How AI can enhance the human experience in healthcare

Position paper

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A note on terminology

This position paper and the examples included in it follow the definition of artificial intelligence (AI) from the EU High-Level Expert Group:

"Artificial intelligence (AI) systems are software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal."

Source: EU High-Level Expert Group

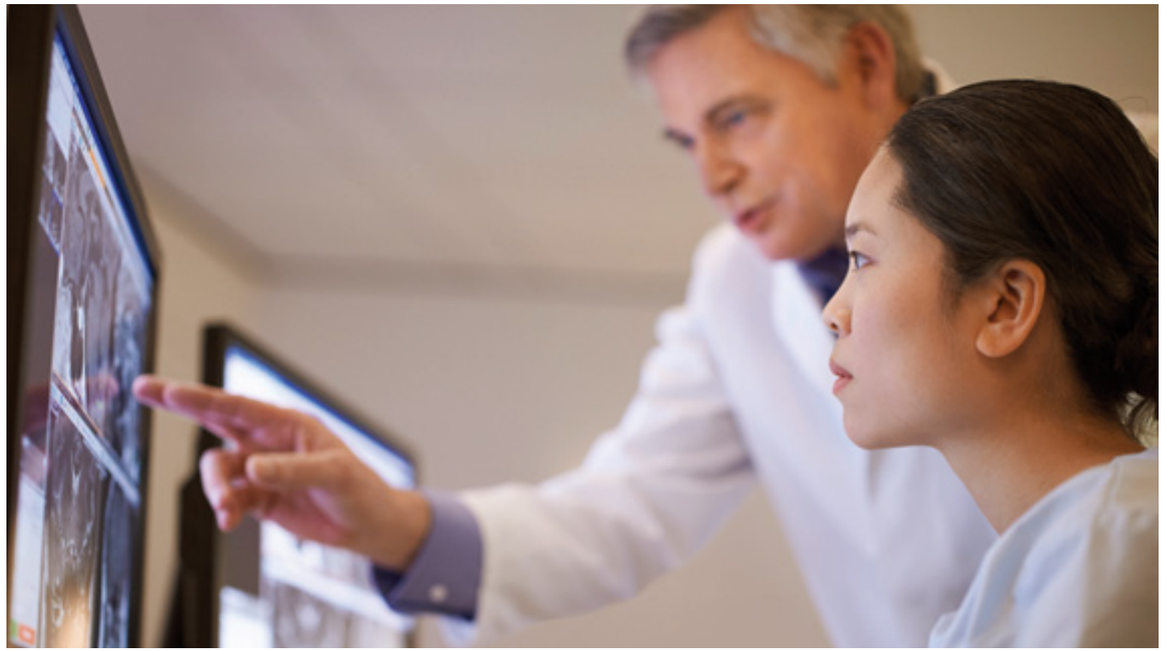
Executive summary

In recent years, Artificial Intelligence (AI) has burst onto the scene in healthcare, propelling new innovations that promise to improve patient care and outcomes while reducing costs. But unlike some of the hype suggests, AI is not a solution in and of itself. At Philips, we believe the value of AI in healthcare is only as strong as the human experience it supports – calling for a people-centric approach that puts healthcare professionals and patients front and center.

From diagnostics to acute patient monitoring and self-management of chronic disease, AI has shown strong potential to support healthcare providers and patients at every stage of the care continuum. But for AI-enabled solutions to take hold, they need to integrate into the workflows of healthcare professionals and people's daily health routines. And only by combining AI with deep clinical knowledge can we glean the most relevant insights from data that truly make a difference at the point of care. That's why healthcare professionals and patients need to be at the heart of AI innovation in healthcare.

We envision three ways in which AI can enhance the human experience in healthcare:

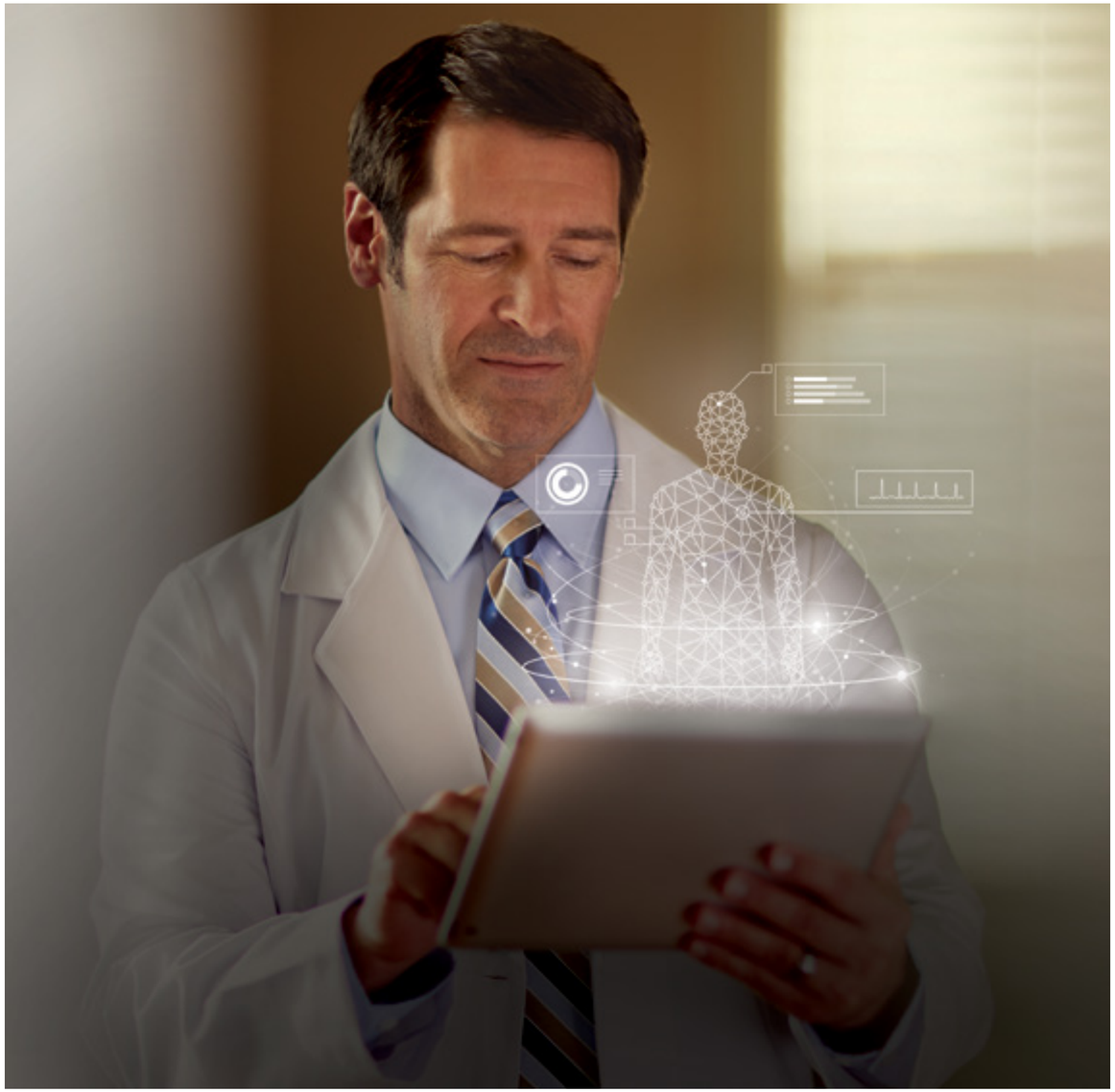
- **AI can augment the expertise of healthcare providers and support their decision-making**, allowing them to do what they do best: detect, diagnose, treat, and monitor disease. For example, AI can aid radiologists, cardiologists and other specialists with the segmentation and quantification of medical images, for enhanced diagnostic confidence and consistency. AI can also enable acute care teams to keep a caring eye on patients and spot early signs of health deterioration, based on an analysis of multiple vital signs, for timely intervention and reduced risk of readmission.
- **AI can improve operational efficiency to help healthcare providers focus on patient care**. For example, workflow automation in radiology can alleviate the burden on time-pressured imaging technologists, allowing them to focus on obtaining optimal image quality. AI can also enable predictive maintenance of medical equipment to prevent avoidable and costly disruptions that frustrate staff and patients alike. And on an enterprise level, AI can help forecast and manage patient flow from admission to discharge, ensuring the right care gets delivered in the right place at the right time.
- **AI can empower people to take better care of their health and well-being** by offering personalized and actionable insights that help them develop and maintain healthy habits. For example, in oral healthcare, AI can analyze an individual's brushing behavior through sensors embedded into a smart toothbrush, and – through a mobile app – offer personalized recommendations for improving one's oral hygiene. Similarly, AI can motivate people with chronic disease to take an active role in their therapy, promoting a shift from reactive to preventative care.



To deliver on the promise of AI in healthcare at scale, we outline four enabling areas that can help guide the way from AI development to AI adoption:

- **People and experiences**
  Following the principles of human-centered design, AI-enabled solutions should support healthcare providers and patients in their workflows or routines, using intuitive interfaces that create frictionless experiences. In addition, training and education is essential in helping both today's and tomorrow's healthcare professionals get the most out of AI, with an appropriate understanding of its strengths and limitations.
- **Data and technology**
  Developing AI-enabled solutions relies on access to high-quality, properly annotated data. But today's healthcare data tends to be siloed and medical systems often do not speak the same language. Cloud-based digital platforms using open data standards can help lay the foundations for increased data sharing across settings, as well as rapid deployment of AI innovation. Next-generation AI methods such as federated learning and hybrid modelling using synthetic data can also help address challenges around data access.
- **Governance and trust**
  Trust is paramount for promoting wider adoption of AI, calling for clearly established guidelines and guardrails that govern its usage and that prevent unintended consequences such as bias. At Philips, we are committed to the safe and responsible use of data in general, and of AI in particular, as captured in our Data and AI Principles.
- **Partnerships and new business models**
  Healthcare providers and payers are increasingly seeking integrated end-to-end solutions. That means ecosystem collaboration is critical. New business models such as SaaS-based software marketplaces can help accelerate adoption of AI, allowing healthcare providers to implement AI applications into their workflows in a flexible and cost-efficient way, without having to worry about point-to-point integrations.

By addressing each of these four enabling areas in a concerted way, always with the needs of healthcare providers and patients in mind, we can deliver on the full promise of AI in healthcare – for better health outcomes, lower cost of care, and improved patient and staff experience.



Why AI in healthcare matters

The need for AI in healthcare has never been felt more strongly. Healthcare systems are struggling to meet growing demand as chronic diseases are on the rise, while advances in digital technology are enabling the capture of more data than ever before – requiring solutions that can assist healthcare professionals and patients in making sense of all that data.

The numbers paint a clear but sobering picture: healthcare systems around the world are on an unsustainable trajectory. Today, one in three adults suffer from one or more chronic diseases such as heart disease, cancer, or diabetes[1]. With populations growing and aging around the world, healthcare systems will have to care for an ever-increasing number of patients with complex needs. For example, in 2020, about 19.3 million cases of cancer were reported – a number that is projected to increase to 30.2 million by 2040[2]. Global healthcare spending is projected to double in that same time period, urging providers and payers to seek more effective and efficient ways of preventing, detecting, diagnosing and treating disease[3].

Without the support of digital health technology and AI, healthcare systems will not be able to keep pace or remain financially sustainable. Patient demand already outstrips supply in many areas of healthcare – a gap that will only widen. The World Health Organization estimates that by 2030 there will be a global deficit of 18 million skilled healthcare professionals[4].

Growing burnout

Physicians and staff are paying a heavy toll. Ever-increasing patient demand, coupled with a steady rise in administrative duties and declining reimbursements, means they are under constant pressure to do more with less. Medical professions like radiology have seen their workloads steadily increase over the decades, with radiologists now having to read 50-100 studies per day[5]. Critical care teams in many hospitals were already stretched to the limit before COVID-19 hit[6]. Unsurprisingly, a 2021 Medscape survey revealed that 42% of healthcare professionals report feeling burned out, with the mental and physical reverberations of the pandemic adding to the strain for many[7].

Healthcare systems face an unsustainable burden

1 in 3

adults worldwide suffer from one or more chronic diseases

World Health Organization

42%

of healthcare professionals report feeling burned out

Medscape survey 2021

18 million

the expected global deficit of skilled healthcare professionals by 2030

World Health Organization

2x

global healthcare spending is projected to double between 2020 and 2040

World Health Organization

Shifting patient expectations

While healthcare professionals struggle to keep up with rising workloads, patient expectations of healthcare are shifting. Having grown accustomed to the convenience and customization of online shopping and banking, patients expect more personalized experiences[8]. They are also showing a growing appetite for digital technology that helps them engage in their own health and care, while staying connected to healthcare professionals remotely – a trend that has been accelerated by the pandemic[9]. This opens opportunities for a more preventative approach to healthcare that could ease the strain on healthcare systems in the long run. Yet today, only a fraction of healthcare expenditure is spent on prevention, ranging from a paltry 1.8% in Australia to 2.8% in the US and 3.0% in Europe[10].

Taken together, these trends are prompting healthcare providers to ask questions such as:

- How can we detect conditions like cancer and heart disease earlier?
- How do we improve the rate of fast and accurate first-time-right diagnosis?
- How can we streamline hospital operations to provide better care at lower cost?
- How can we reduce burnout and ensure that staff spend their time where it adds most value?
- How can we offer patients more convenient ways of engaging in their own care at home?

An explosion of data

At the same time, digital transformation is driving an exponential growth of data, including electronic health records, imaging studies, pathology data, genomics, and vital signs measurements. In addition to these episodic snapshots of a patient's health and condition(s), emerging technologies like wearable sensors, remote patient monitoring, and patient-reported outcomes are creating more continuous streams of patient data.

While all this information offers tremendous opportunities to develop a more holistic and longitudinal understanding of a patient's health, in daily clinical practice it can be more overwhelming than helpful. More data does not equal better understanding.

That's where the promise of AI comes in. With its ability to sift through and learn from large amounts of data, AI can lend healthcare providers and patients a helping hand. It's to this topic that we turn next, with concrete use cases that show AI is already having a positive impact on patient care today.

By 2025, the amount of healthcare data is expected to grow by 36% per year[11]

- Medical imaging
- Patient monitoring
- Home monitoring
- Pathology
- Genomics
- Personal health tracking

How AI can enhance the human experience in healthcare

With AI, we can help people take better care of their health and well-being, and enable healthcare professionals to do what they do best: prevent, diagnose, treat, and monitor.

A rapidly growing body of research has demonstrated how AI can have a wide range of useful applications in healthcare, such as the interpretation of chest X-rays, spotting cancer in mammograms, identifying brain tumors in MR images, and detecting arrhythmias in ECGs[12]. AI has also been used to inform cancer treatment recommendations based on a patient's genetic profile[13] and to predict the likelihood of complications in stroke treatment[14].

With those applications comes the promise of earlier detection of disease, more precise diagnosis, and more personalized treatment – supporting healthcare professionals and patients across the continuum of care. In addition, AI-enabled technology has shown potential in facilitating self-management of chronic disease at home, thereby improving quality of life and reducing the risk of hospital (re)admission[15].

In the next few chapters, we will discuss in more detail how AI can enhance the human experience in healthcare by:

Augmenting the expertise of healthcare providers and supporting their decision-making.

Improving operational efficiency to help providers focus on patient care.

Empowering people to take better care of their health and well-being.

Augmenting the expertise of healthcare providers

Clinical use cases of AI range from supporting image segmentation in radiology to helping identify early signs of patient deterioration in acute and post-acute care – helping healthcare providers perform at their best for better patient care.

The main strength of AI methods like deep learning is that they can detect, quantify, and classify even the subtlest of patterns in data. This makes them ideally suited to support pattern-centric medical disciplines like radiology, which face ever-mounting workloads coupled with growing staff shortages in many parts of the world.

AI can aid radiologists with time-consuming tasks such as image segmentation and quantification, saving them time and thereby enabling them to focus on higher-level interpretation of images. AI can also act as a second set of eyes, serving as an adjunct to the radiologist's decision-making by pointing them to areas of interest or incidental findings they may have overlooked – supporting greater confidence and consistency in diagnosis.

For instance, AI algorithms that scour MR images of the brain for subtle neurological changes over time have been shown to improve diagnostic accuracy in patients with multiple sclerosis by 44%, while reducing reading times[16]. As another example, AI-based lung nodule detection can perform nodule search 26% faster, detecting 29% of previously missed nodules compared to manual inspection[17]. For time-pressured radiologists who have to interpret more images than ever before, such AI-enabled support can make a meaningful difference, while also benefiting the patient.

Worklist prioritization is another area where AI can augment the radiology workflow. Based on an initial screening of images, AI can alert the appropriate subspecialist to critical findings that need urgent inspection, such as a pulmonary embolism. Radiologists remain in charge of diagnosis, but the most suspicious findings are brought to their attention first. As a result, radiologists have to spend less time manually prioritizing case load, while patients may benefit from faster diagnosis and intervention or treatment[18].

Similarly, in cardiology, AI can be used as a preliminary tool to screen images, potentially even partly auto-filling parts

Augmenting the expertise of healthcare providers

- **Image segmentation and quantification**
  For increased diagnostic confidence and consistency
- **Integrated diagnostics**
  For more precise and personalized care
- **Acute patient monitoring**
  For timely interventions and better patient outcomes

of reports for cardiologists to approve – saving them cumbersome manual work[19]. Already today, AI can assist cardiologists with diagnosis and help guide minimally invasive procedures, based on semi-automatic measurements of the anatomy and functioning of a patient's heart.

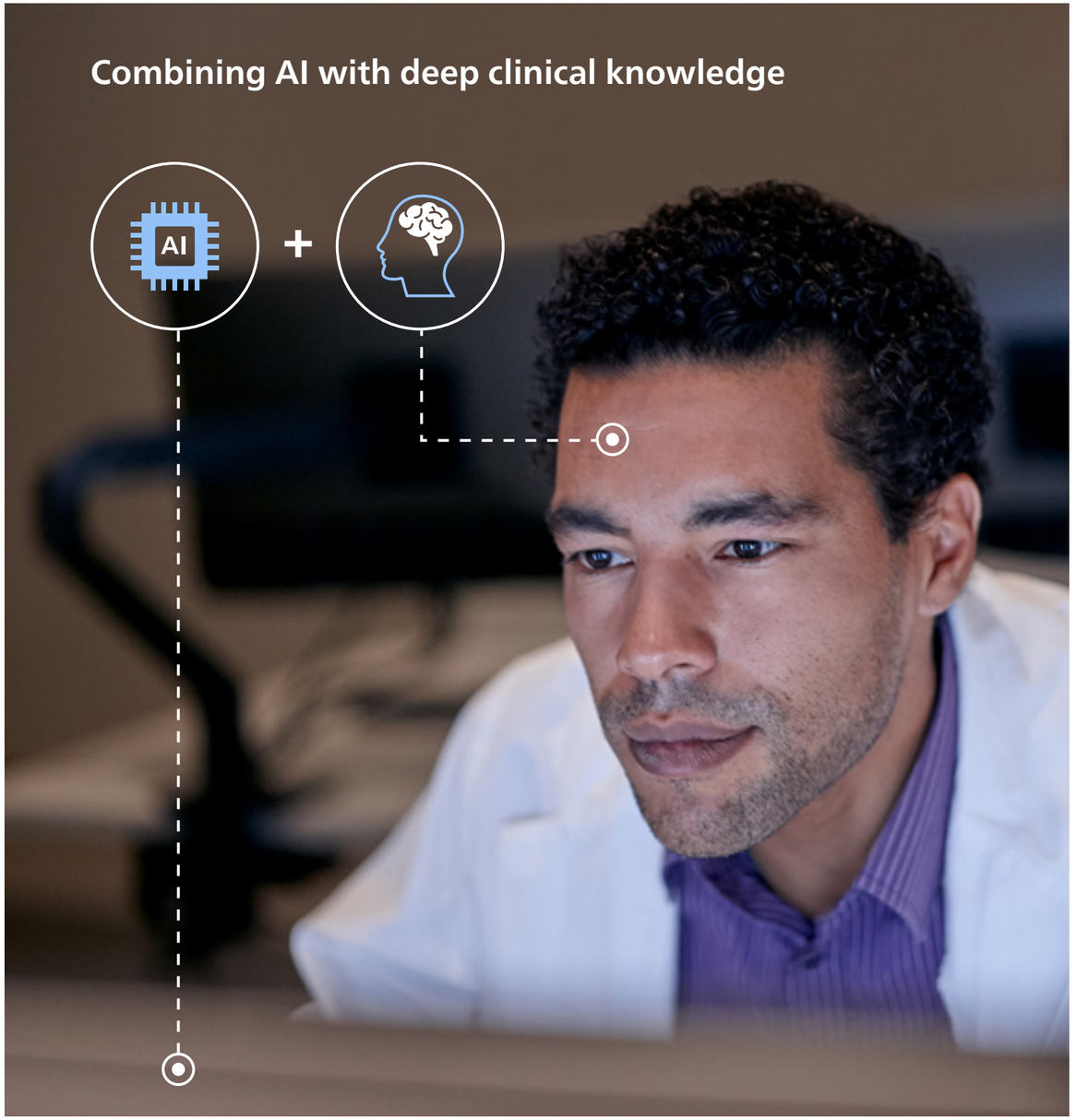
In addition, AI could help reduce unwarranted diagnostic variation in disciplines like pathology, where there can be marked disagreement between experts. Algorithms can point to regions of interest in tissue samples that demand further inspection, while making it easier to discard slides without signs of cancer[20]. Enabled by digital pathology, such algorithms can be trained on large numbers of high-resolution images of tissue samples to detect subtle patterns that may escape the human eye.

What these use cases have in common is that the pattern-detection capabilities of AI algorithms work in conjunction with, and help to elevate the expertise of the physician. It's not a matter of one replacing the other. It's their joint intelligence that counts. As recent studies have shown, coupling AI models with expert human judgment can lead to higher diagnostic accuracy than either physicians or AI could achieve on their own[21,22].

By augmenting human expertise, AI enables physicians to operate at the top of their license and deliver more value than they would be able to deliver without AI. This means specialists like radiologists and pathologists could start focusing more on higher-level diagnostic and consultative tasks, making their work even more impactful and rewarding.

"AI allows us to see more than we ever could with our own eyes. But deep learning is not deep understanding. For AI to have a meaningful impact on patient care, it needs to go hand in hand with with robust scientific insights and deep clinical knowledge."

Henk van Houten
Chief Technology Officer



AI in action

How AI can assist radiographers in acquiring high-quality X-ray images

Next to augmenting the expertise of radiologists in their interpretation of images, AI can also support the technologists who acquire the images – by giving them instant feedback that can help them improve image quality.

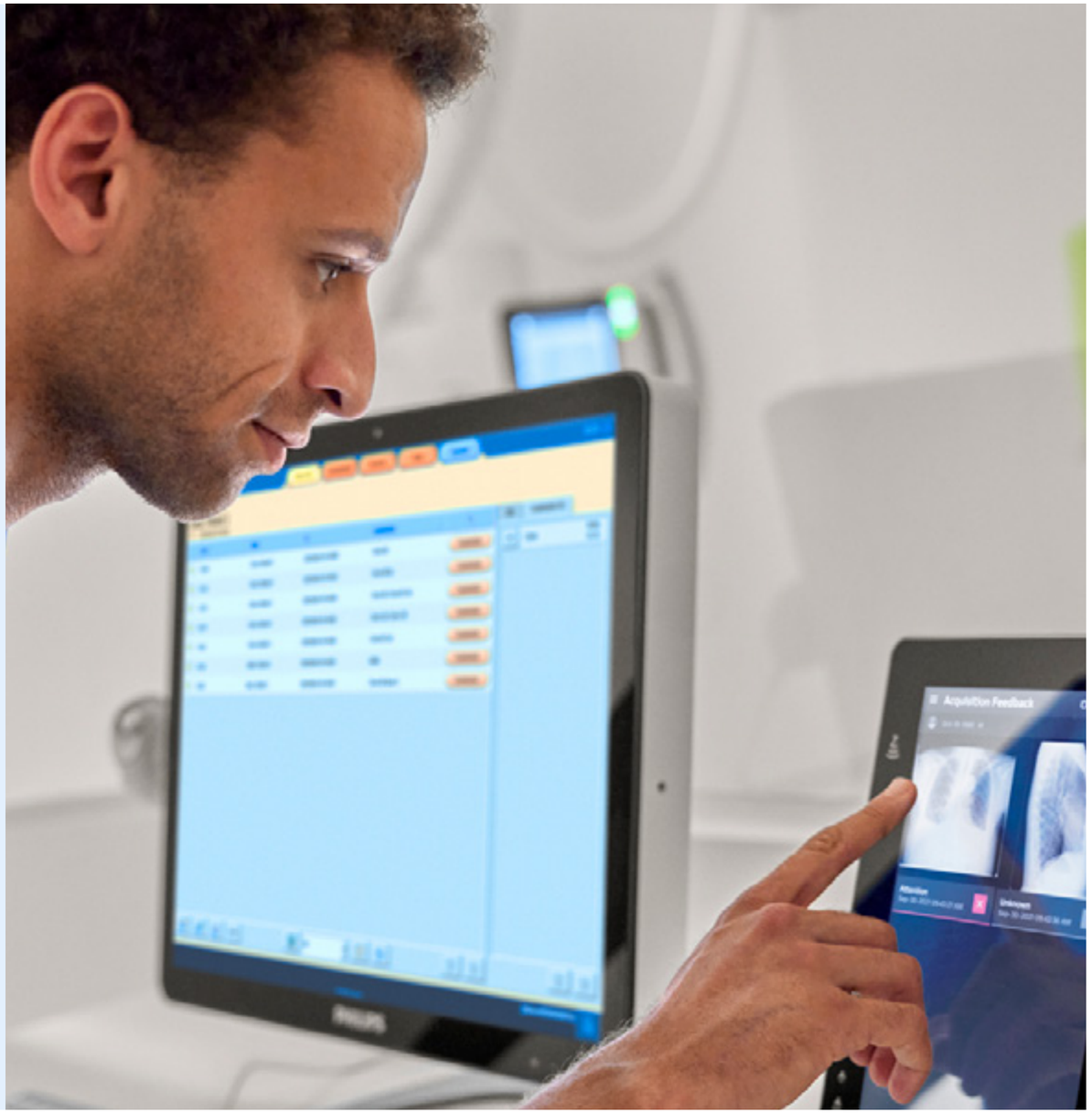
Optimal image quality is a cornerstone of precision diagnosis. It can increase diagnostic confidence during image reading, prevent recalls and reduce the need for follow-up imaging. But even for well-educated technologists, high workloads combined with a lack of objective feedback can make it challenging to perform at their best, which can result in suboptimal image quality and avoidable retakes.

Particularly in high-volume imaging modalities like X-ray, this presents a pressing problem for radiology departments seeking to improve speed and accuracy of image acquisition.

Fortunately, AI can now lend X-ray technologists a helping hand.

Acting like a personal coach, an AI-enabled tool can assist technologists in improve acquisition accuracy for X-ray chest radiograms through continual quality analysis and feedback at the point of image acquisition, without interrupting their workflow. Technologists get instant visual feedback that helps them position patients for optimal image quality. Comparison of one's own performance with departmental benchmarks helps technologists identify individual areas for improvement, while departmental dashboards give quality managers and radiology administrators the insights they need for continuous optimization.

One study showed how this AI-enabled assistance can improve the fraction of X-ray images with optimal positioning by 30%[23] – for enhanced image quality, and ultimately, better patient care.

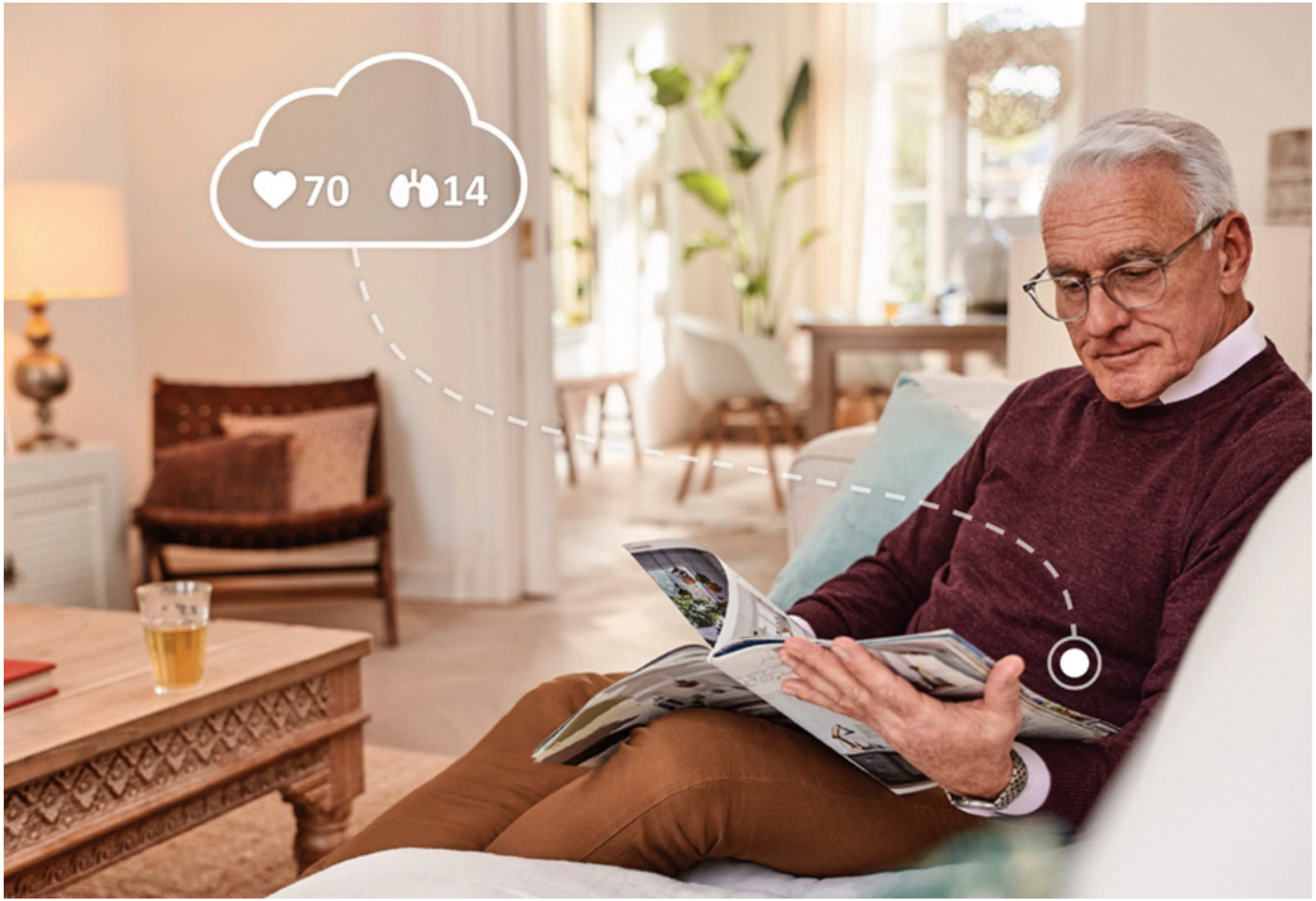


Illuminating a path to precision care

As a next frontier, AI will help connect previously disconnected and disparate patient data to provide novel insights that support healthcare providers in their decision-making.

In cancer care, for example, AI can help integrate information across different clinical domains such as radiology, pathology, EHR systems, and genomics – providing a clear, intuitive view of the patient's disease state. This can assist multidisciplinary tumor boards in making timely, informed treatment decisions, to give every patient the best chance of a positive treatment outcome. In the future, the intelligent integration of data could give further insight into a patient's prognosis, supporting selection of the best care pathway for that particular patient based on an analysis of treatment outcomes for similar patients.

As another example of AI supporting precision care, AI can analyze vital signs in acute and post-acute care to help care teams identify patients at risk of deterioration, allowing for timely intervention. Using this kind of early warning score, one hospital managed to reduce serious adverse events in the general ward by 35% and cardiac arrests by more than 86%[24].



In the future, vital sign measurements could be combined with other health parameters, including EHR data, to enable even more precise and comprehensive patient monitoring across the patient journey.

Home-based patient monitoring

More and more, such monitoring solutions will be extended from the hospital into the home, allowing providers to keep a caring eye on patients as they transition from one care setting to the next.

For example, wearable biosensors worn discreetly on the chest can measure and transmit vital signs such as respiratory data and heart rate, as well as other patient data like posture and activity level. AI algorithms could alert care providers to early signs of patient deterioration that call for intervention. Careful calibration with medical experts will be needed to ensure that such algorithms provide clinically meaningful triggers[25].

By extending the line of sight of healthcare providers from the hospital to the home, AI-enabled remote monitoring can help improve patient outcomes and lower the cost of care, while offering greater peace of mind for patient and provider alike.

Improving operational efficiency to free up focus for patient care

In addition to augmenting the expertise of healthcare providers in their day-to-day work, AI can help streamline operations within and across departments – allowing healthcare providers to focus on delivering optimal patient care while reducing costs and inefficiencies.

Automating routine tasks

One of the most pressing sources of stress and burnout in healthcare is that highly trained professionals spend an undue amount of time on mundane and repetitive tasks, ranging from data entry to protocol selection or reporting. With AI, we now have the tools to start automating such tasks.

In radiology, for example, imaging technologists say that almost a quarter of their work is inefficient and could be automated[26]. Particularly in complex and stressful imaging modalities like MRI, AI can help reduce technologist workload by automating exam planning, scanning, and processing. It can also support with automated breathing detection through camera-based sensing technology, allowing the setup of routine MR exams to occur in less than a minute[27]. As a result, staff have to worry less about getting equipment settings right and get to focus on the patient instead.

Interventional physicians, who perform minimally invasive procedures on patients with heart disease and other conditions, are another group set to gain from workflow automation. Today, interventional physicians may spend two hours reporting on cases at the end of a busy day, after treating six to eight patients. AI could help alleviate this burden by auto-logging different steps of the procedure. The physician would only have to review, complete, and sign off the pre-populated report at the end of procedure – allowing them to give their full attention to providing patient care[28].

Improved continuity of care

Another way in which AI could improve operational efficiencies is through automated patient scheduling and personalized patient engagement. Predictive analytics could help identify which patients are at high risk of not showing up for their appointment, prompting personalized text or voice messages to remind those patients. Studies have shown that such automated reminders have the potential to reduce patient no-shows by 42%[29] and poor patient preparation by 67%[30].

Improving operational efficiency

- **Automating routine and repetitive tasks**
  For increased focus on patient care and reduced risk of burnout
- **Predictive maintenance of medical equipment**
  For increased uptime, cost efficiency, and continuity of care
- **Forecasting patient flow and resource needs**
  For more efficient care delivery across settings

Predictive analytics can also improve operational efficiency and continuity of care by identifying when medical equipment may be in need of maintenance or repair. For example, through remote sensing, we can monitor and analyze over 500 parameters on an MR machine, allowing us to identify proactively when certain hardware parts may need maintenance or replacement. As a result, 30% of service cases can be resolved before downtime is caused – preventing avoidable interruptions to clinical practice and unnecessary patient delays[31]. In the future, having a full digital twin or virtual representation of an entire imaging fleet could allow for even more comprehensive predictive maintenance and continuous operational optimization[32].

But the opportunities for AI-enabled operational optimization extend beyond department walls. On an enterprise-wide level, AI can help predict patient needs as they progress through their care journey – all the way from hospital admission to discharge. For overstretched departments like the ED and the ICU, this can provide much-needed insight into how scarce staff and resources can be used most efficiently. More on this in the "AI in action" box on the next page.

The evolution of equipment maintenance

Reactive

Fix it when it breaks

Preventative

Maintain at regular intervals

Predictive

Predict when maintenance or repair will be needed, and proactively fix it before it breaks

AI in action

How AI can help forecast and manage patient flow to streamline hospital operations

AI algorithms can help patient flow coordinators forecast patient demand and manage patient transitions from one care setting to the next, allowing nurses and physicians at the bedside to focus on delivering patient care.

For hospital leaders tasked with managing unexpected surges in patient demand, the ability to anticipate and adapt to rapidly changing circumstances has become more essential than ever. Managing patient flow requires an enterprise-wide view across different parts of the hospital or hospital network.

By bringing clinical and operational insights together in a command center or central hub, healthcare providers can manage the patient journey across the entire care continuum. Using the power of AI and predictive modelling, we can extract relevant patterns in patient flow and patient care needs from vast amounts of real-time and historical hospital data. This generates actionable insights that can help answer questions such as:

- Which patient should get an ICU bed first?
- Which patient is ready to be transferred from the ICU to a step-down unit?
- Which patient is ready to be discharged for home monitoring?

Equipped with such insights, it becomes possible to manage patient flow proactively from one care setting to the next. By expediting patient transfers throughout their care journey, healthcare providers can prevent congestion in certain areas of the hospital and overutilization of critical resources in others. For patients, this means they don't have to stay in the hospital any longer than necessary. This, in turn, gives other patients a better chance of getting access to the critical care they need.

Empowering people to take care of their health and well-being

While the clinical and operational benefits of AI in healthcare are numerous, arguably the most sustainable way in which AI can help transform health systems is by preventing people from developing diseases in the first place.

In the wake of the COVID-19 pandemic, there is an increased recognition that keeping patients healthy outside of the hospital represents the future of healthcare. The focus will shift from managing episodes of care to a more holistic and longitudinal approach across the care continuum – with an increased emphasis on healthy living, disease prevention, and reducing avoidable hospital readmissions.

Managing chronic disease

We already discussed the emerging role of remote patient monitoring in managing chronic disease, alerting healthcare providers when and where care is needed. In conjunction, digital health technology can also empower patients to take care of their own health and well-being. AI-enabled apps can turn data from connected health devices into actionable insights, offering tailored recommendations based on a person's health condition, goals, and behaviors.

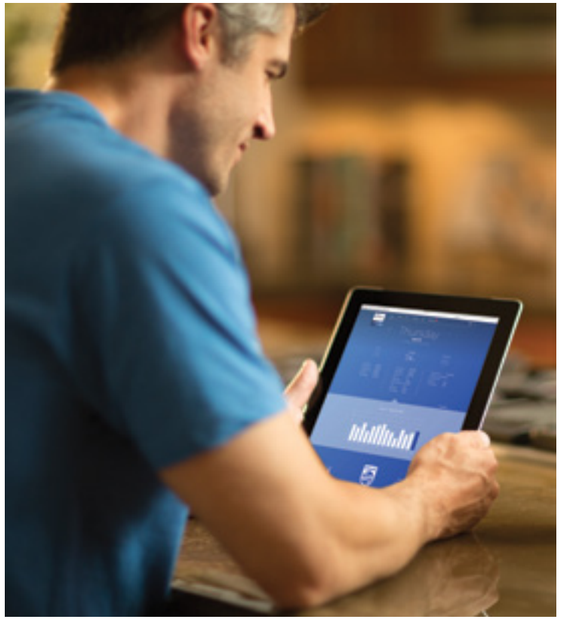
For example, one such app helps people with sleep apnea track their therapy progress so that they can take an active role in their therapy[33]. Over time, such applications could evolve into full-fledged virtual assistants, using a combination of voice technology and intuitive mobile interfaces to motivate patients and support treatment adherence.

The impact on people's quality of life could be significant. Research has shown that patient participation in their own care can lead to increased engagement as well as better outcomes[34]. As populations continue to age, self-management of chronic disease – in collaboration with qualified care professionals – could also enable patients to live longer on their own in the comfort of their home.

Personalized recommendations

In addition, there will be a growing role for AI-enabled applications that help people of all ages develop and maintain healthy habits. For example, in oral healthcare, AI can analyze an individual's brushing behavior through sensors embedded into a smart toothbrush, and – through a mobile app – offer personalized recommendations that encourage people to improve their oral hygiene habits.

AI could also support a healthier diet, through personalized nutrition advice that is based on a person's unique health profile and genetic background[35]. Sleep and exercise are other obvious lifestyle factors that can benefit from personalized coaching by AI-enabled technology[36]. Coupled with the continued rise of telehealth, which allows people to consult care professionals remotely, this could help people stay healthy longer, and thereby set health systems on a more sustainable course for the future.

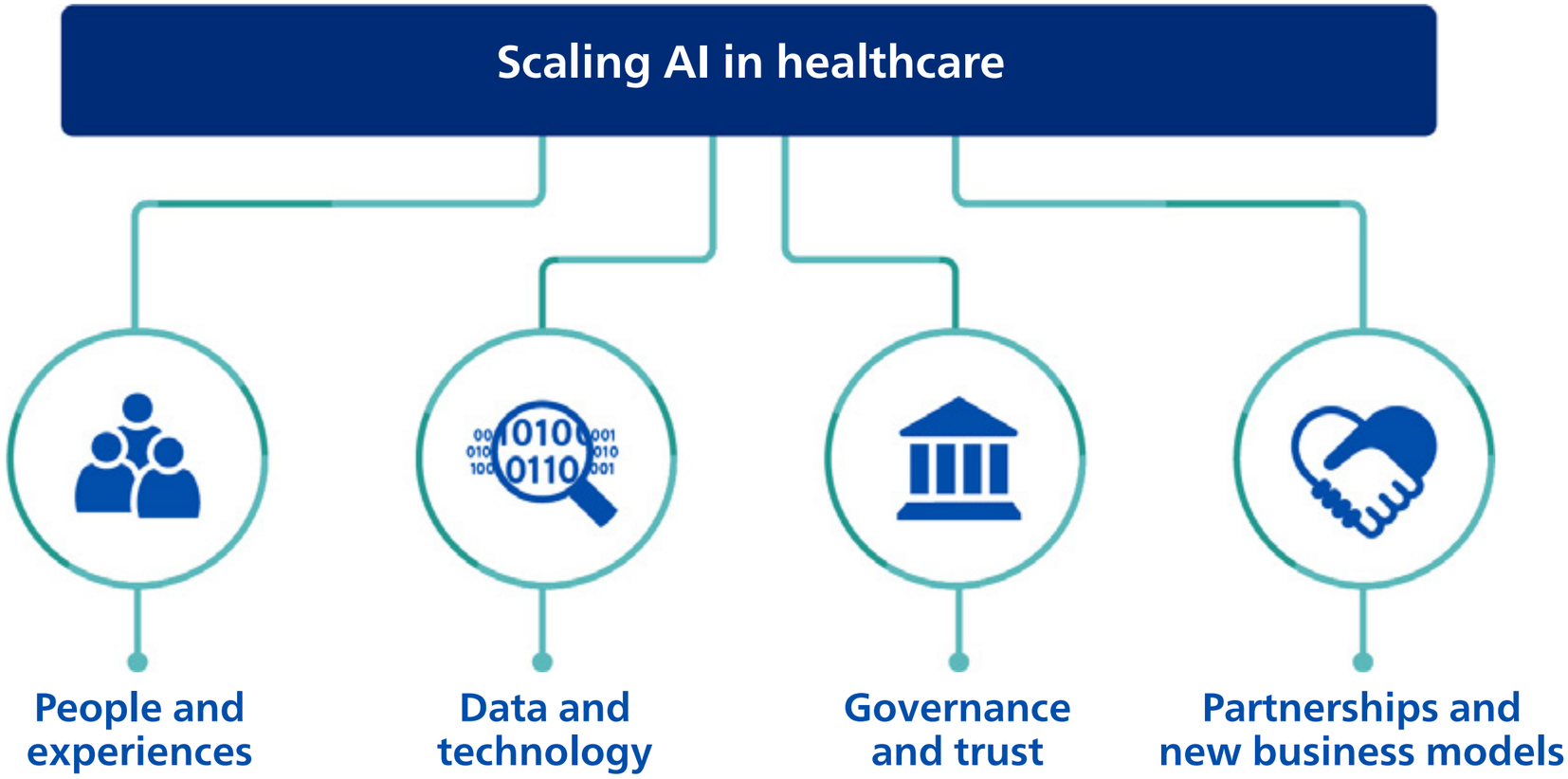


Empowering people to take care of their health

- **Home-based patient monitoring**
  For increased peace of mind and reduced risk of readmission
- **Self-management of chronic disease**
  For increased patient engagement and quality of life
- **Promoting healthier habits**
  For healthy living and prevention of disease

Scaling AI in healthcare: four focus areas to promote wider adoption

What is needed to bring this vision of AI in healthcare to full fruition? We see four enabling areas, each of which is outlined in more detail in the next chapters.



People and experiences

The value of AI is only as strong as the human experience it supports. AI innovation should therefore focus on the unmet needs of healthcare providers and patients first and foremost.

The most beneficial and impactful AI innovations in healthcare, like any other innovation, are need-driven rather than technology-driven. They enhance the human care experience without getting in the way of it. Or as one hospital CIO put it: "Digital medicine is just medicine in the same way that really good technology is not about technology. It blends into the fabric of our everyday lives."[37]

Seamless workflow integration

To achieve this kind of seamless integration, human-centered design of AI applications is critical. This requires involving all relevant stakeholders – including end users – from the very beginning of the development process. At Philips, we use tools such as co-creation sessions, experience flows, and 360-degree on-site workflow analyses to understand the practical and emotional context in which AI technology is used.

For example, we are collaborating with medical experts at the Catharina Hospital and the Leiden University Medical Center in the Netherlands – alongside scientists from the Eindhoven University of Technology – to uncover the experience drivers that help radiology departments get the most value out of AI[38].

One consistent learning from collaborations like these is that AI in healthcare should reduce information overload rather than add to it. What may seem like a useful algorithm in a research setting can actually be a burden to healthcare professionals if it means adding yet another thing to their workflow.

Radiologists work in a complex and time-pressured environment, running different software applications in parallel on multiple screens. If AI algorithms require them to manage additional applications, the net effect may be that radiologists actually spend more – not less – time processing medical images[39]. Instead, algorithms should integrate into the systems and workflows that radiologists are already using, offering a unified experience without requiring additional task-switching.

As another example, emergency care physicians and nurses are already contending with alarm fatigue, with near constant alerts vying for their attention[40]. Instead of adding to the noise, AI-enabled applications should help physicians and nurses separate the signal from the noise. This can only be achieved if such solutions are designed to support their workflows.

Similarly, AI-enabled health applications for patients and consumers should seamlessly support their daily health routines. While early health and fitness trackers helped increase health awareness, people often abandoned them over time because they struggled to make use of the data presented to them[41]. Clearly, it is not more data that people are looking for – they want relevant insights that they can act on.

Request
Referring physician

Scheduling
Administrator

Image acquisition
Radiology technician

Image & data interpatation
Radiologist

Reporting
Radiologist

Follow-up care
Referring physician

Developing an AI-ready workforce

Training and education will also be essential in preparing today's and tomorrow's medical workforce for a future enabled by AI and other digital technology. Our Future Health Index 2021 report revealed that 32% of healthcare leaders consider lack of training to fully utilize digital health technology a barrier to its adoption in their hospital or healthcare facility[42].

Increasingly, physicians will need to be well-versed in both biomedical and data science. Nurses at the bedside should feel comfortable using AI-enabled clinical decision support systems, knowing how to get the most out of machine-generated predictions as a complement to their own professional judgment.

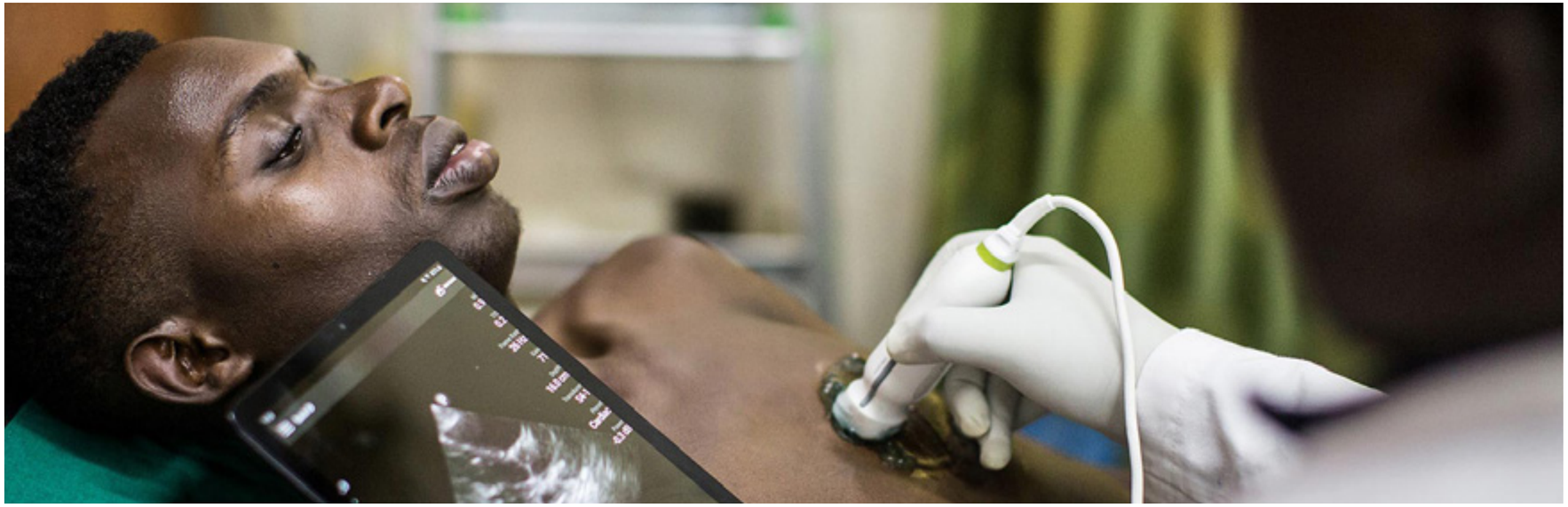
National health systems should therefore prioritize AI and data science in their education curricula. Institutions such as the European Society of Radiology have rightly called for AI and informatics to be included in the curricula for future radiology residents[43]. Other specialties where AI is most likely to spawn new applications first, such as pathology and oncology, would also benefit from new education programs that incorporate the latest knowledge from healthcare practitioners, academia, and industry players.

At Philips, we are exploring potential collaborations with universities to help educate (future) doctors and nurses on the possibilities of AI. In addition, virtual collaboration can support peer-to-peer learning.

We also see a role for health technology companies in creating broader public awareness for the emerging role of AI in healthcare. For example, through the Kickstart AI program in the Netherlands, we have contributed to a national course for AI aimed at the general public[44]. Such initiatives can help to make people more familiar with and receptive to the use of AI in healthcare and personal health devices.

Key takeaways

- AI innovation in healthcare must involve medical professionals from the very beginning of the development process to co-create solutions that serve their needs and integrate into their workflows.
- To help today's and tomorrow's healthcare professionals get the most out of AI, new education programs are needed at the intersection of biomedical and data science.



Data and technology

Developing AI-enabled solutions relies on access to high-quality, properly curated data. The reality, however, is that today's healthcare data is often locked away in disparate and disconnected systems, posing a barrier that needs to be addressed for AI innovation to scale.

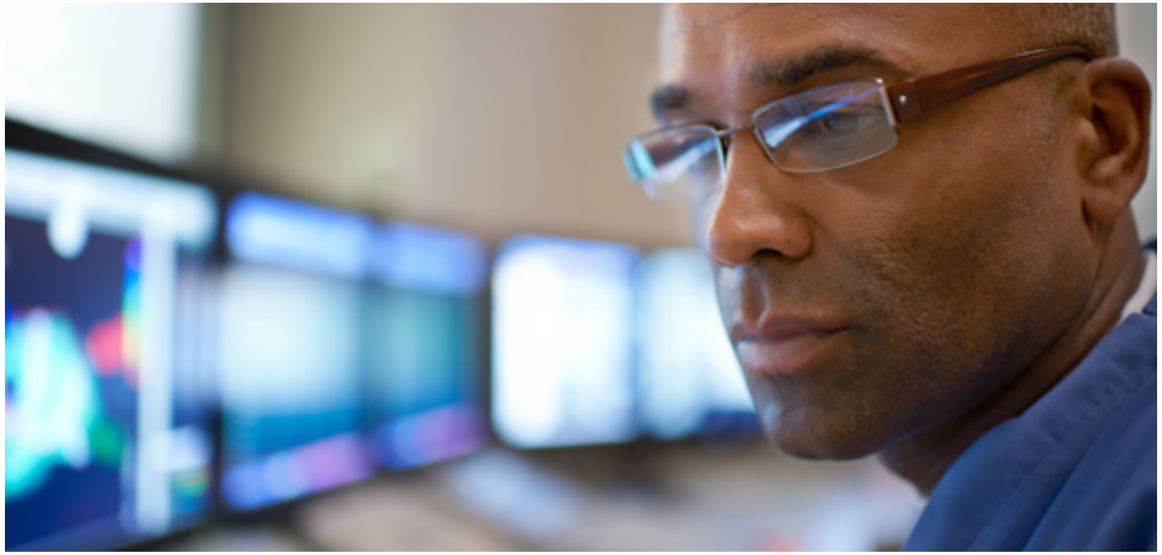
In our Future Health Index 2021 report, healthcare leaders cited difficulties with data management (44%) and lack of interoperability and data standards (37%) as the biggest obstacles to adoption of digital health technology in their hospital or healthcare facility[45]. These challenges can also make it difficult to compile the necessary high-quality data for training AI models, particularly if those models rely on multimodal data from different sources.

Data sharing and interoperability

To overcome these challenges, robust and interconnected platform infrastructures are needed for collecting, combining and analyzing data at scale. As healthcare becomes increasingly distributed, extending from the hospital to the home, such infrastructures need to cover the entire continuum of care to connect patient data across settings and over time. For example, through our Philips HealthSuite platform, we are helping healthcare providers collect, compile, and analyze data from multiple sources, including medical records, imaging and monitoring data, as well as personal devices and technologies.

Second, interoperability and standardized data sharing between different hospitals and health systems is key to exploit the full potential of data and AI. Data should be available in formats that can be shared effortlessly, transparently, and securely. At Philips, we are promoting the use of open data standards and semantic interoperability, through methods such a unified Information Language System, to allow healthcare providers to connect and integrate data in a meaningful way.

Third, regional legislation and collaboration should enable the secure exchange and access to properly annotated data for AI research and clinical practice, while safeguarding patient privacy (more on data governance in the next section). We therefore support initiatives such as the creation of a common European Health Data Space, which is set to promote better exchange and access to different types of health data ranging from EHRs to genomics data, across EU member states[46].



Healthcare providers face data challenges

44%

Difficulties with data management

37%

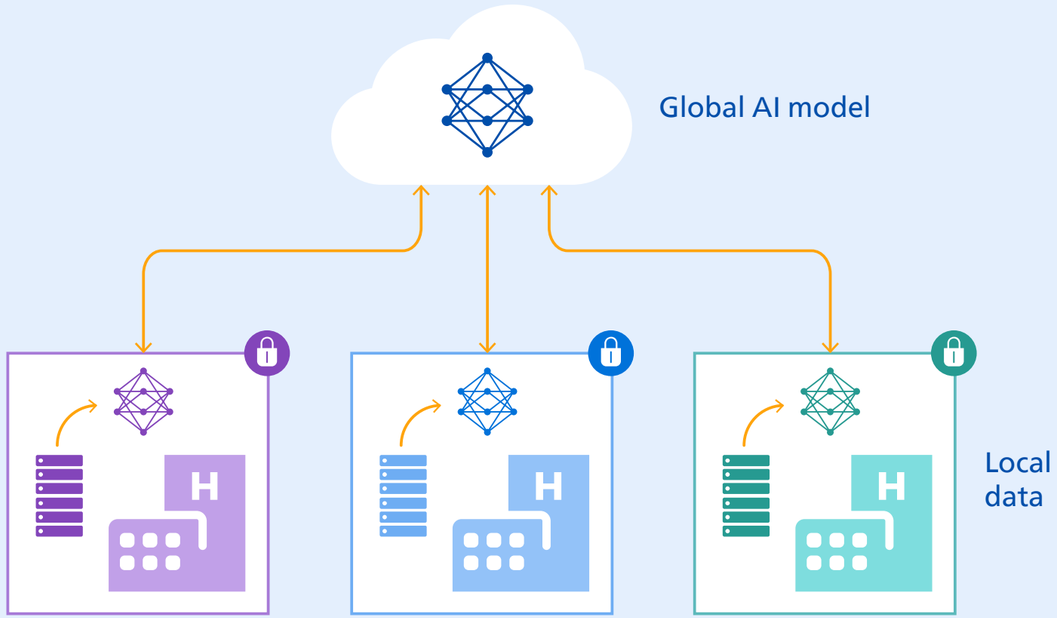
Lack of interoperability/data standards across technological systems and platforms

Philips Future Health Index 2021

Next-generation AI

One particularly promising way of increasing the availability of high-quality data for AI research and development without compromising patient privacy is **federated learning**. Originally developed for other domains, it is now gaining traction for healthcare applications. Whereas standard machine learning models require bringing together training data in one central place, federated learning trains an AI model based on a large body of decentralized data. This allows multiple healthcare institutions to gain insights through a shared machine learning model, without moving patient data beyond the institutions where they reside (see illustration below). The machine learning process occurs locally at each participating institution, and only the characteristics of the AI model are transferred to a central cloud server. The data stays where it is.

Federated learning: training AI based on decentralized data



Recent research has shown that models trained by federated learning can achieve performance levels comparable to ones trained on centrally hosted data sets and superior to models based on isolated single-institution data[47]. A combination of continuous and federated learning will make it possible to tailor AI models to individual sites or geographies for increased accuracy and adoption.

Where data to train AI models is scarce, we can also tap into existing science-based knowledge to help fill the gaps. For example, anatomical and physiological knowledge of the lungs or the heart can be used to create synthetic images that complement existing annotated data. Medical image segmentation models trained on such synthetically augmented data sets have shown better accuracy than models trained only on a small set of real-world data – showing the promise of a hybrid approach that combines the power of data with science-based knowledge[48].

By exploring the possibilities of these and other next-generation approaches to AI, we will be able to take on data-related challenges in AI development with a more versatile and effective toolkit.

Key takeaways

- To foster AI innovation at scale, interconnected and interoperable platform infrastructures are needed for collecting, combining and analyzing data across settings.
- Regional legislation and collaboration should enable the secure exchange and access to properly annotated data for AI development, for example through the creation of common data spaces.
- Next-generation AI methods such as federated learning and hybrid modelling also offer promising ways of addressing data-related challenges in healthcare.

Governance and trust

To strengthen public and professional trust in AI in healthcare, technological advances need to go hand in hand with appropriate governance around data privacy, security, and the ethics of AI.

Because AI in healthcare often involves the use of sensitive personal data, a key priority is obviously to use that data responsibly. When asked what would keep consumers from using digital health technology, 41% ranked "concerns about my privacy or data security" as the number one barrier[49]. Likewise, for healthcare CIOs tasked with keeping patient data safe across a growing plethora of channels and devices, data security is as big a concern as ever[50]. At Philips, we are committed to proactively addressing security and privacy concerns, as captured in our Data Principles.

Yet because AI is set to fundamentally change the way people interact with technology and make decisions, it requires additional standards and safeguards. This led us to develop a set of guiding principles for the design and responsible use of AI (see next page) – all based on the notion that AI-enabled solutions should benefit healthcare providers, patients, and society as a whole, while avoiding unintended consequences.

Importantly, we should encourage appropriate trust in AI while preventing that physicians come to rely on it blindly, because no algorithm will ever be perfect. This calls for expert human oversight to evaluate AI-generated recommendations in their full clinical context, as well as transparency on how the algorithm was trained and validated, to help ensure that healthcare professionals understand its strengths and limitations.

In addition, we must prevent deliberate or inadvertent misuse of AI systems beyond their intended purpose. This could be achieved by monitoring the performance of AI-enabled solutions in clinical practice and by comparing the actual outcomes to those obtained in training and validation. Any significant discrepancies would call for further inspection.

Fair and bias-free AI

We must also be mindful that AI can exacerbate existing health inequalities through biased data sets that do not accurately represent the target population[51]. AI is only as objective as the data we feed into it. To prevent bias, development and validation of AI must be based on data that accurately represent the diversity of people in the target group. When AI is applied to a different target group, it should be revalidated – and possibly retrained – first.

Philips Data Principles

Security

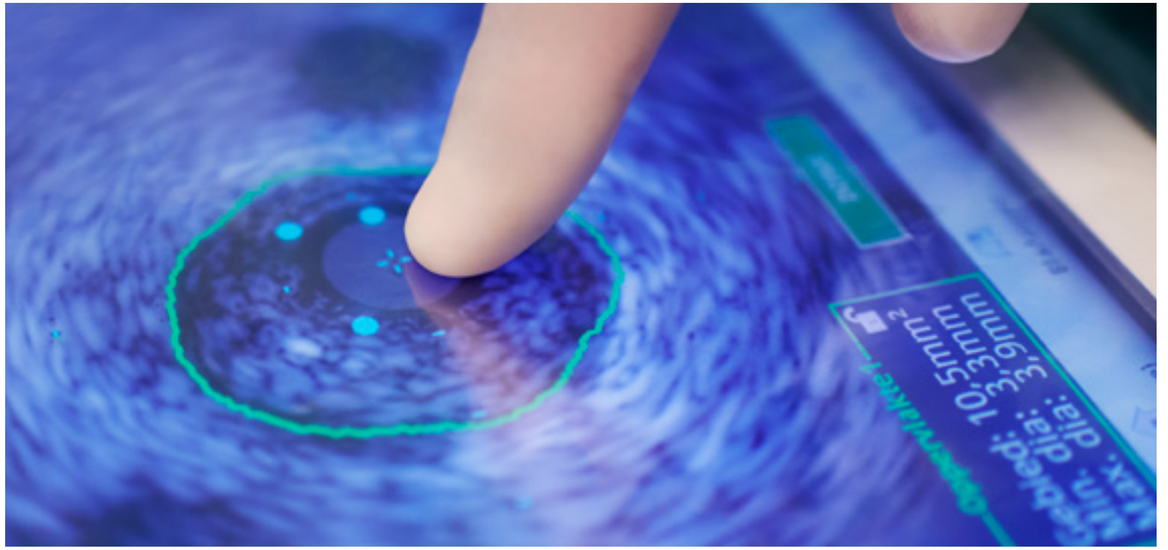
We ensure the security of all data entrusted to us. We operate under global security policies that guide our activities to protect against vulnerabilities and manage any incidents.

Privacy

We handle all personal data with integrity, in compliance with all applicable privacy regulations of the countries in which we operate.

Beneficial

We aim to create innovative solutions that benefit our customers, patients, and society as a whole. We use your personal data in line with your reasonable expectations.



Philips AI Principles

Well-being

We design our solutions to benefit the health and well-being of individuals and to contribute to the sustainable development of society.

Oversight

We design AI-enabled solutions to augment and empower people, with appropriate human supervision.

Robustness

We develop AI-enabled solutions that are intended to do no harm, with appropriate protection against deliberate or inadvertent misuse.

Fairness

We develop and validate solutions using data that is representative of the target group for the intended use, and we aim to avoid bias or discrimination.

Transparency

We disclose functions and features of our offerings that are AI-enabled, the validation process, and the responsibility for ultimate decision-taking.

What's worth highlighting here is that AI is also increasingly being recognized as a force for good that can promote more fair and equitable healthcare. For example, Philips recently received a grant from the Bill & Melinda Gates Foundation to develop an AI-based application to improve the quality and accessibility of obstetric care in low- and middle-income countries[52]. The application will be designed to help nurses identify potential problems in pregnancy at an early stage, thereby giving expecting moms a better chance of bringing a healthy child into the world. This is just one of many opportunities for AI in healthcare to make a difference where it's needed most.

Key takeaways

- As AI relies on access to – often sensitive – health data, strong data governance is required for ensuring privacy and security in order to build and maintain public trust in the use of AI
- Careful design and deployment of AI models is needed to prevent unintended consequences such as bias, which may inadvertently reinforce existing health inequalities

"To reap the full benefits of AI and data science, we have to enable secure exchange of and access to properly curated data while safeguarding patient privacy. And to make sure that AI is fair and bias-free, it is vital that the algorithms we develop reflect the full diversity of the world we live in. That's why we developed the Philips Data and AI Principles – to ensure that everyone gets to benefit from AI and data-driven innovation in healthcare."

Dr Tina Manoharan
Global Lead of Data Science & AI Center of Excellence
Philips

Partnerships and new business models

In a sector as complex as healthcare, no individual player has all the solutions. Partnerships, ecosystem integration, and new business models such as SaaS-based software marketplaces are therefore becoming increasingly important in bringing AI into clinical practice.

Rolling out successful AI projects at scale requires intense collaboration between people with highly diverse backgrounds – from clinicians to data scientists, hospital decision makers and IT professionals. Partnerships are the key to bringing these disciplines together. For example, as part of BigMedilytics – an EU-supported big data consortium led by Philips Research – we have been working closely with clinical partners on developing predictive modelling for prostate cancer surgery outcomes, which can support physicians and patients in their treatment decisions, for better outcomes and quality of life.

SaaS-based AI marketplaces

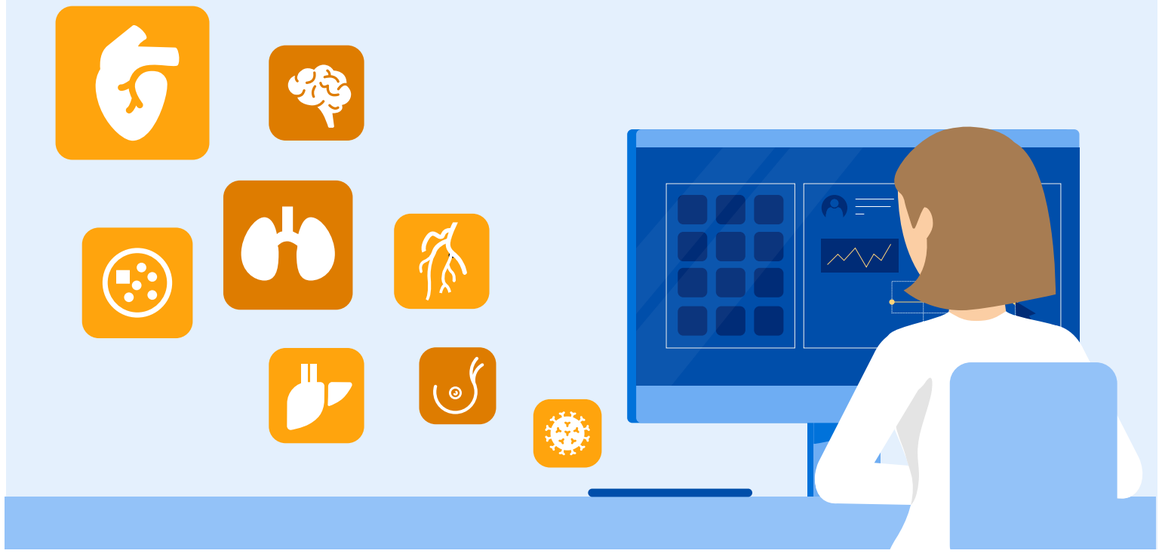
Through partnerships and ecosystem integration, large healthcare solution providers like Philips can also help make AI applications from startups available at scale. For example, in radiology, this can take the form of a curated software marketplace that allows radiologists to download validated apps from a large number of third-party developers via one common platform – without having to worry about point-to-point integrations. By providing such services through the cloud on a Software as a Service (SaaS) basis, AI applications can be deployed more easily and updated over time, for continuous innovation.

Reimbursement and funding

Finally, clear criteria for the reimbursement of AI applications will also be crucial for wider adoption in clinical practice. Today, the financing of AI is still uncertain in many cases. Reimbursement schemes were not designed with AI in mind. A shift from fee-for-service to value-based payment models would go a long way towards creating the appropriate incentive framework for the sustainable adoption of AI in healthcare. This needs to go hand in hand with more prospective clinical studies establishing improved outcomes through the use of AI, demonstrating its value to providers, payers, and patients[53]. In addition, innovative partnerships between providers, payers, and technology vendors can help promote adoption of AI applications for healthy living and preventive healthcare.

By combining the strengths of different ecosystem partners and embracing value-based incentives, we can further accelerate AI innovation in healthcare and deliver on its full promise, for a better and more human care experience.

Integrating third-party AI apps into clinical workflows



Key takeaways

- Scaling AI in healthcare will rely on partnerships, with solution providers like Philips increasingly acting as an integrator of technology.
- SaaS-based software marketplaces allow healthcare providers to access AI apps from multiple vendors via a common-cloud based platform.
- Value-based reimbursement models will be critical for sustained adoption of AI in clinical practice, based on demonstration of better patient outcomes over time.

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