foundations of knowledge, people seek the support and information from sources outside of the formalised health system (eg, 'Dr. Google'), as every individual strives to find a health resource that really understands who they are and what they need, which can be described as the 'Me' level of knowledge. This is illustrated in the following image.

In order to advance towards "know me", there are a number of considerations. In the tertiary hospital, which relies on in-person care delivery models, connecting and integrating information with mobile applications is a challenge. Today, health systems compete on access and patient experience in facility-based care interactions. Health systems of the future, however, will have to transform care delivery approaches to engage patients using digital tools such as mobile apps, smart phones, and a wide variety of consumer technologies, so that if a patient is at home reporting their health outcomes to their provider team, there is a secure and automated link to send patient created data to be stored and integrated

into their health records across the life course. Meaningful virtual connectivity between patients and providers must have a critical role to enable acute care hospitals to engage with community partners and better integrate care in order to achieve seamless care delivery, ensure that care transitions are safe, and offer personalised care that is relevant to a patient's unique life circumstances. New care delivery options will need to be designed for those individuals who would much rather have that checkup sitting in their own home than spend three hours to travel to a traditional provider appointment. Personalised health care will require transformational shifts in the delivery of care and in managing the enormous amounts of data required to ensure that "knowledge of me" can be accomplished. Portals, mobile devices, wearables, websites, chatbots, text messaging and even voice interfaces must all be available and tailored to the unique preferences and needs of patients. Consumer research tells us that it will be imperative for health systems to have sustained loyalty in order to avoid being lost to retail health organisations that can more readily respond to their personal needs and choices.

So how do health systems, and health organisations more specifically, re-design and re-think the patient's journey to align it with the unique values and life circumstances of every individual? The answer will not be to simply rely on technology. There is little chance of success of such a transformation unless three critical elements come together: people, process, and technology. Technology is the most straight forward. The consumerisation of applications and smart phones is rapidly evolving and being launched in markets all globally. Technology today is pervasive. The real question health systems must answer is whether the culture and professional development amongst clinician leaders (eg, physicians, nurses, allied health) is enabling and preparing clinicians for new models of care delivery that offer choice, are designed on the basis of personalised health and wellness care pathways, and are enabled by digital tools and technologies. The processes of care delivery must now be aligned with the personalisation demands of people rather than limited by the standard paradigm of the patient-provider encounter alone. There will always be a significant portion of healthcare delivery that offers in-person encounters. Life-saving surgeries and emergent visits to hospitals will always be needed, but processes such as commissioning, monitoring outcomes, designing accountability frameworks, assessing the needs and demands of patients, and creating quality work environments for providers, will all have to be aligned with new digitally-enabled care delivery processes in order for "outside-in" care delivery to be successfully scaled across health systems.

DIGITAL HEALTH ECOSYSTEMS: A TRANSFORMATIONAL STRATEGY FOR THE PERSONALISATION OF HEALTH SYSTEMS

Digital health has been described as part of the fourth industrial revolution, which is characterised by widespread use of advanced analytics and prescriptive tools such as artificial intelligence, machine learning, neural networks and many more digital technologies.[10] At the heart of the digital health era is the opportunity to transform from today's traditional, provider-centric healthcare system towards a more personalised system. Health systems today are focused primarily on disease management, dependent on care facilities for health services, and guided by care pathways that emerge from clinical trial outcomes and evidence of best practices. Today's health care system has been described as 'reactive', whereby patients engage with health teams only when they

become ill, or when their health declines, and are then diagnosed and treated by provider teams according to standardised care protocols. In this medical model, care delivery is inherently 'one size fits all', where all patients with a specific diagnosis or disease state follow the same established care pathway or protocol designed to achieve specific outcomes grounded in evidence. Care pathways and protocols are not designed to be tailored or personalised to the unique needs or circumstances of individual patients, and the standardisation of care (eg, compliance with pathways) is highly incentivised through a variety of policies and accountability frameworks. Doran et al. (2011) have indicated that the incentivisation of certain aspects of care in the UK has had long-term, detrimental effects on non-incentivised care activities.[11] There is concern as well among patient advocacy groups that financial incentives may diminish the ability of patients to have access to 'off-pathway' care options and opportunities.[12]

The creation of a digital health ecosystem entails a transformational shift in health-care delivery towards a proactive and predictive health system that identifies people and populations at risk and focuses on personalised care delivery approaches that are tailored to the unique circumstances of every individual, including proactive interventions that mitigate risks and sustain health and wellness. Personalised care is guided and informed by the unique needs, values, and life circumstances of every individual, community and population served by a health system. Individuals seeking care are engaged in the self-management of their health and wellness and supported by provider teams as trusted partners who work collaboratively to advance personalised health, wellness and quality of life goals. These goals are established and informed by the needs, values and unique life circumstances of the individual. In this digital ecosystem model, digital health is defined as the following:

> *Digital health connects and empowers people and populations to manage health and wellness, augmented by highly accessible and supportive provider teams working within flexible, integrated, interoperable, and digitally-enabled care environments that strategically leverage digital tools, technologies and services to transform care delivery.*[13]

Digital health ecosystems align the needs and values of people with the processes of care delivery. Digital technologies enable a new architecture and collaborative care environment, which extends beyond traditional human reach and actively participates in the digital societies in which global citizens participate every day. Digital health ecosystems engage meaningfully in digital communities, full of rich data and information, which is cross-disciplinary in learning and flexibility.[14,15] A digital health ecosystem connects and partners clinicians and provider teams with individuals seeking to achieve their personal health and wellness goals, ensuring that care processes empower every individual to manage their health and wellness. These care processes are enabled by digital tools to report progress and outcomes in a secure and private digital environment. Operational processes across health systems are also informed by data and the insights that data generates, which can guide and inform leadership decisions that prioritise the advancement of exceptional quality, safety and performance, are measured and evaluated based on outcomes and real-world evidence of value, and are aligned with individual and population health needs. There are four dimensions of digital health ecosystems, which have been defined and informed by a critical analysis of the current evidence, empirical digital health frameworks, and models.[16]

GOVERNANCE AND WORKFORCE

The governance and workforce capacity of digital health systems is foundational to providing the leadership and accountability required for robust, high-performing digital health systems. In this dimension, workforce is combined with governance to reflect the highly integrated relationship between governance, leadership and a robust and sustainable digital health workforce.

Governance creates the oversight and stewardship of digital health systems. The flow of personal health data across health organisations, provider teams, connected digitally to individuals, presents new ethical considerations and challenges that must be considered and regulated by policy frameworks. Effective governance frameworks must recognise that the policy frameworks of today's health system will not be effective for the future digital health system.

Current policies and governance frameworks are lagging significantly behind technology development, creating substantive challenges in advancing digital health systems. Barriers include the inconsistent use of standards (eg, Fast Healthcare Interoperability Resources [FHIR], Health Level 7 [HL7]), inconsistent application of policies, siloed health information systems, digital platforms and technologies that are not interoperable, and IT systems that do not interface or work together.[17] As digital health evolves, leaders can expect to experience employee and professional challenges. Digital competencies must be developed and clinician teams must be supported to transform care delivery models through an appropriate organisational and system-wide digital health strategy. Lack of expertise or experience in digital leadership, rigid organisational structures and policy settings, and traditional funding models, are all challenges that must be overcome to advance digital health ecosystems.[18] Governance and workforce must define a clear digital health strategy that is focused on the transformation of care and is supported by new governance structures and tools. This will support the ability of the health workforce to deliver care within highly integrated and seamless digital work environments, which incentivise advances towards a robust digital health system.

Digital health begins with the recognition and acknowledgement that the governance frameworks and solutions of current health systems are no longer effective or adequate for the digital health ecosystems of the future. The governance of digital health systems has been examined in many key reports, including: Transforming Health Systems through Good Digital Health Governance by the Asian Development Bank[19]; Information Governance Principles for Healthcare by the American Health Information Management[20]; and the work of Benedict and Schlieter.[21] To date, digital health efforts have focused predominantly on the digitisation of today's health system data, including digital enterprise infrastructure such as electronic medical records (EMR). While these digital infrastructures have been important, renewed efforts must re-imagine the transformation of care delivery to person-enabled models of care, focused on managing health and wellness and connected meaningfully to provider teams when and where needed. There is now an urgent need to build on progress with EMRs in order to advance to personal health records (PHRs), which combine and connect health records from different health organisations, and enable patients to use, save, manage, and exchange their personal health records with health care practitioners when needed.[22] PHRs enable every patient to share their personal health record with their provider, giving providers access to complete health records across the journey of care. A PHR strategy offers clinicians access to patient data to inform decisions, while patient/citizens use their PHR as a basis for managing their personal health and wellness. Taiwan is an example of a country that has advanced

and successfully implemented a national PHR infrastructure,[23] which enables every citizen access to their personal health data, and supports the exchange of patient's EMR data with health organisations outside the hospital system. The data schema and formats make data exchange and interoperability possible, supported by international data standards, including HL7, Clinical Document Architecture (CDA) and FHIR.

Principles of digital health governance have informed the design and development of the important sub-dimensions of a digital health system. Data stewardship is guided by principles of confidentiality and accountability; transparency is guided by principles of accountability; policy and decision-making processes are informed by principles of accountability, equity and inclusiveness; and mobilising individual engagement with health systems and teams is based on principles such as responsiveness, participation, equity and inclusivity. The important features of the governance and workforce dimension of digital health systems are summarised in the following[24]:

- **Data Stewardship:** Stewardship describes the leadership, culture, vision and objectives required to support digital health. It includes accountability frameworks and management processes, such as the responsibility of planning, building, running, and monitoring digital health, as well as the resources and expertise necessary to evaluate and use new technologies. The adoption of new digital tools is informed by evidence and best practices to support system-wide adoption and utilisation at scale. Criteria aligned with the use of data and digital technologies are guided by, and inform, best-practice decision-making to improve quality of care.
- **Policy and Decision-Making Processes:** Policy and decision-making processes describe the measurement, learning and feedback, resource allocation, and coordination used for governance processes that encompass the policy and decision-making required to support digital health transformation. Policy and decision-making processes include: evidence informed digital health strategy, alignment of digital processes, and value-based health system incentives and frameworks focused on outcomes. The impact of digital transformation requires policy frameworks that support and incentivise performance (eg, efficiency, productivity, quality and cost) outcomes and enable health system stakeholders to build and sustain meaningful relationships with the people and populations health systems serve.
- **Transparency:** Digital health systems support connectivity and relationships with people and populations, including digitally-enabled communication and transparency of quality, safety, and performance outcomes. Every person is considered a partner in healthcare whereby governance and oversight ensure transparent access to personal health information and health system level performance outcomes, as well as equity in access to healthcare services, data, and digitally enabled care delivery.
- **Workforce Capacity and Competency:** The rapid evolution of digital health ecosystems requires knowledge, skills and abilities across the workforce to support and enable adoption of digital health strategies that support person-enabled care focused on health and wellness. Workforce policies support and retain a high-performing workforce that is incentivised to design, adopt and scale digitally-enabled care processes and operational strategies focused on outcomes, value and impact for people, populations and operational performance that advances health system sustainability. It has been widely reported that healthcare workers are suffering from exhaustion and burnout, and with the International Council of

> Nurses warning of an exodus of nurses, which could lead to a global shortfall of 10 to 14 million nurses by 2030.[25] If digital health ecosystems are to aid in the retention of healthcare workers, then traditional workforce regulatory mechanisms will need to be broadened to facilitate and support the acquisition and management of capacity, talent and skills related to digital technologies, while also promoting well-being and quality of work environments (both digital and in person) for the health workforce.

Digital health requires unique governance structures and workplace environments to transform current care delivery models toward digitally-enabled care approaches that mobilise and meaningfully engage every individual.[26] The rise of genomics, digital medicine, and AI is changing the landscape of healthcare, and with new emerging technologies there is a need for a new type of workforce.[27] The opportunity offered by these new technologies, however, can only achieve value if the workforce has the knowledge and competency to adopt these new technologies into practice. For this reason, digital technologies have been categorised on the basis of both their type and intended use.[28]

INTEROPERABILITY

Meaningfully connecting people, populations and health teams to optimise health and wellness is a key outcome of the interoperability dimension of digital health systems; interoperability bridges data silos and facilitates these meaningful connections. Interoperability has long been considered a critical infrastructure capacity for health systems, which can enable data to be seamlessly mobilised across multiple sources and flowed directly to patients and their provider teams. Interoperability serves the critical functions of democratising data, mobilising data from multiple and varied sources, storing data safely and securely, and ensuring that health information data is seamlessly available for stakeholders, including patients, to inform care decisions. Interoperability makes it possible to connect meaningfully with individuals and their personal health ecosystems, as well as to formalised health system teams when and where needed.

Connectivity also means internally connecting stakeholders within health organisations (eg, between departments of a hospital, clinic, provider teams, lab, pharmacy, data repositories) and externally across separate, autonomous organisations (eg, from one healthcare system to another, one jurisdiction to another, and across organisations from primary care to community care to hospital care).[26]

To date, there is some evidence of progress among some health systems in advancing internal interoperability. Comprehensive internal and external interoperability, however, remains elusive, as a number of challenges and barriers have limited progress towards seamless interoperability across global jurisdictions. For example, images such as X-rays, video loops from CT scans, unstructured text of a specialist's consultation, or a structured text such as a tabular lab report, are just a few of the many types of health data, demonstrating the ubiquity and multi-modality of this data. In many organisations, health data is collected and stored, often forgotten in medical archives and only recently have patients been afforded access to their raw health data (eg, lab or imaging test results). Data are collected and stored in chronological order of care transactions, most often in categories dictated by billing or reporting mandates. The storage location, format, ownership, security and privacy measures for this data vary widely. Effectively then, health systems have scattered data, obtained at excessive health system costs, which is often not used effectively by patients, clinician teams, or health system leaders. Data that are collected are immobile, exist in disconnected platforms, or "silos," and vary widely in quality and utility.

External interoperability that transcends global borders and offers access to people and populations remains vastly under-developed in the health sector. The challenge of external interoperability is described in the following quotation:

> *Although every nation has a different healthcare system, all nations use health data standards. Countries and territories are at different stages of adoption and implementation of these standards. Thus, harmonization is crucial in promoting the interoperability of electronic health records (EHR's) and empowering patients with their data across the globe.*[29]

The seamless flow of data requires connected, integrated, safe and secure management of data integrity, as well as the coordination and oversight to ensure information systems are interoperable and that data is easily accessible when and where it is needed. The capture and mobilisation of data across multiple sources, makes it possible to fully document the patient's journey, provides a 360 degree understanding, and meaningfully connects clinician teams and health services, to people and populations, enabling care to be accessible, transparent and seamlessly interoperable, as illustrated in Figure 3.[30]

Interoperability requires exceptional data processes, structures and platforms to connect, exchange data, track outcomes, and communicate with stakeholders. To achieve interoperability four unique sub-dimensions

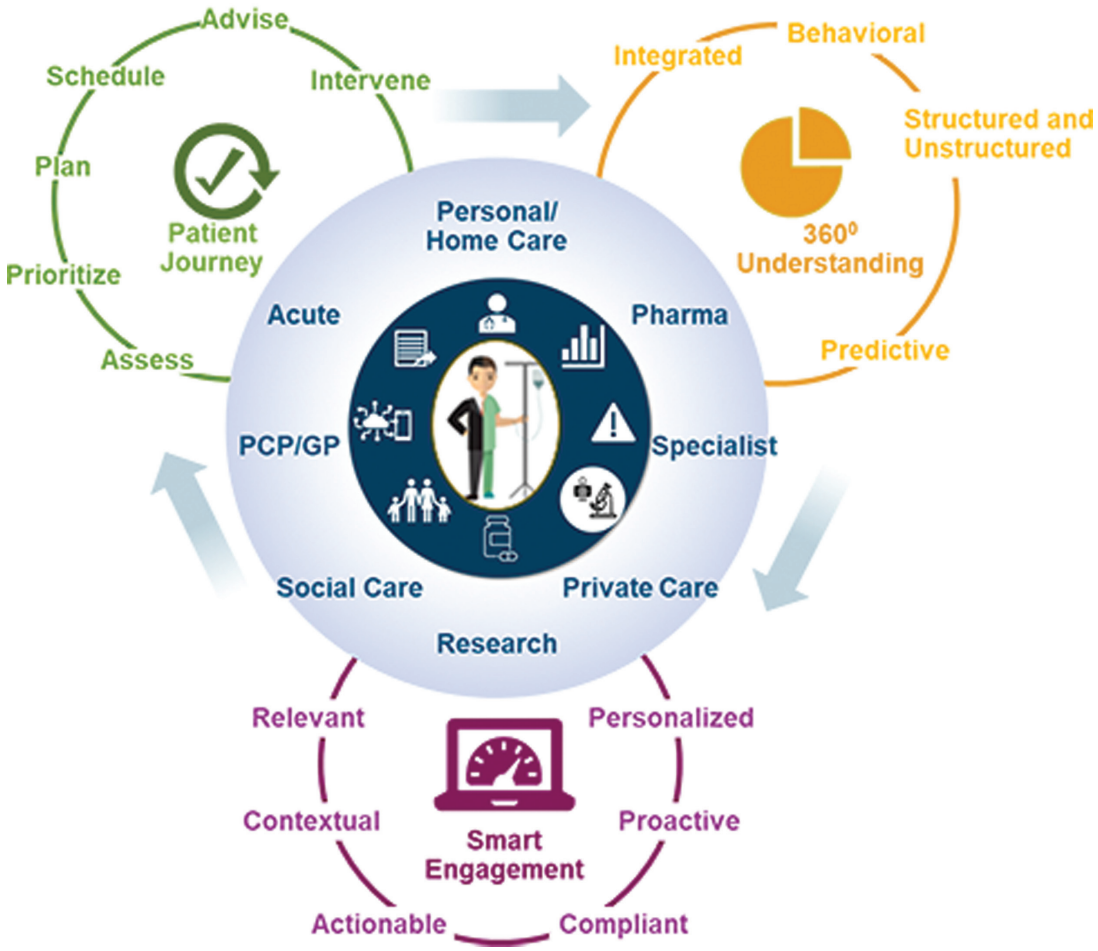

Figure 3 Guiding Principles for Better Data and Interoperability in Healthcare

must be advanced, which are described in the following section:

a. **Foundational Interoperability:** Establishes the interconnectivity requirements needed for one system or application to securely communicate data to, and receive data from, another system or application. It is defined as the exchange of data at the individual level, which is accessible across clinical, social, and community settings. Foundational features of interoperability include: data and information capture; capacity for data storage and data management; access to data to inform communication between individuals, clinicians, teams, and organisations; capacity for wireless and multimedia data exchange; and virtual/remote information exchange to communicate information.
b. **Structural Interoperability:** Defines the format, syntax, and organisation of data exchange, including at the data field level for interpretation. It describes the flow of data and information that is automated and integrated across multiple and varied sources of data, data reporting and access functions, data center structure, data integrity, and information exchange across multiple and varied platforms.
c. **Semantic Interoperability:** Provides for common underlying models and codification of the data, including the use of data elements with standardised definitions from publicly available value sets and coding vocabularies, providing shared understanding and meaning to the user.
d. **Organisational Interoperability:** Includes governance, policy, social, legal and organisational considerations to facilitate the secure, seamless and timely communication and use of data both within and between organisations, entities and individuals. These components enable shared consent, trust and integrated end-user processes and workflows.[31]

Interoperability is an important dimension of digital health that creates the "end-to-end" visibility across the spectrum of data sources, supporting and enabling a person's health journey. Visibility and transparency in a healthcare system has been suggested to benefit the health of people and populations.[32]

PREDICTIVE ANALYTICS

Data and analytics have a foundational role in digital health systems. Health systems today are generating massive amounts of data, which is growing exponentially, as over 12 billion devices are now connected to the internet. This is expected to increase to 75 billion devices by 2025.[33] Yet, in order for data to offer value to people, populations and health systems, it must be captured and then analysed so that it can be transformed into knowledge, information and insights to guide and inform decisions.

Predictive analytics assume a critical role in digital health ecosystems as analytics makes it possible for systems to learn what care works best, for whom, and under what conditions. Predictive analytics tracks data across the journey of care to enable people, populations and their provider teams to track, monitor, and fully understand progress toward personalised health and wellness goals. Data mobilised at the system-level informs every care delivery strategy and informs decisions to optimise operational performance in order to ensure that every person receives the best possible care, personalised to their unique goals and life circumstances.

Analytics in a person-enabled health system are defined as: predictive analytics that focus on mobilising data to create

real-world evidence by transforming data into knowledge and insights in order to inform decisions for individuals, health teams, and health system leaders. Data in digital health systems can inform care delivery and operations only when analytics tools and care processes create the evidence and knowledge to inform strategies to personalise care delivery for every individual and tailor care to unique population segments. Predicting risk accurately affords health teams the capacity to optimise outcomes and track population health to identify opportunities to proactively intervene, sustain, and strengthen population health and wellness. Analytics not only strengthen health system performance but, most importantly, enable the transformation toward predictive, proactive digital health systems, in which individuals are supported and enabled to manage their health and wellness. For example, predictive analytics could proactively identify risk for developing chronic conditions such as hypertension, diabetes, or chronic obstructive pulmonary disease, so as to alert provider teams to inform preventive and proactive care delivery. These same predictive tools could offer primary care teams insights into risk at the individual patient level, to inform personalised care approaches to mitigate risks and support a patient's health and wellness.

Prescriptive and predictive analytics inform personalised care strategies by tracking and tracing outcomes across the journey of care for every individual. Analytics are used to track progress towards established health goals and identify potential risks of poor outcomes proactively in order to cue clinician teams and individuals to intervene and prevent deterioration in health and wellness. Analytics also segment populations based on outcomes to identify strategies for strengthening quality and safety outcomes for the populations that health systems serve. Personalised analytics collect individual data from multiple sources (eg, personal digital tools, mobile devices, wearables) and include "progressive" data sources (eg, genomic and biometric). Personalised analytics enable and support people to report their progress, outcomes, and experiences, flowing data to their care network, and provider teams to track and report outcomes, side effects, and adverse events, which are then analysed to examine progress towards health and wellness goals and to track population-level health outcomes.

Finally, operational analytics use digital tools and dashboards to make data, knowledge and insights available at the point of care for clinicians and to inform leadership decisions, based on the real-time flow of data across programmes, organisations and health systems. Decision-makers and leaders track operational outcomes such as efficiency, productivity, quality, safety, access, equity, and cost, using analytics tools on handheld devices such as smart phones, tablets, or online tools to support proactive decisions based on accurate and complete real-time data. For example, during the COVID-19 pandemic, many health systems were caught off guard, with little to no digital infrastructure or analytics to assess and track inventory data and determine whether there was adequate supply of critical products available to protect staff and patients from transmission of the virus. Organisations rapidly developed dashboards to mobilise supply data, enable analytics modeling to track product utilisation, and predict supply volumes in order to inform decisions on supply procurement and distribution that would align with implementation of public health measures. Operational analytics enable leaders and decision-makers to assess value, system learning, and sustainability (eg, workforce sustainability, financial sustainability). Aggregate performance outcomes are reported publicly to inform individuals, product manufacturers, suppliers,

government and funders of performance progress and outcomes. Analytics tools also offer leaders real-time data to inform key decisions in day-to-day operations to optimise processes in real-time.

PERSON ENABLED HEALTH

The hallmark of digital health ecosystems is person-enabled care, whereby care delivery is personalised to the health and wellness goals of the individual, and aided and supported by digital tools and technologies in order to track progress and outcomes toward personal health goals and achieve value for people and populations. Digital tools and technologies enable and support people to manage their health and wellness, connecting them in meaningful ways to their health teams, and offering them choices for how, when, and where care is delivered. To date, there is emerging evidence that digital health engages people in managing their health, leveraging care approaches that are personalised to individual needs and circumstances. Outcomes of this approach that have been documented include: improved medication adherence, health behaviors that are aligned with best practice care pathways, significant reductions in adverse outcomes, and reduced total healthcare costs.[34]

Person-enabled health is defined as a health system focused on meeting and delivering on individual needs, values, and personalised health goals. It recognises the value and importance of connectivity between people and their care teams, creating a partnership based on individual needs and choice. It leverages digital options such as online tools, handheld devices for "care anywhere" approaches, or apps that enable on-demand health and wellness care to support the self-management of personal health and wellness goals, informed by the preferences, health needs and choices of the individual.[35]

Digital health ecosystems focus centrally on enabling people to manage their health and wellness and can be defined by three sub-dimensions:

a. **Personalised Care Delivery**

Personalised care delivery requires a transformational shift from the dominant focus on disease management, common in health systems today, towards a more personalised approach in which the individual and their provider teams establish care strategies that are guided by personalised health goals and informed by needs, values, and unique life circumstances. Individuals are partners in their care, with provider teams who work together to create a care pathway that meets the personal health and wellness goals of the individual. Disease management pathways and evidence of best practices are considered and reviewed for opportunities to advance personal health goals and personal choice for care delivery (eg, virtual, in person, online). Personalised care strategies are seamlessly integrated across provider teams (eg, specialist teams, primary care) to support the progress of health and wellness for individuals across the life course. Digital ecosystem environments enable care delivery choices (eg, telehealth, virtual care visits, online applications, personalised digital tools) that are uniquely tailored to the needs and choices of each individual and focused on enabling individuals to self-manage their health and wellness with the support of provider teams.

b. **Proactive Risk Management and Preventive Approaches focused on Health and Wellness**

Personalised care in digital health ecosystems proactively identifies risks to health and wellness in order to inform the

decisions of the individual and provider teams and ensure that care mitigates risks and sustains and supports health and wellness. Digital tools track progress towards health goals and alert individuals and their provider teams to risks in order to enable proactive interventions that prevent risk and sustain or strengthen health and wellness. Proactive risk management requires that care delivery approaches proactively identify risks to health and wellness, whereby alerts or secure messaging cue individuals and their provider team partners of the risks and inform decisions to proactively intervene to mitigate risks, prevent decline in health, and optimise progress towards health goals. Proactive care delivery requires a transformational shift from disease management care pathways that focus on compliance to established care delivery protocols and do not consider the unique life circumstances, choices, and values of the individual. Proactive care delivery means anticipating and identifying people and populations who are at risk for changes in health status, such as a deterioration in health, and proactively intervenes to support and strengthen health and wellness. Advances in artificial intelligence have demonstrated value and impact on the transformation of data into knowledge to inform decision making, such as sepsis algorithms that accurately predict risk of sepsis to enable provider teams to proactively intervene and prevent sepsis from occurring. A knowledge-driven, patient-centered care approach to knowledge gathering and data sharing enables rapid detection of risk (eg, deterioration in health) and identifies the best treatment options available, informed by evidence and based on historic patient datasets. Intelligence tools can be focused at an individual level, mining a patient record; at an organisational level, exploring case comparators within the organisation; and at a wider population level, in which multiple connected organisations share data to build a more global knowledge base of emerging patterns, threats, and care outcomes, without compromising patient privacy.

c. **Predictive Population Health**

Population health is an important feature of digital health ecosystems, whereby digital tools track progress towards health outcomes for cohorts of individual patients with similar health profiles to identify care strategies that offer the best possible health outcomes and the circumstances under which best possible outcomes can be achieved. Health system data is mobilised and robust analytics tools track population cohorts for progress towards health outcomes and risks to health and wellness. Analytics models enable health systems to anticipate risks (eg, gaps in health screening, risks of chronic illness outcomes, risk of medical error) which informs decisions to strengthen health programme strategies to manage and reduce risks to population segments and ensure that every person and population cohort has equitable access to the best available care. Thus, population health in digital health ecosystems requires mobilising digital tools, dashboards, and analytics to inform strategies to strengthen care delivery, optimised to the needs of every population cohort and focused on supporting and strengthening health and wellness to advance population health outcomes.

Person-enabled health requires health systems to transform care delivery towards digitally enabled models that meaningfully connect people with their provider teams in order to support and enable the self-management of health and wellness and proactively manage risk to keep people and populations well.

SUMMARY

The HIMSS Digital Health Framework is designed to guide health system transformation that enables people and populations to stay well, leveraging digital technologies to redesign how care is delivered and how value is achieved. It is informed by the evidence, knowledge, science and theory development available to date.[36,37] The ultimate goal of digital health ecosystems is to advance and strengthen health system sustainability worldwide. The automation of care processes within digital environments, and the prioritisation of care delivery focused on keeping people well, collectively advances health system sustainability from financial, workforce, and population health perspectives. For example, automated work environments able to proactively identify providers at risk of burnout and stress could enable proactive interventions to mitigate risks of burnout though employee health and wellness approaches. Access to care within robust digital environments supports people and populations to self-manage their health and wellness proactively with the support of provider teams who offer "high touch", data informed care delivery, anywhere and anytime support is needed. Self management care approaches that enable people to manage their care conditions proactively with the support of their provider teams, have been demonstrated to not only improve health outcomes for patients, but also reduce hospitalisations, and health system costs for chronically ill populations[38]. Transparency and traceability of data and outcomes in real-time across the journey of care, provides real-world evidence of the value of care delivery outcomes and measures that value in terms of the outcomes a person defines from their unique values, perspectives, and life circumstances. Digital health creates the capacity for health systems to learn what care processes, programmes and approaches offer the best outcomes, for whom, and under what conditions, which in turn informs operational and programme level decisions that are uniquely tailored to meet the health and wellness of populations worldwide.

To date, many countries and regions have adopted EMRs and associated digital technologies, but progress toward the transformation of health systems into proactive, predictive, and high performing digital health ecosystems that are focused on supporting population health and wellness has been limited. Digital health ecosystems offer a comprehensive strategy for re-imagining health care in order to drive value for every global citizen and ensure that healthcare is accessible, equitable, and high performing.

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