Digital health: addressing modern healthcare challenges with sensors

Digital technology is playing an increasingly critical role in modern healthcare. As society faces new healthcare challenges – including a rise in chronic diseases and an aging population – public health will increasingly benefit from the growing role of digital technology.

In this article, we explore the big questions surrounding digital health: Why does modern society need digital health? And how is digital health organized and implemented? Finally, we focus on sensing technologies driving the implementation of digital health.

Modern health challenges: a driver for digital health?

Globally, healthcare providers are dealing with an increase in the incidence of noncommunicable diseases such as cardiovascular diseases, cancers, diabetes and chronic respiratory diseases such as chronic obstructive pulmonary disease (COPD) and asthma.

On the one hand, this is a result of reducing deaths from infectious diseases such as tuberculosis. Nonetheless, as noted by the World Health Organization, noncommunicable diseases pose devastating health consequences and socioeconomic effects, which make their control a major challenge that needs to be addressed.[4]

The occurrence of such diseases is increasing with the aging population. As birth rates decline and healthcare improves in many regions, the World Health Organization estimates that the proportion of the world's population over 60 will almost double by 2050. The aging population requires global health, activity, and medication monitoring. Hospital stays are costly and increase the risk of infections; therefore, drug delivery in a homecare setting, and perhaps remote monitoring, is expected to reduce healthcare costs and improve outcomes.[5]

At the same time, environmental conditions are amplifying some of the diseases mentioned above. The increase of ultrafine particles due to urban traffic, industrial processes, pollution and increasing wildfires worldwide are worsening environmental conditions for patients with asthma and COPD, as well as being linked to diseases such as cancer and even dementia.

Digital health plays a vital role in helping our healthcare systems evolve and meet these challenges. Digital health undeniably plays a major role in modern healthcare: digital technology is embedded within global healthcare, from online appointment booking to continuous glucose monitors to digitizing patient records. Many of these provisions – such as virtual platforms and video call appointments – were expedited during the COVID-19 pandemic, as necessity pushed through years' worth of reforms in the space of just a few months.[6]

Following this recent push, the infrastructure of digital health is now being defined and consolidated by governments, healthcare providers and industrial partners.

How is digital health organized and implemented?

"Digital health" is a broad, all-encompassing term for the application of digital technology to healthcare. Organization of healthcare services (for example, digital real-time patient data management, medical act management and billing tools) is one of the key ways in which digital health is currently implemented.

However, digital health means more than just this. Arising applications of digital health include new types of medical devices (such as drug injection devices) that implement new monitoring and diagnostic functions.[7] These medical devices are placed close to the patient, often as wearable (such as an insulin pump) or hand-held devices (such as smart inhalers). Moreover, new well-being devices such as smart watches, sleep monitors, and breath analyzers deliver additional health-relevant information.

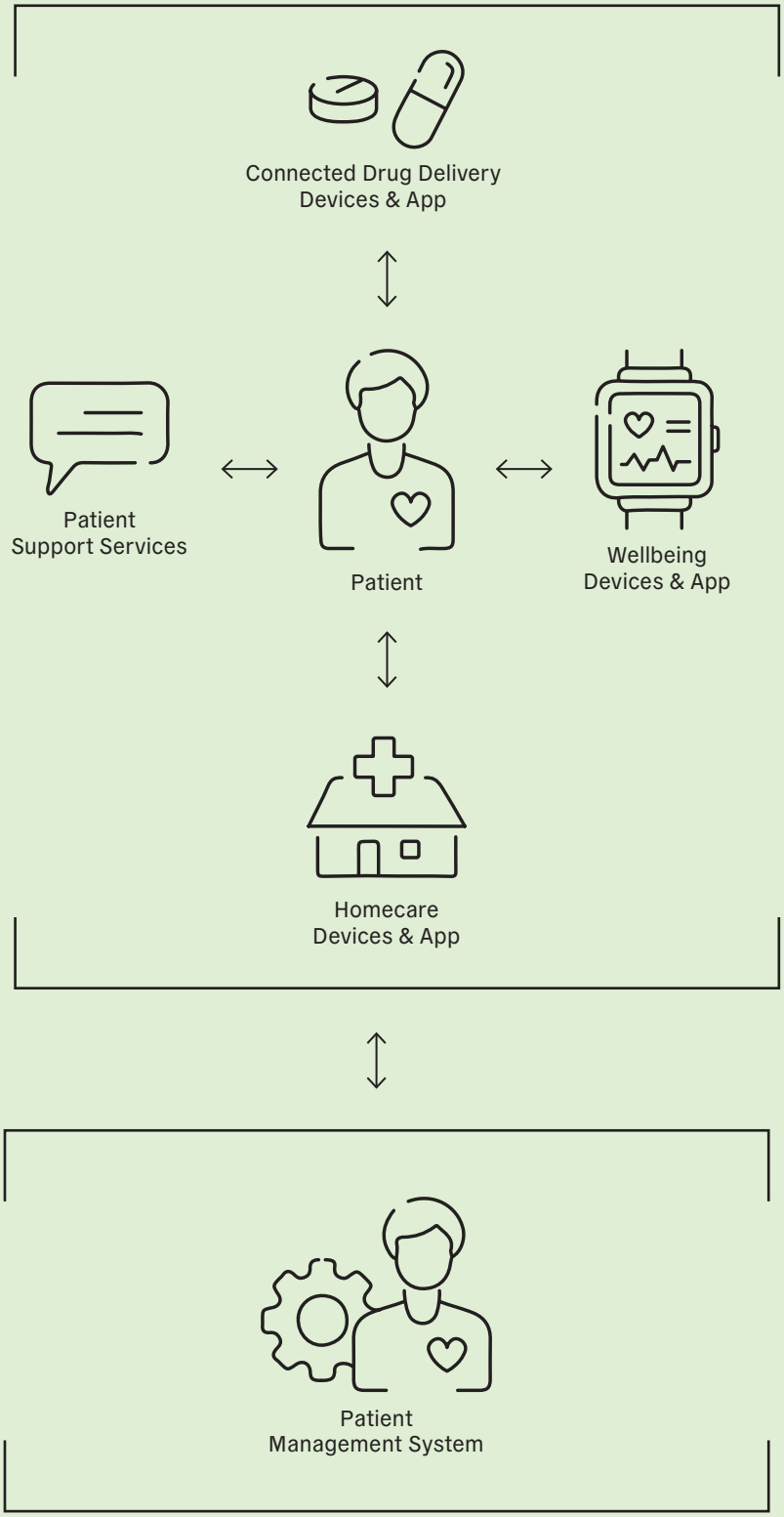

Figure 1: Relationship between the patient, various healthcare apps, patient support services and the patient management system.

At the patient level, digital health enables health-relevant information to be shared directly between the patient and connected drug delivery devices, wellbeing devices, homecare devices and patient support services (Figure 1).

In turn; these devices, services and apps can transfer patient information to service providers where it can be stored and analyzed. Sharing this information with healthcare providers enables diagnoses, treatments and disease management procedures to be assessed, which can in turn be relayed to patient management systems and shared with payors (Figure 2).

The increased availability of health-relevant patient data can play an important role in drug development, enabling the realization of personalized therapy or drugs on a large and practical scale. Moving further along the healthcare value chain, connected medical devices make it easier for patients and caregivers to monitor healthcare and manage the therapies.

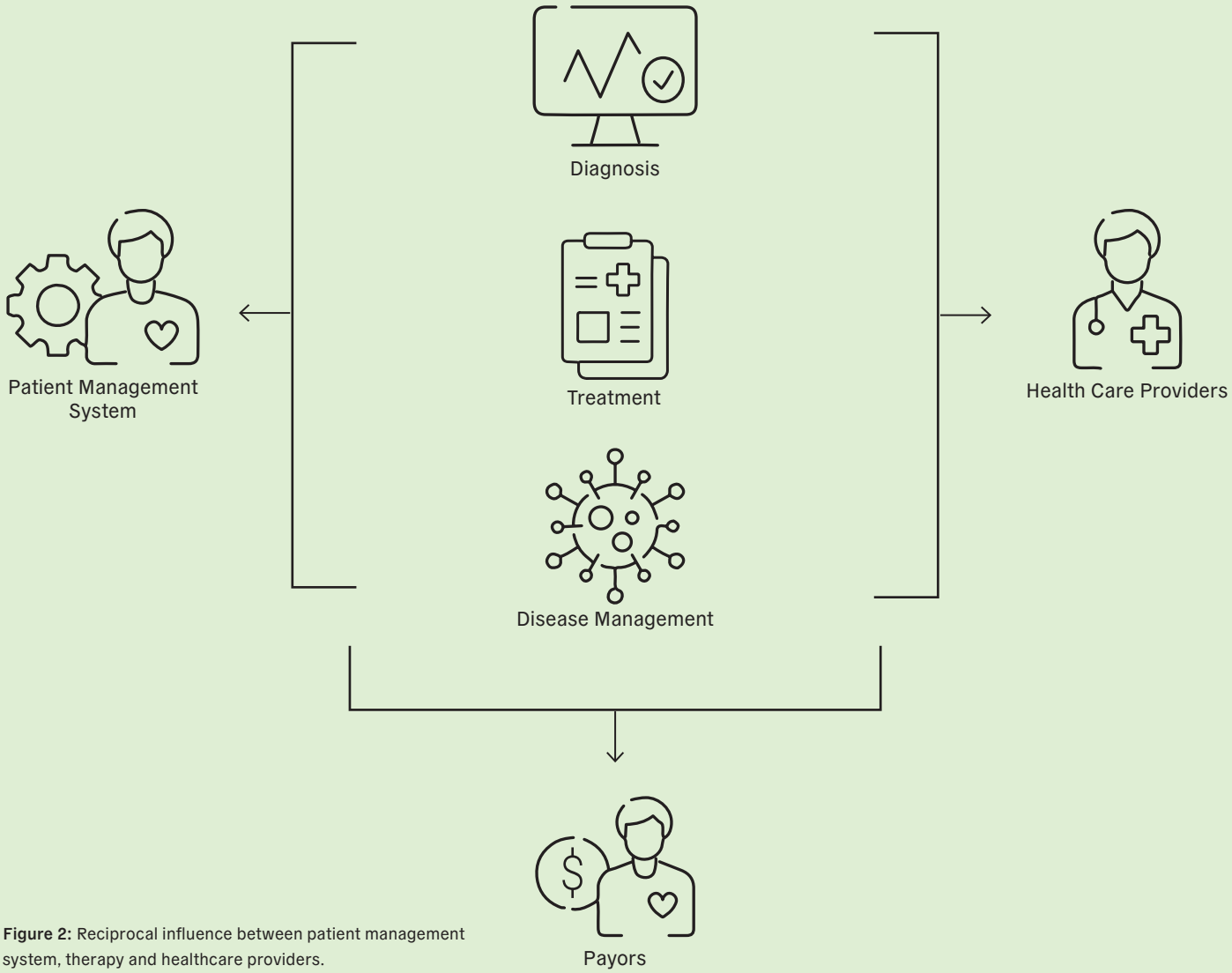

Figure 2: Reciprocal influence between patient management system, therapy and healthcare providers.

Clinical studies and research work have highlighted the potential of digital health technologies to reduce non-adherence.[8] Non-adherence to asthma treatment is a major issue that causes exacerbation, hospitalization, and high financial costs. However, patients using the next generation of smart inhalers can monitor the quality of their inhalation, obtain feedback on the drug delivery efficiency and even on the course of the disease. The adherence of these patients could be significantly improved, leading to improved outcomes and lower healthcare costs.

Given the high value for the patient, partnerships are forming between pharma companies and technology companies around the world, resulting in the development of a spectrum of new drug delivery devices.[9] GSK, for example, recently partnered with Propeller Health to develop a digital inhaler; while AstraZeneca partnered with Adherium to bring an adherence monitor to market to support AstraZeneca's Turbuhaler medication.[10,11]

The implementation of digital health is also being supported by governments. New legislation – such as DiGA in Germany and Article 51 in France – lays the foundations for digital health by supporting new care pathways like doctors' prescription of digital health apps.[12,13] Also, the extended definition of remote patient monitoring in the USA with additional Current Procedural Terminology (CPT®) codes since 2022 is further advancing the utilization of connected devices.[14] These devices enable monitoring of non-physiological information to help assess patient adherence to a prescribed therapy: for example, by determining whether patients are following their care regimen and how effectively the therapy is working. This helps us recognize the likelihood of potential failures of patient adherence and allow us to make the appropriate adjustments.

The successful implementation of new digital health technologies – such as these drug delivery systems or smart inhalers – relies not only on software solutions but also on developing new measurement and feedback solutions. Such new solutions are most powerful if they can interact with the patient by collecting data, analyzing it and providing feedback to the patient and the healthcare provider. This is where the right sensors provide a strong value proposition by collecting usage, safety, and diagnostic data.

"Digital Health is the field of knowledge and practice associated with the development and use of digital technologies to improve health."[1]

Definition by the World Health Organization

Sensing solutions

What are the benefits for the patient?

The nature of the interaction between a patient and a wearable device comes down to the sensor. Choosing an optimal sensor solution can be challenging from a design perspective as it must fulfill its intended function and seamlessly integrate into the patient's user experience. On its path towards digital health, Sensirion has thus far developed different sensing technologies. In the following sections, we will focus on three of them.

Air flow sensing

Smart inhaler add-ons are medical devices that bring additional functionality to regular inhalers by gathering information about inhaler usage. This information can easily be transmitted to a smartphone application and provide patients and caregivers with insights into inhaler usage. This information can contain details on the patient's adherence to therapy as well as details on how the inhaler is operated, such as exhaled volume, inhaled volume, and a detailed inhalation flow profile containing inhaled flow rate over time including the timing of inhaler actuation. This feedback allows the caregiver to recognize patients who poorly adhere to the therapy or who urgently require additional training on correct inhaler use. The significance of the problem is highlighted by countless studies. A study on in-vitro lung deposition for example reported that patients make at least one mistake when using an inhaler as often as 70–90% of the time, resulting in only 7–40% of the drug being delivered to the lung16.

The feedback to the patients that they are using the inhaler correctly can be motivational and affirmative. Also, it can put the worried minds of parents regarding their children using an inhaler to rest as it confirms the correct use and dose reaching the lungs. Recording physiological inhaler usage data with every use of the inhaler and without interfering with the patient's user experience is a powerful tool and recent studies have demonstrated that the collected data relating to peak-inspiratory flow or inhaled volume already provide an information base able to assess the course of the disease, improve its control and prevent exacerbation and hospitalization[17]. Gathering accurate physiological data on every inhaler-breath taken will help to unlock many more insights and generally improve inhaler-based therapies in the future.

Air flow sensors are an essential part of smart inhalers. Sensirion's SDP3x line of differential pressure sensors is optimized for air flow sensing in smart inhalers and allows for sensitive and accurate measurement of air flow rate while offering other benefits for healthcare applications:

- Immediate feedback on the inhalation procedure due to direct and fast measurement.
- Meaningful feedback and improved patient confidence and usage of the inhaler by accurate inhalation-to-inhalation and breath-profile comparison, enabled by high accuracy and time resolution.
- Monitor the course of the disease over time, predict and prevent exacerbations by measuring and monitoring lung function parameters from the recorded breath profile.
- Seamless user experience by allowing small form factors due to the small size of the sensor and the low power consumption of a coin cell.
- Robust and unsusceptible to environmental conditions and user errors thanks to the two-port design and operation of a coin cell beyond one year.
- Enables breath-triggered drug release by providing fast response time and high sensitivity for even the smallest flows.

Drug flow sensing

Large-volume injectors (LVI) – also known as on-body delivery systems, patch pumps or wearable drug-delivery devices – have been replacing conventional intravenous infusion with wearable automated subcutaneous injection devices.15 These enable patients to receive precisely controlled drug dosages automatically, continuously, and with minimal disruption to their day-to-day lives.

LVI systems enable the application of "red biotechnology" approaches, which make use of biological materials such as proteins and large molecules to treat disease targets more effectively than existing pharmaceuticals and with fewer side effects. Typically, these therapeutics are expensive, viscous, highly concentrated formulations, often requiring lyophilization (freeze-dried) and reconstitution prior to use. This means that they generally cannot be administered orally; instead, requiring subcutaneous or parenteral (IV) administration in large volumes of up to 50 ml. LVIs provide a simple, versatile platform for the administration of these emerging therapeutics.

In addition, LVIs will play a vital role in the delivery of precision medicine for predictive, preventative, personalized and participatory patient care. With prices and reimbursement levels based on evidence-based criteria, such therapies will likely depend on proof of patient compliance – LVIs provide a straightforward and measurable approach to ensuring adherence, thus maximizing the efficacy of personalized therapies.

Controlling flow rate and closely monitoring for failures is critical in automatic drug delivery systems. Sensirion's LD20 liquid flow platform of single-use flow rate sensors offer a dedicated solution for LVIs:

Controlling flow rate and closely monitoring for failures is critical in automatic drug delivery systems. Sensirion's LD20 liquid flow platform of single-use flow rate sensors offer a dedicated solution for LVIs:

- Precise measurement of the delivered drug with high accuracy is essential when the dosage is critical for the patient, such as with specific painkillers or chemotherapy drugs. It is also desirable with expensive, viscous, or highly concentrated formulations such as some oncologic treatments. Accurately measuring the flow with the LD20 technology platform enables a reliable assessment of the remaining drug inside the cartridge and can become more important as prices and reimbursement levels start to become reimbursed based on evidence-based criteria such as proof of correct drug delivery and patient compliance.
- Detection of failure mechanisms such as open flow and occlusion is another valuable feature. As a matter of fact, wearable LVIs are very close to the patient and occlusion may happen for various reasons such as tissue growth or clotting of the cannula outlet. In some cases, the patient may mistake the assembly of the parts of the LVI or the reconstitution of the drug, leading to an open flow condition. The remote detection of such failures assists the patient, improves the patient journey, and maximizes the benefits of the therapy while helping save costs by enabling remote drug administration.
- Flow range, size and interfaces are adjustable for very compact integration into the LVI due to the modularity of the LD20 technology platform. This is an essential feature to address the versatility of the drug delivery systems depending on the drug type, concentration, and viscosity while keeping the system as compact as possible, so that the wearable device does not impact the physical and social comfort of the patient.
- Sensor compatibility with different drugs is essential, enabling the use of a single device platform for different drugs and for the reconstitution of lyophilized drugs. This feature is enabled by our in-house sensor calibration for one or more drugs, taking their different viscosities and properties into account.

Breath analysis

Breath analysis provides a non-invasive insight into the human body allowing for fast, pain-free and low-cost diagnostics. Today this mainly covers gases such as CO_2, O_2, acetone, NO, as well as other gases being investigated by medical research teams around the globe.

Sensirion's STC31 platform allows for the measurement of CO_2 concentration in the challenging environment of human breath. As opposed to optical type sensors which are used in capnography applications and often in the lower 4-digit price range, the STC31 platform enables entirely new applications with its low-cost technology structure. Applications in both medical and consumer sectors bring value to the user by providing measurement-based insight into their own metabolism or fitness.

- Easy solution for a compact integration of the STC31 into portable medical devices with the compact form factor. This allows for discrete and portable products that can be used in all environments, such as at home, outdoors, or in the gym.
- Improved user experience by highly robust and reliable sensing solution as there are no moving parts or sensitive optics involved. No complex assembly or alignment during manufacturing further helps to save on the cost and form factor side.
- New applications and use cases in compact and discrete portable devices that only require small batteries and allow for longer run times without the need for charging.

The 21st century has brought a number of completely new healthcare challenges: increasing numbers of chronic diseases, including cancer, COPD, asthma, and diabetes in an aging population; and broad changes to both environment and lifestyle that amplify the occurrence, consequences and cost of such diseases. Digital health infrastructure recently received a major push forward to address the healthcare challenges. It not only automatizes sharing patient data, accessing sites of care and simplifying the payment flow. It will also further empower patients in everyday life to monitor their own health from their homes, get their drugs administered without a healthcare provider required to be present, and obtain feedback on drug delivery and the course of the disease. Such functions are implemented and enabled by portable, wearable and interactive devices that use sensors to monitor the patient. Sensirion is actively supporting this developing ecosystem with sensors built to address these needs: measuring patient air flow, drug flow and patient breath gases. As this journey has only just begun, we are working to extend the technologies and sensors offered in digital health. To find out more about any of our products, get in touch with Sensirion today.

References

1. Global Strategy on Digital Health 2020-2025 | World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/344249/9789240020924-eng.pdf.

2. Covid-19 Created an Elective Surgery Backlog. How Can Hospitals Get Back on Track? https://hbr.org/2020/08/covid-19-created-an-elective-surgery-backlog-how-can-hospitals-get-back-on-track.

3. Ham, C. The challenges facing the NHS in England in 2021. BMJ 371, m4973 (2020).

4. Noncommunicable diseases. https://www.who.int/health-topics/noncommunicable-diseases.

5. Ageing and health. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.

6. PricewaterhouseCoopers. Global Top Health Industry Issues 2021. PwC https://www.pwc.com/gx/en/industries/healthcare/top-health-industry-issues.html.

7. Dossier: Medizin der Zukunft. https://www.handelsblatt.com/technik/dossier-zum-download-dossier-medizin-der-zukunft/24958036.html.

8. Alsumidai, M. Non-Adherence: A Direct Influence on Clinical Trial Duration and Cost. Applied Clinical Trials (2017).

9. Exciting Partnerships Forming Between Big Pharma and Tech. Pharmacy Times https://www.pharmacytimes.com/view/exciting-partnerships-forming-between-big-pharma-and-tech.

10. Ricci, M. GSK and Propeller prepare to launch digital inhaler -. https://pharmaphorum.com/news/gsk-propeller-health-expand-rd-partnership/ (2017).

11. Adherium. Adherium - Adherium Releases Next Generation Adherence Monitor, SmartTurbo Model 4, for AstraZeneca's Turbuhaler. Adherium https://www.adherium.com/news/adherium-releases-next-generation-adherence-monitor-smartturbo-model-4-for-astrazeneca-s-turbuhaler/.

12. Why Germany's DiGa is the future of Digital Health. Why Germany's DiGa is the future of Digital Health https://vertrical.com/.

13. Townsend, A., de Trogoff, H., Szwarcensztein, K., & participants of Giens XXXIV Round Table "Health and economy". Experimentation to favor innovation: Promoting the success of Article 51 transformation projects. Therapie 74, 51–57 (2019).

14. Remote Therapeutic Monitoring (RTM) Codes | CareSimple. https://caresimple.com/remote-therapeutic-monitoring-rtm-codes/ (2022).

15. Liquid flow sensors for drug delivery. https://sensirion.com/products/product-insights/specialist-articles/subcutaneous-drug-delivery/.

16. Biswas R, Hanania NA, Sabharwal A, "Factors Determining In Vitro Lung Deposition of Albuterol Aerosol Delivered by Ventolin Metered-Dose Inhaler". J Aerosol Med Pulm Drug Deliv, 2017, Vol 30(4), pp 256–266.

17. Levy ML, et al., Presented at ERS 2020. Abstract in ERJ 2020;56:1361