joep lange institute

DIGITAL TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN HEALTH I: UNDERSTANDING THE LANDSCAPE

Framing paper for civil society delegations on the Global Fund Board

Author: **Sara L.M. Davis**

August 2020

Frontier technologies, including new digital technologies, blockchain, and artificial intelligence (AI), are beginning to radically reshape public health. They offer the potential to significantly change how health services are delivered in low-resource settings, and to accelerate progress towards the Sustainable Development Goals (SDGs).

This paper draws on a rapid review of peer-reviewed research and WHO guidance, and aims to introduce these new technologies and the opportunities they offer to programs funded by the Global Fund to Fight AIDS, TB and Malaria ("the Global Fund"). At the same time, these new technologies bring an array of new risks as well. For that reason, this paper should be read alongside the companion paper, Digital Technologies and Artificial Intelligence in Health: Human Rights Principles (July 2020), which addresses governance challenges.

As the field is a large one, there are many publications to inform an overview, including gray literature that was not reviewed. The studies cited here were found through searches on PubMed using "eHealth", "mHealth" "e-learning", "mobile health wallets", "digital health wallets", "3D printing", "digital health financing", "cryptocurrencies", and "blockchain" separately and in combination with the terms "HIV", "tuberculosis" and "malaria" during 2017-20. This report emphasizes systematic reviews (structured reviews of scientific research), and where these were not available, single studies that used randomized control trials (RCTs), a study design that randomly assigns participants into an experimental group or a control group to reduce risk of bias. As a rapid review, this white paper is limited in scope and a more comprehensive search done over a longer period would probably turn up additional studies.

It begins by introducing key concepts that may be unfamiliar to some, and then looks at the role of new digital technologies, blockchain and AI in a variety of implementations, following the classification system developed by the World Health Organization (WHO). Each section also looks at evidence of impact on health outcomes, where this was located.

I. KEY CONCEPTS: DATA, BIG DATA AND MACHINE LEARNING

Before delving into the applications of digital technologies in health, it may be helpful to briefly introduce some key concepts. Other important terms are introduced in text boxes throughout the paper.

First, all digital technologies are informed and shaped by data, sets of facts or statistics used for computer operations. Quantitative data is of course the most critical for the purposes of this discussion: it is numerical information (such as HIV prevalence in a country); while qualitative data is descriptive or narrative (such as a report or a legal brief).

Health data can include electronic health records, national healthcare databases, or data produced by mobile phone applications or wearable devices such as fitness watches. Data for health can include data that indirectly affects health, such as temperature, educational level, age, and other data that informs public health policy decisions.

While all digital technologies use and produce data, some that are AI-enabled rely on big data. It may be helpful to clarify that not all data is big data. Much of the data the Global Fund and its partners work with in designing, monitoring and evaluating interventions for HIV, TB and malaria would not be considered big data. For instance, TB incidence, key population size estimates, national health budget data are all forms of quantitative data that can be managed and analyzed on traditional software on a laptop (for instance, at a basic level, an Excel spreadsheet); so these are not considered to be big data.

Big data is a data set too large to be captured, managed and processed by traditional software, and too large to store on a single computer server. Censuses and national health surveys, for example, produce big datasets; some other big datasets are produced by humans in our routine interactions with websites, such as social media, online shopping, e-mail, texting and more.

To analyze big data generally requires using algorithms which have the capacity to identify patterns and relations. An algorithm is a series of instructions given to a computer to perform a task. An algorithm can also be used to create a mathematical model; in global health, such models are used to calculate epidemiological situations, to forecast future transmissions, or to calculate costs and impacts of interventions.

Some computer applications analyze big data by both performing assigned tasks, and then improving on performance of those tasks through experience, based on which of their answers are labeled as valid. This autonomous improvement loop is machine learning –"pattern recognition that learns and improves from experience without being programmed"-- and it is a core part of artificial intelligence (USAID 2019, 7). Machine learning applications can be used to conduct predictive analytics, because the algorithms analyze data from the past in order to predict future patterns.

In addition to machine learning, some important aspects of artificial intelligence that are used in health applications include natural language processing (computer analysis of large amounts of data that are written or spoken in everyday language: for instance, questions people might ask to Siri on an iPhone), computer vision (automated inspection and analysis of images), and image and speech generation, in which applications automatically create images using AI, or automatically produce human-like speech using AI (Siri's answers to questions, for example). Deep learning is a class of machine learning in which algorithms use layers of perception produced by large artificial neural networks, which simulate the way neurons work in the human brain.

> Biometrics are one form of data drawn from physical characteristics used to authenticate an identity, usually to enable access or to control movements (for example, at national borders). Biometric identifiers can include fingerprints, iris scans, voice, gait, facial patterns, veins, and more.

All these areas of artificial intelligence – natural language processing, computer vision, image generation, and speech generation -- in turn generate data that can help machine learning to learn and improve. For this reason, designers of AI systems need big data. In data mining, semi-automatic or automatic exploratory data analysis can identify hidden patterns in large data sets. This can be valuable as a way to improve machine learning and predictive analysis: like a child given more and more books to read, the more data the system analyzes, the more it is able to learn and improve.

Thus, as with any other form of decision-making that relies on data, in order for machine learning to be effective, it is crucial that the big data these systems use is of good quality. Despite optimistic predictions of the value that big data analytics could hold for health care, health has lagged behind other industries in the application of big data, in part because health data is often weak (Car et al 2019). A mix of factors, including provider rotations, disruptions to care processes, lack of user acceptance of new digital technologies, and other factors may result in poor quality data to inform systems (Landis-Lewis et. al. 2015).

As a result, companies developing machine learning applications are continually looking for big datasets that they can use to train and improve algorithms. For example, some leading tech companies were recently sued after they obtained biometric data from photo-sharing sites such as Flickr, in order to help them to train algorithms to reduce racial biases in facial recognition (Lancaster 2020). The supply of big data in the Global North is not enough to meet the growing demand, and privacy regulations in the Global North are becoming stricter. Health systems in low-resource settings offer potentially vast, as-yet-untapped reserves of big data.

These pressures on the private sector to improve and launch new tools are growing more intense in the COVID-19 pandemic. This means that the private sector has a strong interest in partnering with governments and other health agencies in low-resource settings to roll out new AI-enabled digital health tools, improve them through implementation, and in the process improve the tools by gaining access to big data which they cannot access in other ways. They may therefore benefit significantly from philanthropic partnerships in which there is no immediate financial profit, if they can access big data through that partnership. This creates obvious opportunities for the Global Fund, as well as obvious risks, discussed in the other paper.

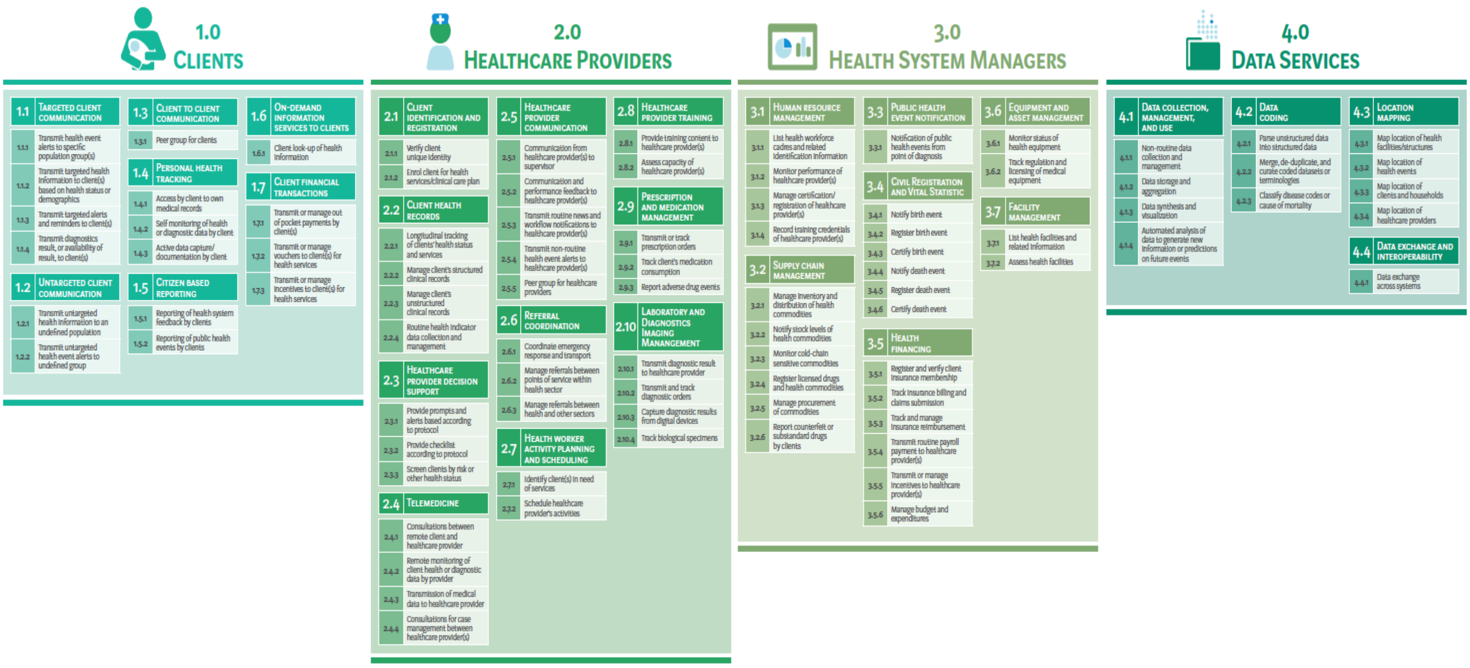
The next section explores some of the opportunities and uses of digital technologies and AI in health systems, before turning to consider opportunities in health financing and community-led monitoring.

II. DIGITAL HEALTH INTERVENTIONS

Digital technologies have been integrated into many forms of health care, reshaping how health systems are run and accessed. Health systems use digital technologies at many levels to gather, analyze and use information in order to make decisions and offer treatment and care. These uses include "searching medical knowledge resources, facilitating clinical support, monitoring quality of care, and mapping and monitoring the spread of infectious diseases, as well as tracking supplies of drugs and vaccines" (WHO 2018, 2). Artificial intelligence is also integrated into a growing range of health applications, including "patient education, geocoding health data, social media analytics, epidemic and syndromic surveillance, predictive modeling and decision support, mobile health, and medical imaging (e.g. radiology and retinal image analyses)" (Shaban-Negad et. al. 2018). This includes many applications that were previously analog, but are now digital or AI-enabled.

The World Health Organization (WHO) has created a classification system for digital technologies for health, grouping them as "interventions for clients", "interventions for healthcare providers", "interventions for health system or resource managers", and "interventions for data services" (WHO 2020, see Figure 1). This paper follows WHO's classification system to briefly introduce some specific uses, and summarizes research that shows evidence of impact, where this could be found.

Figure 1: WHO Classification of Digital Health interventions



Source: WHO, Classification of Digital Health Interventions v 1.0, p.1

A. INTERVENTIONS FOR INDIVIDUALS USING MOBILE APPS

Mobile apps and other digital technologies now enable health providers and individuals to communicate in new ways (see Figure 2). Mobile apps used to communicate, share information, and track personal health are known as mHealth. Mobile apps can also be used for community systems strengthening: for peer group support, community-led monitoring and advocacy.

Figure 2: Interventions for clients

Source: WHO, Classification of Digital Health Interventions v 1.0, p.6

1. MHEALTH

mHealth applications use mobile and wireless devices to provide individuals with health information, enable individuals to share health information with health providers, can track personal health, promote behavior change, and link individuals to services. As mobile phones are widely used in low-resource settings, they offer promise as a way to provide patient care and information in remote communities or communities that lack other health facilities or infrastructure.

Some examples of mHealth interventions include:

- a mobile phone app that screens for symptoms and refers individuals at risk to a clinic for screening
- a Bluetooth-enabled phone that patients can use to access a location-based electronic pharmacy network and identify which pharmacy in the patient's geographic area stocks the prescription they need
- an SMS service for people living with HIV, through which health care providers send weekly messages to check in on patients and follow up with those who need assistance
- mobile apps used to change behavior, for instance to track diet, weight or exercise
- mobile apps can also be used for diagnosis, health monitoring and compliance with treatment; there are now apps that do this for people affected by diabetes, obesity, HIV, TB, mental health, and more (Abaza and Marschollek 2017).

Precision medicine

There is a growing excitement about the potential of "precision medicine", sometimes called P4 medicine (predictive, preventive, personalized and participatory), in which genome sequencing and data analysis are used to tailor diagnosis and treatment to individual patients (genome sequencing is the process of determining the complete DNA sequence of an organism's genome; the human genome is made up of over 3 billion DNA nucelotides).

Researchers have noted privacy and security risks, and called for further research (Carrasco-Ramiro, Peiró-Pastor, Aguado 2017).

2. MOBILE APPS FOR COMMUNITY SYSTEMS STRENGTHENING

Mobile apps can also complement community systems strengthening interventions.

Mobile apps can be used for peer group support for treatment adherence, for example (labeled as "1.3.1 peer groups for clients" in the WHO classification chart, figure 2). Mobile apps can also be used for community-led monitoring and advocacy ("1.5, Citizen based reporting" in the WHO chart, figure 2). They could be used to monitor and report stock-outs, or to pool finances among cash-strapped community-based groups. In addition, new digital technologies enable community-based epidemiological surveillance: the detection of public health events by community members can enable early reporting of public health risks and outbreaks (WHO 2014).

One example of a mobile phone app used for health rights advocacy has been piloted by Nazdeek, an NGO in Delhi. Their SMS-based tools are used by women (especially Dalit and Muslim women) to monitor health sector discrimination, poor availability of health services, cumbersome bureaucratic processes, and other barriers to access (Nazdeek 2018). Nazdeek trained community paralegals to use the system to gather data, code it, report rights violations, verify reports, and aggregate reports on an open-source platform for use in meetings with authorities (Nazdeek 2018: 8-9).

Human rights organizations have also developed mobile apps for human rights documentation, litigation and advocacy. For example, HURIDOCS' tool Uwazi is a "free, open-source solution for organizing and analyzing information" developed for human rights investigation and advocacy, which could potentially be adapted to document rights violations linked to health (HURIDOCS 2020). UPRInfo, the NGO that supports civil society engagement with the Universal Periodic Review at the UN Human Rights Council, has created an AI-enabled online database of UPR recommendations and voluntary pledges by states. The site uses machine learning algorithms to automatically fetch new UPR documents online and update the database. The tool can be used by advocates within countries to play watchdog and advocate for governments to uphold their international commitments, including in regard to the right to health, and rights of women and marginalized groups (Finch 2020).

3. EVIDENCE OF IMPACT OF MHEALTH (MOBILE APPS)

The evidence for impact on health by mHealth interventions is growing, though challenges remain, and there is a need for further research. Two 2018 systematic reviews of recent research found that mHealth interventions for HIV do improve cascade outcomes, especially medication adherence and virus suppression, but that there are no studies yet to show sustainability of this approach, or to assess longer-term outcomes and impact of these apps (Kemp and Velloza 2018, Henry et. al. 2018). Another systematic review of mobile phone messages to promote compliance with anti-TB treatment found a modest effect, but found also that the quality of evidence was low and that further research is needed (Gashu et. al. 2020). Iribarran and colleagues (2017) conclude in their systematic review that the evidence that mHealth interventions are cost-effective or cost-saving is weak.

While acknowledging weak evidence of impact, WHO does recommend use of some mHealth applications in settings that meet specific conditions: where health systems can support implementing them in an integrated manner, for tasks already defined within the scope of practice for health workers, and where concerns about privacy and communications can be addressed (WHO 2020, xxi). WHO and the International Telecommunications Union (ITU) have set up a Be He@lthy, Be Mobile (BHBM) initiative to work with governments to scale up mHealth services.

At the same time, WHO notes some challenges and concerns in relation to integration of apps in health systems, sustainability, and privacy risks. The companion paper to this paper which focuses on human rights discusses these, including inequitable access to mobile technologies, threats to privacy and autonomy, and other risks for women and marginalized groups.

In addition, mobile health apps designed in one country should be adapted before being applied in another country. Apps for mHealth should be tailored to local languages, local culture, and social understandings of health, which can vary significantly among countries, and even within diverse groups in the same country. One scientific study of SMS text reminders used to promote treatment adherence for children with malaria in Kenya found that such applications must be developed, tested and refined before implementation to ensure they are written for their target population (Githinji et. al. 2017).

While there are scientific studies of the effectiveness of community-led monitoring of health for accountability, these studies largely rely on traditional paper scorecards, report cards and surveys, and shared during in-person meetings with health officials (Green 2011). A search for "community" "monitoring" and "review" during 2017-20 in the PubMed database turned up no systematic reviews or RCTs of community-led monitoring using digital technologies. Again, as this was a rapid review, these studies may still be found with more time and a more comprehensive search. It could also be fruitful to look at studies in field of citizen science, environmental studies and climate change, which have a longer history of using digital technologies and mobile apps to support public monitoring.

B. DIGITAL FINANCING FOR HEALTH

Health systems in low- and low-middle-income countries have faced significant financial challenges due to liberalism, privatization and the growth of the private health sector. This is in part due to the harmful impact of Structural Adjustment Programs that were imposed on some countries as a condition of aid, and which imposed fiscal limits on health policies (Thomson, Kentikelenis and Stubbs 2017). In a health care landscape in which households may seek care from both public and private clinics, given low levels of public financing and uneven health insurance coverage, households must increasingly cover a share of the costs of care themselves. The result is that health care is inaccessible to many households.

Health financing has three functions: "collecting funds, pooling funds, and purchasing health services" (Meessen 2018, S30). Digital technologies are increasingly being deployed to complement and supplement traditional appproaches to financing health, and offer one way to progress towards Universal Health Coverage. This section explores two ways digital technologies are being used to mobilize financial resources for health in low-resource settings: through mobile platforms, and using blockchain (these are the interventions WHO groups under "1.7 Client financial transactions", figure 2).

1. MOBILE HEALTH FINANCING

Through pooling of funds, it is possible to create a large and sustainable pool that enables the "redistribution of financial risk between the healthy and sick and the rich and the poor" (Meessen 2018: S30). Mobile platforms for financing health are one potential solution: they enable the collection and storing of funds from a diverse group of people who live and work in contexts where the formal banking system is weak or absent; as well as enabling direct financial transactions, such as payments. In Kenya, for example, M-TIBA is a mobile money medical savings account which encourages households to put money aside for future health expenses, or to collect contributions from family members (Meessen 2018: S31). As of 2017, nearly 900,000 users were reported registered in M-TIBA (ibid.).

In other countries, platforms like these do more than pool funds. They can also link with insurance packages, including community-based health insurance and micro-insurance programs. For example, in Tanzania, Jamii is a startup digital platform linked to Vodaphone which links users to various health coverage options (Jamii 2016-17). Open IMIS is an open source system used for health financing interventions, developed under a program funded by the Swiss government through the Swiss Tropical and Public Health Institute; in Tanzania, for example, it supports a cashless health financing programme with claims submitted through Android phones or a website (openIMIS 2020).

Blockchain and cryptocurrencies

Another technology on the rise in banking and finance, now increasingly used in development finance, is blockchain. Blockchain is a chain of digital pieces of information ("blocks"), for instance, the date, time and dollar amount of a transaction, or a group of transactions.

Each block stores information about who is engaged in that transaction, using a unique digital signature to identify the individual. Each block is given a unique code (a "hash") that distinguishes it from other blocks. A network of computers verifies the information in the block and gives it a hash once it is verified, adding it to the blockchain.

Once the new block is verified, the transaction information is publicly available. Because each computer in the network has a record of this information, and because the new block is linked to other blocks before and after it in the chain, it becomes very difficult for a hacker or anyone else to manipulate or change the information in the block. This shared, decentralized record is known as a "distributed ledger".

Bitcoin and other cryptocurrencies utilize blockchain to track and record transactions, so that instead of being controlled and regulated by one central bank, the currency and transactions are verified by the decentralized network of computers.

2. BLOCKCHAIN TECHNOLOGY AND CRYPTOCURRENCIES

Blockchain technology and cryptocurrencies are also being used by some agencies for health financing and for direct financial transfers as part of development and humanitarian aid interventions in low-resource settings. By removing intermediaries (such as Principal Recipients or Sub-Recipients in the case of the Global Fund), cryptocurrencies could provide individuals with direct and verifiable access to funds without fees, processing delays, or other transaction costs (Till et. al. 2017). The World Food Program has piloted blockchain financial transfers to 10,000 Syrian refugees, reducing transfer fees to almost zero; the World Bank is exploring use of blockchain as part of mobile phone-based bond issuance programs in Kenya aimed at promoting household savings, called M-Akiba (ibid.). There are some limited implementations of blockchain for insurance claim processing (Agbo, Mahmoud and Eklund 2019).

Active government stewardship will be essential to avoid fraud, control the proliferation of competing and siloed financing platforms, as well as to promote interoperability, integration, open source solutions, and above all, access to health coverage for those most marginalized (Meessen 2018: S38).

3. EVIDENCE FOR IMPACT OF DIGITAL HEALTH FINANCING

These new forms of health financing have generated excitement and offer opportunities to improve access to health services in low-resource settings. No systematic reviews of studies demonstrating positive health impacts were located in this rapid review. A more comprehensive search could turn up more evidence. Given the digital divide, there is a risk that mobile health financing platforms may continue to exclude the poorest and most vulnerable; in particular, women, youth and marginalized groups who may have to share mobile phones face challenges in terms of both access, financial control and privacy. Recent hacker attacks on cryptocurrencies have utilized mobile phone numbers to access private accounts (Popper 2017). Critics also point to the risk of fragmentation and inefficiency in health financing as siloed mobile health financing platforms grow.

Two individual randomized control trials were located that show promise: In Madagascar, a mobile health wallet enabled women to pay directly for routine antenatal or postnatal care, and was perceived as beneficial and practicable by the majority of participants (Muller et. al. 2019). In Kenya, a study of Connected Diagnostics described its approach to combining point-of-care diagnosis of images with a rapid diagnostic test reader, which was also connected to mobile payment mechanisms, enabling treatment of febrile illness among nomadic populations (Smith et. al. 2019).

C. INTERVENTIONS FOR HEALTH SYSTEMS STRENGTHENING

In addition to supporting population health and linking individuals to health information and services, some digital technologies are being used to strengthen health systems. This can include a range of interventions grouped under eHealth, as well as eLearning tools to build capacity of the health workforce. Unmanned aerial vehicles (drones) and 3D printing are also examples of innovative technologies that are being piloted in diverse settings. This section discusses interventions that are largely grouped by WHO's classification system under interventions for health care providers and health system managers (see figure 3).

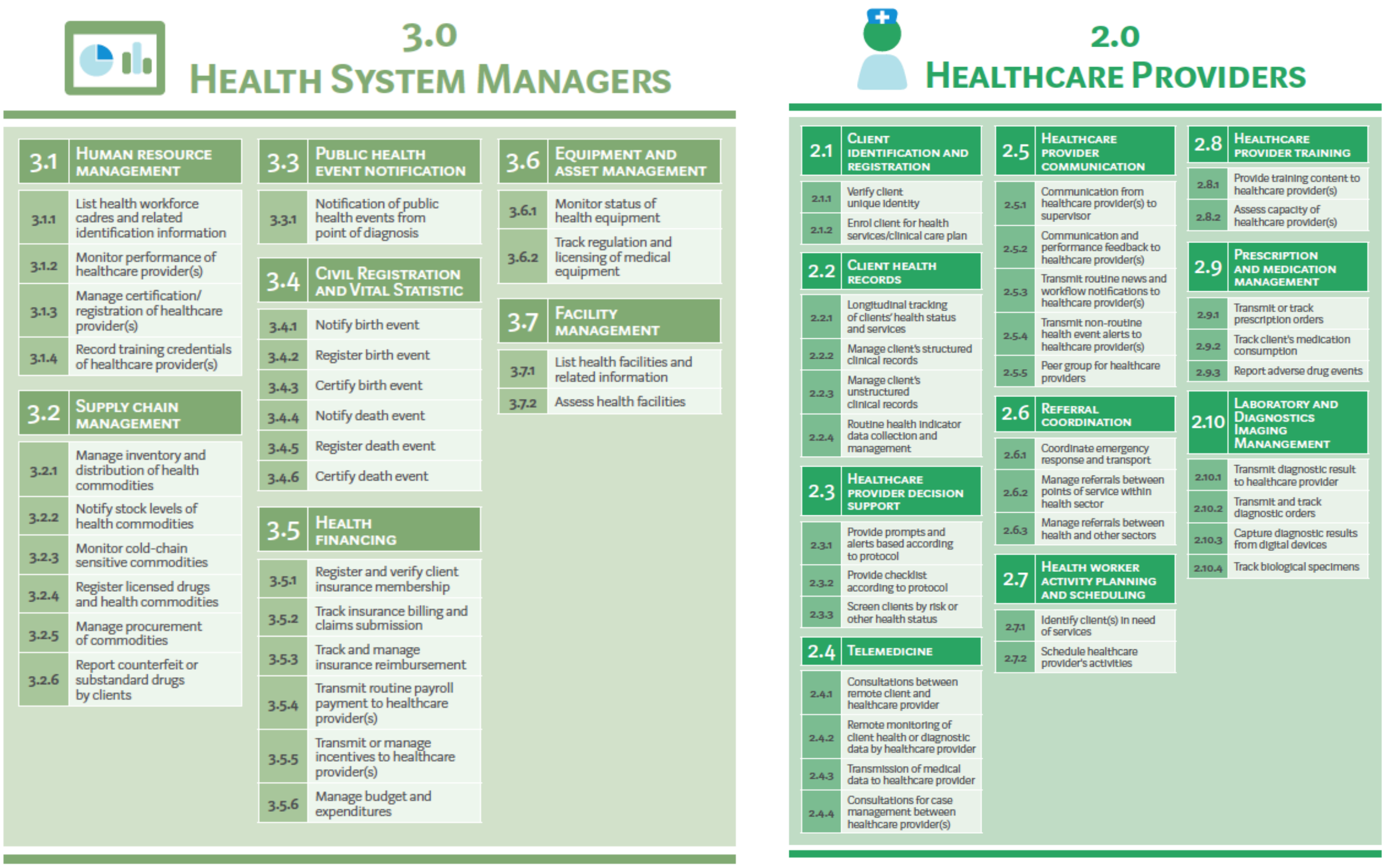
1. EHEALTH

eHealth is the term that describes digital technologies and AI systems used to gather, manage and analyze health data. They can include Health Management Information Systems (HMIS) and Logistics Management and Information Systems (LMIS); and other systems used to store and manage eletronic health records, patient registries and digitized medical records. eHealth can thus facilitate tracking and management of drugs, vaccines and other health goods through procurement, supply and distribution chains. mHealth and telehealth are sometimes also grouped under eHealth.

Examples of eHealth used for health systems strengthening include:

- Health management information systems (HMIS) such as DHIS2, an open source, web-based system used for data warehousing, data visualization, and real-time health data analysis.
- Other forms of Electronic Medical Record (EMR) software can also be used to track patient care and share information among health providers to enable care coordination, communication and documentation. Blockchain is sometimes used for this purpose as well due to its decentralization, reliability, security and privacy; for example, in Estonia, blockchain is used to secure over 1 million health records (Kuo, Kim and Ohno-Machado 2017).
- Online portals that enable patients to book appointments and use tools to manage their chronic conditions
- Smartphone platforms that health care personnel use to report stock levels, receipts and orders. This allows supervisors to monitor health care personnel and drug stock-outs remotely
- Monitoring and quantification of antibiotic prescriptions, in order to enable oversight of prescribing patterns in private not-for-profit clinics (Mekuria et. al. 2019).

Figure 3: Interventions for Health Systems Strengthening



Source: WHO, Classification of Digital Health Interventions v 1.0, p.7-8

2. TELEHEALTH

Telehealth, including teleradiology, telepathology, remote patient monitoring, and teledermatology, enable long-distance patient and health provider contact, and sometimes use AI to diagnose illnesses by identifying patterns in patient imaging. Many traditional diagnostic tools are now AI-enabled or have incorporated telehealth.

Telehealth applications can include diagnosis, monitoring, treatment (including robotic surgery), consultation and education for health care workers. Telemicrobiology enables the remote analysis of digital images; it appears likely to expand access and efficiency of clinical microbiology laboratories (Rhoads et. al. 2016).

Some examples of telehealth include :

- Electronic sensors that enable health experts to remotely monitor patients at risk of falls, heart attacks or strokes
- a smartphone-powered cloud-enabled portable electrocardiograph, which enables remote diagnostics for patients at risk of heart attacks. It allows patients in remote, low-resource settings to connect with cardiologists in urban settings.
- Computer Aided Detection (CAD) software that can immediately analyze digital x-rays for abnormalities to diagnose TB.
- A portable smartreader that allows healthcare workers to transmit HIV and other rapid diagnostic tests with GPS location and other data to the cloud, using cellular networks.
- A radiologist at a public hospital uses an AI-enabled radiology tool to rapidly diagnose tissue samples from women reporting lumps in their breast, along with degree of certainty of the diagnosis (USAID 2020, 15).

Telehealth applications can also be developed for mobile phones: for example, a mobile phone-enabled pulse oximeter that links a smart phone to a filter, enabling clinicians to remotely track oxygen saturation for people (including newborn infants) with pneumonia.

3. ELEARNING

Health systems strenthening requires building the capacity of the health workforce. eLearning is increasingly used to train and educate medical students and health professionals: it can include webinars, online courses, learning through mobile apps, and more. Before COVID-19, eLearning was increasingly favored for training of health care personnel because it is less expensive than in-person training. However, during the COVID-19 pandemic, eLearning is increasingly common in place of face-to-face courses.

4. OTHER INNOVATIVE TECHNOLOGIES

Other innovative technologies for HSS – Some innovative new technologies enable health systems to "reach the last mile" by delivering services and goods to hard-to-reach or poorly-supplied health facilities. Unmanned aerial vehicles (UAVs), or drones, can reach otherwise inaccessible patients, especially in conflict settings. This can include search and rescue missions, telemedicine assignments, medical supply routes, epidemiological surveillance, and disaster management (Braun et. al. 2019). Drones are being used for diagnosis and treatment in remote areas, but further research is needed into their safety, public acceptance and participation (Rosser et. al. 2018). For health providers that lack access to supply chains, three-dimensional (3D) printing is gaining application in pharmaceutical manufacturing and in surgery, in order to manufacture drug delivery systems, surgical guides, anatomical models and custom implants. 3D printing is one promising technology to provide customized drug formulations, though here again, more study is needed to assess quality and sustainability (Kotta, Nair and Alsabeelah 2018)

5. EVIDENCE OF IMPACT FOR HEALTH SYSTEMS STRENGTHENING

WHO has conducted systematic reviews of the evidence for digital interventions for health system strengthening, and has observed that while eHealth "has the potential to address problems such as distance and access", it also faces "many of the underlying challenges faced by health system intervention in general, including poor management, insufficient training, infrastructural limitations, and poor equipment and supplies" (WHO 2019, xiii). They urge implementers to assess given contexts, warning that "there is a risk of a proliferation of unconnected systems and a severe impact on the effectiveness and sustainability of the health intervention" (WHO 2019, xiv).

A number of systematic reviews of studies of eHealth were located for this rapid review. Two 2018 systematic reviews of recent research found that there is little literature to show how likely eHealth interventions are to be adopted by health facilities and staff, and no studies to show sustainability or longer-term outcomes (Kemp and Velloza 2018, Henry et. al. 2018). A comparative review in sub-Saharan African countries found that both eHealth and mHealth technologies were "useful for adherence, diagnosis, disease control mechanisms, information provision, and decision-making referrals" (Bervell and Al-Samarraie 2019). However, they also found that challenges in rural regions include lack of ICT (information and communications technology) infrastructure, trained personnel, literacy, and lack of multilingual text and voice messages (Ibid.). A 2017 study of e-TB Manager, a web-based eHealth system used in 10 resource-constrained countries that account for one-third of the world's TB burden evaluated user experience of the system. This multicountry study found that while users gave the application high ratings, there is a need for additional training to build institutional capacity to provide support

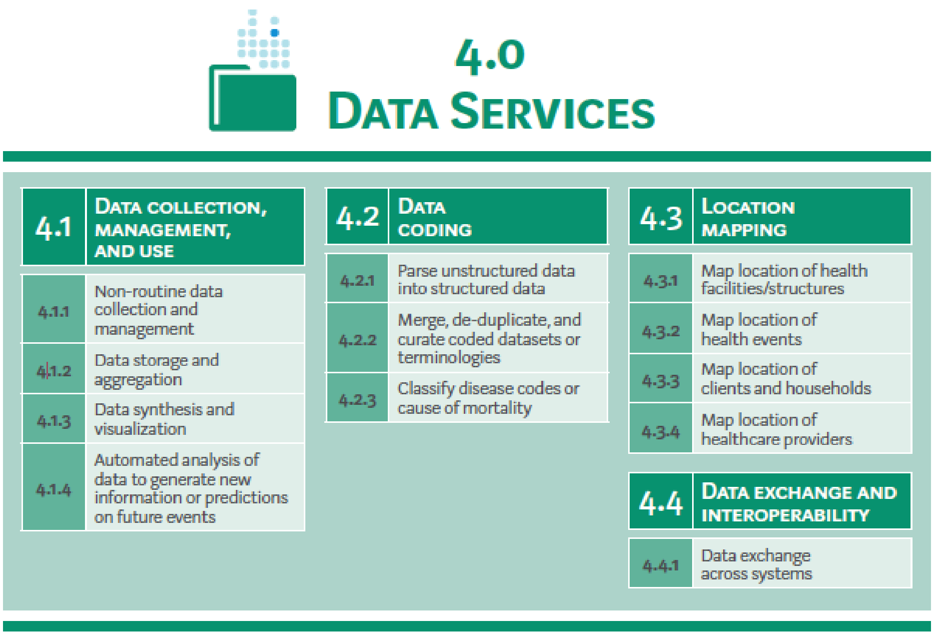
(Konduri et. al. 2017).

A systematic review of studies of eLearning programs found little or no improvement in patient outcomes or health professionals' behaviors, skills and knowledge when compared with traditional in-person courses (Vaona et. al. 2018). One study finds that adaptive e-Learning environments is effective; an adaptive approach tailors the online learning experience to individual students' personal and unique needs and learning styles (Fontaine et. al. 2019). A systematic review of surgical papers finds that while there are several advantages to 3D printing, further research is needed, including cost-effectiveness analysis (Tack et. al. 2016).

D. INTERVENTIONS FOR POPULATION HEALTH

Digital technologies and artificial intelligence can be powerful tools for surveillance and targeting of health interventions at the national and global levels, especially in response to outbreaks. Epidemiological surveillance for early detection of disease outbreaks can significantly speed the ability of health experts to detect suspected outbreaks of infectious diseases, including biological attacks, by scanning for symptoms and patterns of disease in a population (these are grouped under "4.0 Data services" in the WHO classification system, see figure 4).

Figure 4: Data Services



Source: WHO 2020, p. 9

Increasingly, epidemiological surveillance of populations can be conducted in real time. Real-time epidemiological surveillance utilizes big data that is routinely gathered for other purposes by local and national health care facilities and businesses, such as data on symptoms reported in emergency rooms, absenteeism, sales of over-the-counter health care products, contact tracing apps on mobile phones, or data on population movements to generate alerts and enable rapid responses (Tsui et. al. 2003).

Almost any of the applications described above, including mobile health apps, could potentially be enabled to direct anonymized data to a central Ministry of Health, which could use this data to conduct national-level or localized epidemiological surveillance, intervention selection, and intervention targeting (USAID 2020, 11).

Examples of digital technologies and AI used for epidemiological surveillance include:

- In August, Google Cloud and the Harvard Global Health Institute released COVID-19 Public Forecasts which aim to predict expected cases, infections, hospitalizations and deaths in US counties for the next 14 days (Sava 2020)
- Given the risk of outbreaks in crowds during the Hajj in Saudi Arabia, one proposal considered by authorities was to establish sensor networks to monitor the biometrics (such as heart rate, blood pressure), identifying pilgrims who fell ill in the large crowds, and coordinating ambulatory services to reach them (Boudhir 2013).
- National surveillance is being used by the US CDC to detect potentially failed suicide attempts based on data gathered and reported in emergency rooms, enabling a program to rapidly intervene to prevent suicides (Griffin and Harder 2016).

One controversial approach, nonetheless increasingly adopted, is molecular surveillance, which analyzes molecular data to understand patterns and clusters of virus transmission among individuals and to pinpoint new outbreaks in an epidemic. A related approach, whole genome sequencing (WGS), is increasingly used to investigate infectious disease and transmission patterns, to trace the source of transmissions, and to assess microbial virulence and antimicrobial drug resistance. The European Centre for Disease Prevention and Control has a strategy to scale up WGS across Europe (ECDC 2019).

III. CONCLUSIONS AND QUESTIONS FOR DISCUSSION

Many of the applications of digital technologies and AI for health discussed above are still at an early stage of use. While there is genuine excitement about the potential they offer, scholars are cautiously optimistic that continued research will demonstrate their applicability, but it is clear that there are real challenges in practice and more research is needed. At the same time, a growing number of actors (private sector, private foundations, government, bilateral donors, academic and others) are engaged in piloting and promoting digital technologies and AI for health in countries that implement Global Fund financing. This raises important questions for civil society representatives on the Board of the Global Fund to deliberate.

On the one hand, the results of this rapid review suggest that while there are many promising new uses of digital technologies and AI for health, it would be prudent to have more in-depth independent studies of implementation in practice, in order to guide decisions about whether to finance them through the Global Fund. Car and colleagues (2019) argue for this cautious approach, noting that there has been a great deal of "hype" about AI in health, but that there is a critical need to fund implementation science as the bulk of funding currently "disproportionately favors discovery". They note,

> Overall, we remain positive that big data studies and associated new technologies will continue to guide novel, exciting research that will ultimately improve healthcare and medicine—but we are also realistic that concerns remain about privacy, equity, security, and benefit to all (Car et. al. 2019, 17).

Similarly, many of the systematic reviews consulted for this framing paper, while optimistic about these opportunities, also caution that the emphasis is still on the discovery phase for many of these new tools and approaches. Thus, it could be argued that the Global Fund should be cautious not to expose communities to undue risk, to support experimentation that may cause harm as well as good, or to potentially reduce funding for other interventions for which the evidence base is stronger.

On the other hand, the studies reviewed for this paper do agree that new digital technologies and artificial intelligence for health offer significant promise for every aspect of the HIV, TB and malaria response: from epidemiological surveillance, to secure management of patient records, to diagnosis, treatment and care, to financing the response and community systems strengthening. Given the speed with which many countries are embracing digital technologies in health, it could also be argued that the Global Fund has a responsibility to engage proactively to promote the values it upholds, and should encourage and promote positive innovation, working with partners to lead and initiate further exploration and research with the goal of initiating positive change.

While WHO has acknowledged in its review of health systems strengthening that the quality of evidence is weak, it nonetheless has recommended implementing some specific interventions where conditions enable this to be done safely (WHO 2020). For the Global Fund, assessing the context for implementation of new technologies could include consideration of the factors identified by WHO, including the ability of the health system to integrate the intervention and ensure it is sustainable, privacy protections, IT support, and adaptation to local language and context. WHO does not address other human rights risks, but given its mandate, the Fund may add to this list doing due diligence into the legal and human rights concerns identified in the companion paper. WHO also encourages countries to ensure their resources are spent well by developing national eHealth strategies with action plans and monitoring frameworks (WHO 2012). As of 2016, more than half of WHO member states had a national eHealth strategy (WHO 2016, 6). WHO maintains an online directory of national eHealth policies.

WHO has guidance on ways to assess the environment before scaling up digital interventions (WHO 2015). Ross et. al. (2016) identify a set of factors to assess in identifying how well e-health applications will work in a given setting, including innovation characteristics of the application, factors in the external setting, factors within the implementing organization, knowledge and beliefs among users , and planning for implementation. Similarly, Ferretti (2020) recommends criteria to consider before implementing digital contact tracing, such as an inclusive oversight body.

Drawing on these resources, the Global Fund may wish to develop a checklist for approval of financing new digital technologies and AI for health, in collaboration with WHO and technical partners, as well as with affected communities and civil society. Such an approach could enable the Fund to develop an approach to investing in new digital technologies that supports innovation while protecting those most vulnerable.

Sara L.M. Davis, Geneva, 26 August 2020

SOURCES

Articles listed below include Digital Object Identifiers (DOIs), which are a way to permanently identify articles or documents, and link to them online.

Abaza, Haitham and Michael Marschollek. 2017. "mHealth application areas and technology combinations: A comparison of literature from high and low/middle income countries". Methods Inf Med 56.7: e105-e122. doi: 10.3414/ME17-05-0003.

Agbo, Cornelius C., Qusay H. Mahmoud, and J. Mikael Eklund. 2019. "Block-chain technology in healthcare: A systematic review". Healthcare (Basel) 7.2: 56. doi: 10.3390/healthcare7020056

Bervell, Brandford and Hosam Al-Samarraie. 2019. "A comparative review of mobile health and electronic health utilization in sub-Saharan African countries". Social Science Medicine 232: 1-16. doi: 10.1016/j.socscimed.2019.04.024.

Boudhir A, M. Bouhorma, M.Benahmed, S. ElbrakA real time health control and localization of pilgrims in El Hajj: BSN Application J Theor Appl Inf Tech-nol, 49 (2013), pp. 488-496

boyd, danah and Kate Crawford. 2011. "Six provocations for big data". Paper pre-sented at Oxford Internet Institute's "A decade in internet time: Symposium on the dynamics of the internet and society". September 21. https://osf.io/nrjhn/

Braun, Jonathan, S. David Gertz, Ariel Furer, et. Al. 2019. Journal of Trauma, Acute Care and Surgery 87.1S (Suppl. 1): S28-S34. doi: 10.1097/TA.0000000000002221.

Car, Josip, Aziz Sheikh, Paul Wicks, and Marc S. Williams. 2019. "Beyond the hype of big data and artificial intelligence: Knowledge and wisdom". BMC Medicine 17: 143. https://doi.org/10.1186/s12916-019-1382-x.

Carrasco-Ramiro, F., R. Peiró-Pastor, B. Aguado. 2017. « Human genomics projects and precision medicine". Gene Therapy 24.9 : 551-561. doi: 10.1038/gt.2017.77.

Euronews. 2020. "What French doctors and the WHO really said about vaccine testing". August 4, https://www.euronews.com/2020/04/07/what-french-doc-tors-and-the-who-really-said-about-africa-and-vaccine-testing.

European Centre for Disease Prevention and Control. 2019. "ECDC strategic framework for the integration of molecular and genomic typing into European sur-veillance and multi-country outbreak investigations". 4 April. https://www.ecdc.europa.eu/en/publications-data/ecdc-strategic-framework-integration-molecu-lar-and-genomic-typing-european.

Ferretti, Luca, Chris Wymant, Michelle Kendall, et. al. 2020. "Quantifying SARS-Cov-2 transmission suggests epidemic control with contact tracing". Science 368.6491: eabb6936. DOI: 10.1126/science.abb6936

Finch, Lauren L. 2020. "UPR Info is making human rights recommendations more accessible – with a little help from machine learning". On HURIDOCS website, https://www.huridocs.org/2020/07/upr-info-is-making-human-rights-recommendations-more-accessible/.

Fontaine, Guillaume, Sylvie Cossette, Marc-André Maheu Cadotte, et. al. 2019. "Efficacy of adaptive e-learning for health professionals and students: A systematic review and meta-analysis". BMJ Open 9.8: e025252. doi: 10.1136/bmjopen-2018-025252.

Gashu, Kassahun Dessie, Kassahun Alemu Gelaye, Zeleke Abebaw Mekonnen, et. Al. 2020. "Does phone messaging improve tuberculosis treatment success? A systematic revview and meta-analysis". BMC Infectious Disease, 20.1: 42. doi: 10.1186/s12879-020-4765-x.

Githinji, Sophie, Caroline Jones, Josephine Malinga, et. al. 2017. "Development of a text-messaging intervention to improve treatment adherence and post-treatment review of children with uncomplicated malaria in western Kenya". Malaria Journal 14 :320.

Griffin, J. M. Van Beek, and P. Harder. 2016. "Suicide Prevention Action Network of Idaho (SPAN) Suicide in Idaho: Fact sheet" [Internet]. Sept. [cited 2018 Jun 21]. Available from: http://healthandwelfare.idaho.gov/Portals/0/Users/059/07/2107/2016%20sept%20fact%20sheet.pdf

Henry, Kirk D., Aisha L. Wilkes, Christina M. McDonald, et. al. 2018. "A rapid review of eHealth interventions addressing the continuum of HIV care (2007-2017)" AIDS Behavior 22.1: 43-63. Doi: 10.1007/s10461-017-1923-2.

HURIDOCS. 2020. Webpage, https://www.huridocs.org/.

Green, Cathy. 2011. Community monitoring in a voluntary health worker setting: A review of the literature. Report from inSCALE (Innovations at Scale for Community Access and Lasting Effects), Helath Partners International. https://www.malariaconsortium.org/upscale/local/downloads/report-community-monitoring-report-cathy-green.pdf

Iribarran, Sarah J., Kenrick Cato, Louise Falzon, and Patricia W. Stone. 2017.

"What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions". PloS One 12.2: e0170581. doi: 10.1371/journal.pone.0170581

JAMII. 2016-17. Website, available at http://www.jamiiafrica.com.

Kemp, Christopher G. and Jennifer Velloza. 2018. "Implementation of eHealth interventions across the HIV care cascade: A review of recent research". Current HIV/AIDS Rep. 15.6: 403-413. doi: 10.1007/s11904-018-0415-y.

Konduri, Niranjan, L. Gustavo V. Bastos, Kelly Sawyer and L. Fernando A. Reciolino. 2017. "User experience analysis of an eHealth system for tuberculosis in resource-constrained settings: A nine-country comparison". Int J Med Inform 102: 118-129. doi: 10.1016/j.ijmedinf.2017.03.017.

Kotta, Sabna, Anroop Nair, and Nimer Alsabeelah. 2018. "3D printing technology in drug delivery: Recent progress and application". Curr Pharm Des 24.42: 5039-5048. doi: 10.2174/1381612825666181206123828.

Kuo, Tsung-Ting, Hyeon-Eui Kim, and Lucila Ohno-Machado. 2017. "Blockchain distributed ledger technologies for biomedical and health care applications". Journal of American Medical Informatics Association 24.6: 1211-1220. doi: 10.1093/jamia/ocx068.

Lancaster, Alaina. 2020. "Microsoft, Google and Amazon Face Privacy Suit Over Biometrics". July 15, Law.com.

Landis-Lewis, Zach, Ronald Majomo, Oliver J. Gadabu, et. al. 2015. "Barriers to using eHealth data for clinical performance feedback in Malawi: A case study". Int J Med Inform 84.10: 868-75. doi: 10.1016/j.ijmedinf.2015.07.003.

Meessen, Bruno. 2018. "The role of digital strategies in financing health care for Universal Health Coverage in low- and middle-income countries". Global Health Science and Practice 6(Suppl 1): S29-S40. doi: 10.9745/GHSP-D-18-00271.

Mekuria, L.A., T.F. Rinke de Wit, N. Spieker, et. al. «Analyzing data from the digital healthcare exchange platform for surveillance of antibiotic prescriptions in primary care in urban Kenya: A mixed-methods study". PloS One 14.9: e0222651. doi: 10.1371/journal.pone.0222651.

Muller, Nadine, Peter Martin Ferdinand Emmrich, Elsa Niritiana Rajemison, et. al. 2019. «A mobile health wallet for pregnancy-related health care in Madagascar: Mixed-methods study on opportunity and challenges". JMIR Mhealth Uhealth 7.3: e11420. doi: 10.2196/11420.

Nazdeek. 2018. Women lead the way: Monitoring and improving government services and facilites in Delhi. NGO report. Available at: https://indd.adobe.com/view/24c15fa2-2e91-46cc-b6ec-01e67c6c715b.

openIMIS. "Tanzania". Web page. No date, accessed 26 August 2020. https://www.openimis.org/tanzania.

Popper, Nathaniel. 2017. "Identity thieves hijack cellphone accounts to go after virtual currency". The New York Times, August 21. https://www.nytimes.com/2017/08/21/business/dealbook/phone-hack-bitcoin-virtual-currency.html?referringSource=articleShare.

Rhoads, Daniel D., Blaine A. Mathison, Henry S. Bishop, et. al. 2016. "Review of telemicrobiology". Arch Pathol Lab Med 140.4: 362-70. doi: 10.5858/arpa.2015-0116-RA.

Ross, Jamie, Fiona Stevenson, Rosa Lau, and Elizabeth Murray. 2016. « Factors that influence the implementation of e-health: A systematic review of systematic reviews (an update)". Implement Sci 11.1: 146. doi: 10.1186/s13012-016-0510-7.

Rosser, Jr., James C., Vudatha Vignesh, Brent A. Terwilliger, and Brett C. Parker. 2018. "Surgical and medical applications of drones: A comprehensive review". Journal of the Society of Laparoscopic & Robotic Surgeons 22.3: e2018.00018. doi: 10.4293/JSLS.2018.00018.

Sava, Dario. 2020. "Google Cloud AI and Harvard Global Health Institute Collaborate on new COVID-19 forecasting model". August 3, Google Cloud Platform. https://cloud.google.com/blog/products/ai-machine-learning/google-cloud-is-releasing-the-covid-19-public-forecasts.

Shaban-Nejad, Arash, Martin Michalowski and David. L. Buckeridge. 2018. Health intelligence: how artificial intelligence transforms population and personalized health. npj Digital Med 1, 53 (2018). https://doi.org/10.1038/s41746-018-0058-9.

Smith, S., R. Koech, D. Nzorubara, et. al. 2019. "Connected diagnostics: Linking digital rapid diagnostic tests and mobile health wallets to diagnose and treat brucellosis in Samburu, Kenya". BMC Med Inform Decis Mak 19.1: 139. doi: 10.1186/s12911-019-0854-4.

Tack, Philip, Jan Victor, Paul Gemmel, and Lieven Annemans. 2016. "3D-printing techniques in a medical setting: A systematic literature review". Biomed Eng Online 15.1: 115. doi: 10.1186/s12938-016-0236-4.

Tapscott, Don and Alex Tapscott. 2016. Blockchain revolution. London: Penguin Books.

Thomson, Michael, Alexander Kentikelenis and Thomas Stubbs. 2017. "Structural adjustment programmes adversely affect vulnerable populations: A systematic-narrative review of their effect on child and maternal health". Public Health Reviews 38: 13. https://doi.org/10.1186/s40985-017-0059-2.

Till, Brian M., Alexander W. Peters, Salim Afshar, and John G. Meara. 2017. "From blockchain technlogy to global health equity: Can cryptocurrencies finance universal health coverage?" BMJ Global Health 2.4: e000570. doi: 10.1136/bmjgh-2017-000570.

Tsui Fu-Chiang, Jeremy U. Espino, Virginia M. Dato, et. al. 2003. "Technical description of RODS: A real-time public health surveillance system". Journal of American Medical Informatics Association 10(5): 399-408. doi: 10.1197/jamia.M1345.

USAID. 2018. Artificial intelligence in global health: Defining a collective path forward. Report, USAID and The Rockefeller Foundation.

Vaona, Alberto, Rita Banzi, Koren H. Kwag, et. al. 2018. "E-learning for health professionals". Cochrane Database of Systematic Reviews 1.1: CD011736. doi: 10.1002/14651858.CD011736.pub2.

West, Darrell M. and John R. Allen. 2018. "How artificial intelligence is transforming the world". Brookings, April 24. https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/.

World Health Organization (WHO). 2019. Recommendations on Digital Interventions for Health System Strengthening. https://apps.who.int/iris/bitstream/handle/10665/311941/9789241550505-eng.pdf?ua=1.

-- 2018. Classification of Digital Health Interventions v1.0. WHO/RHR/18.06. https://www.who.int/reproductivehealth/publications/mhealth/classification-digital-health-interventions/en/.

-- 2018. Digital technologies: Shaping the future of primary health care. WHO/HIS/SDS/2018.55. https://www.who.int/docs/default-source/primary-health-care-conference/digital-technologies.pdf?sfvrsn=3efc47e0_2(accessed.

-- 2017. Policy on use and sharing of data collected in Member States by the World Health Organization (WHO) outside the context of public health emergencies (Provisional). 22 August. https://www.who.int/docs/default-source/publishing-policies/who-data-sharing-policy-collected-by-member-states-outside-of-public-health-emergencies61d03608e6134ba786ad94403e947013.pdf?sfvrsn=bb52b31d_26.

- 2016. Global diffusion of eHealth: Making universal health coverage achievable. Report of the third global survey on eHealth. https://apps.who.int/iris/bitstream/handle/10665/252529/9789241511780-eng.pdf?sequence=1.

- 2015. WHO compendium of innovative health technologies for low-resource settings. https://apps.who.int/iris/handle/10665/202537.

-- 2015. The MAPS toolkit: mHealth assessment and planning for scale. https://apps.who.int/iris/bitstream/handle/10665/185238/9789241509510_eng.pdf?sequence=1.

-- 2014. Early detection, assessment and response to acute public health events: implementation of Early Warning and Response with a focus on Event-Based Surveillance. Interim version. Lyon. https://www.who.int/ihr/publications/WHO_HSE_GCR_LYO_2014.4/en/

- 2012. National eHealth strategy toolkit. https://apps.who.int/iris/bitstream/handle/10665/75211/9789241548465_eng.pdf;jsessionid=A0D4BFBF37E2C20F6CF722BBDD15BF0D?sequence=1.

- 2011. mHealth: New horizons for health through mobile technologies. https://www.who.int/goe/publications/goe_mhealth_web.pdf.

Joep Lange Institute
Paasheuvelweg 25, Tower C4
1105 BP Amsterdam Zuidoost
The Netherlands