Deloitte.

Commissioned by

MedTech Europe
from diagnosis to cure

The socio-economic impact of AI in healthcare

October 2020

Executive Summary 5

Introduction 9

AI in healthcare 10

Methodology 14

Socio-economic impact of AI in healthcare 16

AI in healthcare: barriers to adoption and policy recommendations 30

Conclusion 34

Appendix 36

Deloitte and MedTech Europe gratefully acknowledge the financial support of Intel, Johnson & Johnson, Medtronic and ResMed for this report.

List of abbreviations

AI = Artificial Intelligence

CAD = Coronary Artery Diseases

CCTA = Coronary Computed Tomographic Angiography

CE = European Conformity

CT = Computerized Tomography

COPD = Chronic obstructive pulmonary disease

EHR = Electronic Health Record

EU= European Union

HC = Health Care

HCP = Health Care Professional

ML = Machine Learning

MRI = Magnetic Resonance Imaging

IT = Information Technology

PET = Positron Emission Tomography

PREM = patient-reported experience measures

PROM = patient-reported outcome measures

Q&A = Questions and Answers

qPCR = Quantitative Polymerase Chain Reaction

R&D = Research and Development

RWD = Real World Data

VHA = Virtual Health Assistance

Authors: Eliana Biundo, Andrew Pease, Koen Segers, Michael de Groote, Thibault d'Argent, Edouard de Schaetzen


V2
aVL
aVF
II
III

Executive summary

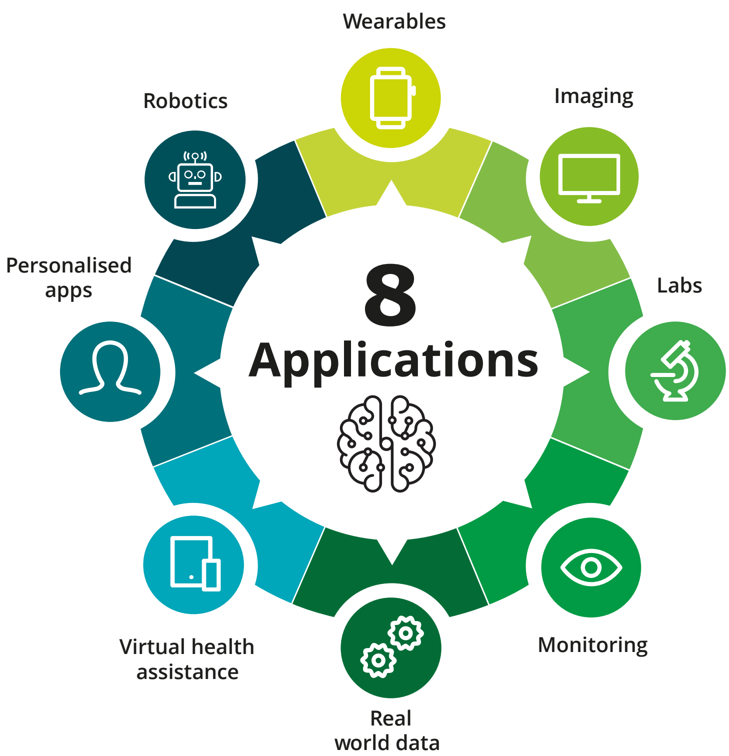
AI can have a significant socioeconomic impact on European health systems

Evolving technologies such as AI have the potential to assist European health systems in responding to major challenges they face. AI technologies can empower people, for example by helping citizens to be more informed and make healthier choices, and by supporting doctors in diagnosis and treatment decisions. Estimating the socioeconomic impact of AI on European health systems is fundamental to advancing the current discourse on the role AI can and should have in health.

This study covers AI applications that can be used across the entire patient journey. Eight application categories are mapped: wearables, imaging, laboratory applications, physiological monitoring, real world data, virtual health assistance, personalised apps and robotics.

The socioeconomic impact is quantified through impacts on health outcomes, financial resources and time spent by healthcare professionals (HCPs). By estimating the number of saved lives, the cost savings and the hours freed up for HCPs, it is possible to quantify the potential impact of AI on Europe's healthcare systems.

First, annually 380,000 to 403,000 lives can potentially be saved. Wearable AI applications could have the largest impact, saving up to 313,000 lives. This is followed by AI applications in monitoring (42,000 lives) and imaging (41,000 lives).



Second, €170.9 to 212.4 billion could be saved annually, including the opportunity costs of HCP time. Wearable AI applications could have the largest impact with €50.6 billion of potential savings. Add to that AI applications in monitoring (€45.7 billion) and real world data (€38 billion).

Finally, AI applications have the potential to free up 1,659 million to 1,944 million hours every year. This impact is led by AI applications in virtual health assistance (VHA) that could save up to 1,154 million hours per year. Other savings through AI applications include robotics (367.5 million hours) and wearables (336.1 million hours). This would allow HCPs to dedicate considerably more time to high-value activities.

AI could have a substantial socioeconomic impact in healthcare by improving patient outcomes and access, and optimising the use of resources. However, to reach its full potential a series of barriers that must be addressed by public and private stakeholders:

- **Data challenges** include the fragmented data landscape and interoperability, as well as data quality, data privacy and protection and cybersecurity. High-quality data is important to train unbiased, robust and safe AI.
- **Legal and regulatory challenges** are due to different legal frameworks regulating AI and data in healthcare. Guidance on applying and interpreting existing regulation should describe novel approaches to meet the requirements, promoting innovation and competitiveness.
- **Organisational and financial challenges** arise where digitalisation and inclusion of AI in European health systems require substantial investments in several areas: infrastructure, digitalisation adoption, technologies, skills and training and shift from care to prevention. Additionally, broader adoption of AI in healthcare will require novel approaches to how technologies are funded, evaluated and reimbursed.
- **Social challenges** need to be addressed regarding trust and understanding, governance and patient empowerment.

400,000 lives saved yearly

That's the population of a medium-sized city, or **almost two thirds of Luxembourg**[1]

200 billion Euros in annual savings (including opportunity costs)

These findings are then translated into policy recommendations that can accelerate the benefits of AI and ensure they are harmonised across all EU Member States.

1. Develop policy frameworks to build trust and foster the adoption of AI in healthcare.
2. Build and maintain a balanced regulatory environment, based on existing applicable regulations, that enables and stimulates future technological innovation and evolution.
3. Build data policies and infrastructure (in line with the European Health Data Space project) to foster seamless access, connectivity and sharing of high-quality, harmonised data.
4. Define clear governance and partnerships across healthcare professionals, academia, decision-makers and industry.
5. Ensure appropriate commercial incentives and reimbursement mechanisms to foster innovation in Europe and support patient access.
6. Advance data interoperability by defining data format standards, so data is generated and transferred in a more consistent way across market participants and Members States.
7. Advance AI skills among HCPs, and digital health literacy among citizens (especially patients) to ensure the benefits will be achieved equitably across the EU regardless of proximity to a centre of excellence.

To unlock the full potential of AI in healthcare, European health systems and the broader ecosystem need to make improvements in a number of areas, including the ways such technologies are evaluated and reimbursed, workforce skills and training, and data interoperability and ownership. These barriers can be overcome with the collaboration of all stakeholders in the ecosystem: policy makers at all levels (EU, national and regional), healthcare providers, academia, industry and citizens. With this broad partnership, AI innovation and adoption can help ensure high-quality care for European citizens and put the EU at the forefront of a very innovative industry.

Which is approximately **12% of the total European healthcare expenditures** in 2018[2]

1.8 billion hours freed up every year

That's the equivalent of having **500,000 additional full time health care professionals**[3]

Image caption lorem ipsum evel mollame

Introduction

AI in healthcare: hype vs. reality

Artificial intelligence (AI) has evolved from a niche research topic into a large collection of powerful technologies with mainstream applicability. It is poised to transform the way we interact with each other, take decisions, and obtain goods and services from multiple industries.

The healthcare industry is no exception. With significant challenges lying ahead, such as an ageing population, growing demand for services, increased costs and healthcare staff shortages, this industry is increasingly looking towards AI. And rightfully so. In recent years, the speed of innovation in AI applications for the healthcare industry has reached an all-time high. The number of scientific papers being published is skyrocketing. A thriving ecosystem of start-ups, large medical technology players and 'Big Tech' companies are starting to roll out AI-enabled solutions.

In a nutshell, AI in healthcare carries a lot of promise. But one key question remains: what value will it deliver in reality?

The objective of this report is to provide an answer to this question by assessing the socio-economic impact of AI for European healthcare systems. More specifically, it will attempt to provide a clear view of the impact that AI can have throughout the patient journey (see Figure 1) on four key domains: workforce, financial resources, access and quality of care, and health outcomes. The findings are translated into specific policy recommendations to accelerate the socioeconomic benefits and ensure they are harmonised across all EU Member States.

The AI applications covered in this research are already available and used in certain settings, although not consistently across Europe. However, in order to unlock the full potential of AI in healthcare, European healthcare systems and the broader ecosystem will need to improve the ways such technologies are evaluated and reimbursed, as well as workforce skills and training, and data interoperability and ownership, among other areas.

AI in healthcare

AI can play a vital role to support healthcare systems in a variety of areas, from disease prevention to care delivery and patient empowerment

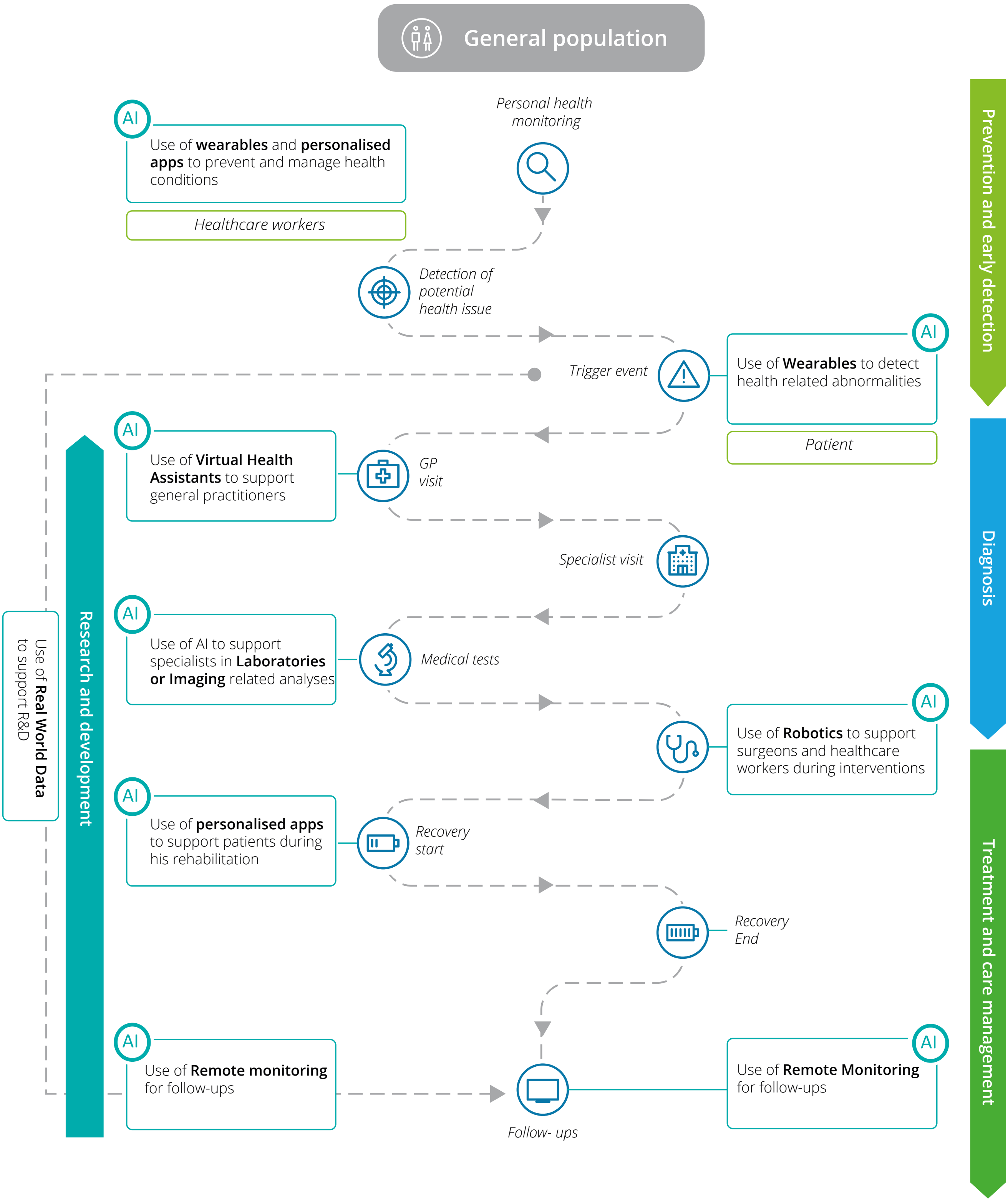
AI applications have the potential to improve the ways healthcare systems function and how individuals make lifestyle and care decisions. Hence, they can have a major impact on the healthcare sector. AI applications can play a wide role: from preventing the onset of diseases, improving diagnosis and supporting treatment decisions and interventions, to optimising research and development.[1,2,3]

European health systems face shortages of critical medical professionals, long waiting times, rising demand for services driven by an ageing population, and financial constraints. AI could ease some constraints by reducing the time healthcare professionals spend on repetitive tasks, thus allowing them to focus on high-value activities, such as spending more time with patients or seeing more patients. Additionally, AI can support faster and/or more accurate diagnosis and treatment decisions, thanks to the ability of processing large amounts of information quickly.[4,5]

Patient journey
The journey starts in the prevention phase with personal health monitoring and lifestyle choices. Clinical abnormalities can then be diagnosed, leading to decisions on care and treatment. AI applications can support every step of this journey, enabling individuals to be better informed and make healthier choices, and supporting the care decision-process. Figure 1 maps the role of AI across this journey.

Figure 1: The role of AI at each step of a patient journey (non-exhaustive)

AI is present all along the patient journey



AI in healthcare

AI technology is being developed for use across the broad spectrum of healthcare provision. Because innovation is happening so rapidly, it is important to clearly define what AI can do and where. In this report, AI technologies have been mapped to **eight application categories:**

Wearables

Wearables can monitor and respond to health events. AI applications are present in accelerometer bracelets, smart watches and activity trackers. Additionally,

Imaging

Imaging refers to image capturing and processing technologies used mostly in radiology and pathology. For instance, AI-supported imaging can greatly support diagnosis of cancers, respiratory diseases or cardiovascular conditions.

Laboratory applications

Laboratory applications include laboratory data analysis and research and development support. There are AI applications in pathology, infection testing and laboratory database management.

Physiological monitoring

Physiological monitoring covers the detection and monitoring of normal physiology, as well as health conditions and abnormalities. AI-enabled monitoring can be applied to medication adherence and treatment decisions. Eye-tracking technologies in neurology are also relevant AI applications.

Real world data

Real world data (RWD) refers to analysis of large-scale datasets of populations. AI can be applied to RWD for patient recruitment and retention in clinical trials. It can also potentially be applied to drug effectiveness assessments and pharmaco-vigilance.

Virtual health assistance

Virtual health assistance includes digital technologies that support healthcare professionals (HCPs) and that provide virtual care or other help to patients. Examples of AI applications are virtual scribe or smart-speaker devices used to transcribe clinical data and extract information.

Personalised apps

Personalised apps consist of tailored digital applications for patients and healthcare professionals. AI applications are present in metabolic pathologies, habit recommendations and in-patient tracking via virtual nurses.

Robotics

Robotics can support HCPs and patients with daily tasks. Robot-assisted surgery and auxiliary robot assisting-nurses are some examples of AI applications within robotics.

Methodology

| Definition of AI

AI refers to systems that, given a complex goal, act in the physical or digital world. They perceive their environment, collect and interpret structured or unstructured data, reason based on knowledge derived from this data, and decide the best action to take to achieve the goal. AI technologies can also learn to adapt their behaviour by analysing how the environment is affected by their previous actions.

As a scientific discipline, AI includes several approaches and techniques. They cover machine learning (including deep learning and reinforcement learning), machine reasoning (planning, scheduling, knowledge representation, reasoning, search and optimisation), and robotics (control, perception, sensors and actuators, and the integration of other techniques into cyber-physical systems).[6,7]

Research approach

This study has been organised in three phases:

1. Reviewing existing AI applications: mapping AI applications in healthcare through desk research and interviews with subject-matter experts.
2. Impact assessment: clearly qualifying and quantifying the impact of single AI applications based on literature and estimations.
3. Reporting results: consolidating insights (AI applications and their estimated impact) derived from primary and secondary research, and formulating strategic recommendations on how to reap the full benefits of AI in healthcare.

AI applications included

The previous section introduced the eight application categories that this study focuses on. Each has been populated with single AI technologies (applications). The list is not exhaustive and has been based on the available evidence about the impact these technologies can have. Findings are based on the set of AI application presented below and can provide an estimation of the potential socioeconomic impact of AI in healthcare. The scope of this report covers CE-marked software, used with medical purpose, and goes beyond, to AI applications, which are used in the area of healthcare, but are not qualified as a medical device.

A.	**Wearables**	D.	**Physiological monitoring**
1	Prediction of falls	1	Medication adherence
2	Prediction of heart failure	2	Prediction seizures and early detections health abnormalities
3	Continuous glucose monitoring	3	Retinal scan for monitoring Multiple Sclerosis
4	Remote monitoring with arm straps	4	Screening of diabetic retinopathy
5	Pre/post-surgery monitoring with activity trackers	**E.**	**Real world data**
6	Patient's recovery monitoring in neurology	1	Patient recruitment and retention for clinical trials
7	Pill-cam	2	Prediction of drug effectiveness
B.	**Imaging**	3	Automation of pharmacovigilance
1	Detection of pulmonary pathologies with chest X-rays	**F.**	**Virtual health assistance**
2	Detection of coronary artery diseases	1	Automation of medical records transcription
3	Detection of breast cancer	2	Extraction of information to answer patients questions
4	Image acquisition and reconstruction	3	Administrative timesaving
5	Detection of COVID-19	**G.**	**Personalised apps**
6	Diagnosis of dermatological conditions	1	Behavioural counselling for metabolism pathologies
7	Preparation time for radiation	2	Personalized monitoring by a virtual nurse assistant
8	Skin cancer self-scanning solutions	**H.**	**Robotics**
C.	**Labs**	1	Robot-assisted surgeries
1	Detection of pathogens	2	Auxiliary robot assisting nurses
2	Automation of data workflows in laboratory	3	Sleep assistant
3.	Characterisation of genomic sequencing		

All sources used to quantify the potential impact of AI of the different application categories can be found in the reference table in appendix

Impacts quantification

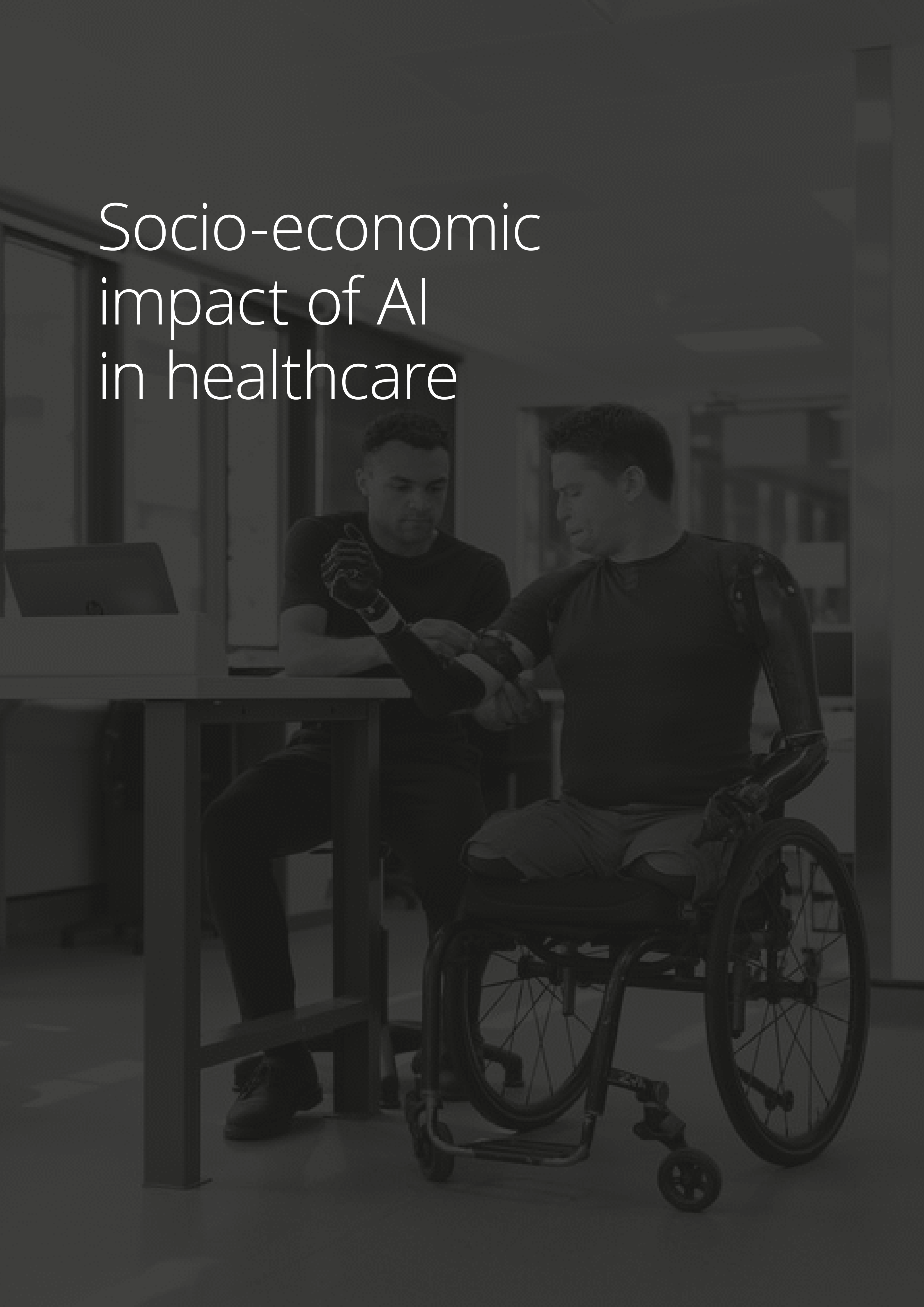
Once the different AI applications were clearly defined and mapped to eight application categories, the impact of AI in healthcare in Europe was estimated based on publicly available sources, such as peer-reviewed articles, reports, articles and blogs. Impact in healthcare was defined across four dimensions: healthcare workforce, financial resources, access and quality of care, and health outcomes. Impacts were quantified through three indicators:

- Lives saved – estimated by applying the impact that using AI has on mortality, and then multiplying this percentage by the annual number of deaths associated with a given condition (e.g. deaths related to breast cancer).
- Financial resources saved – estimated by applying the impact that using AI has on resource utilisation and costs. This indicator accounts both for savings (reduced cost of activities such as patient recruitment for trials) and opportunity costs (better use of HCP time, such as a doctor seeing more patients instead of working on health records).
- Time saved – estimated by applying the impact that using AI has on the duration of certain tasks performed by HCPs or patients (e.g. the time a nurse spends on home visits).

The impact was estimated for each AI application included in the eight application categories. Results were then aggregated and are presented by category.
Estimates are based on percentage year variation on a variable, e.g. accuracy rate of diagnosis, linked to the use of a given AI application. These values are based on published sources collected via targeted literature searches. The impact was calculated by translating the variation into one of the three indicators and extrapolating it for the entire European Union. Hence, figures presented in the report are annual values accounting for the EU 27. Results are presented in the body of the report, while the detailed list of sources used for each calculation is provided in the reference section. This is a standard approach to estimating socioeconomic impacts and in line with EU guidelines on impact assessment.[8]

The objective of this exercise was to provide an overall estimation of the socioeconomic impact of AI in healthcare in Europe. Some assumptions have been made to account for the lack of EU-wide data in this area, and results are presented as ranges to account for the uncertainty associated with the extrapolation. Investments related to adoption, capacity building and organisational change lie outside the scope of this report.

Socio-economic impact of AI in healthcare



1. Wearables

From smart watches and fitness trackers to biosensors and continuous glucose monitoring devices, wearable hardware can capture large amounts of personal health data. AI software can analyse it and make real-time recommendations to patients and healthcare professionals

The socioeconomic benefits of AI-enabled wearables can mostly be reaped in workforce improvements, reduced patient presentations, freeing healthcare professionals to concentrate on what they do best, and financial resources. Furthermore, significant improvements were observed in the access and quality of care, as well as health outcomes, thanks to the role these technologies play in enabling patient-centric prevention and care.

298,000 - 313,000
lives saved

€46.6 – 50.6
billion in savings (including opportunity costs)

301.6 - 336.1
million hours freed up

Wearables can be used in a variety of settings, including fall prevention, diagnosing cardiovascular disease, treating diabetes or COPD, remotely monitoring a patient's vital signs, and tracking patient activity pre- and post-surgery to monitor recovery.

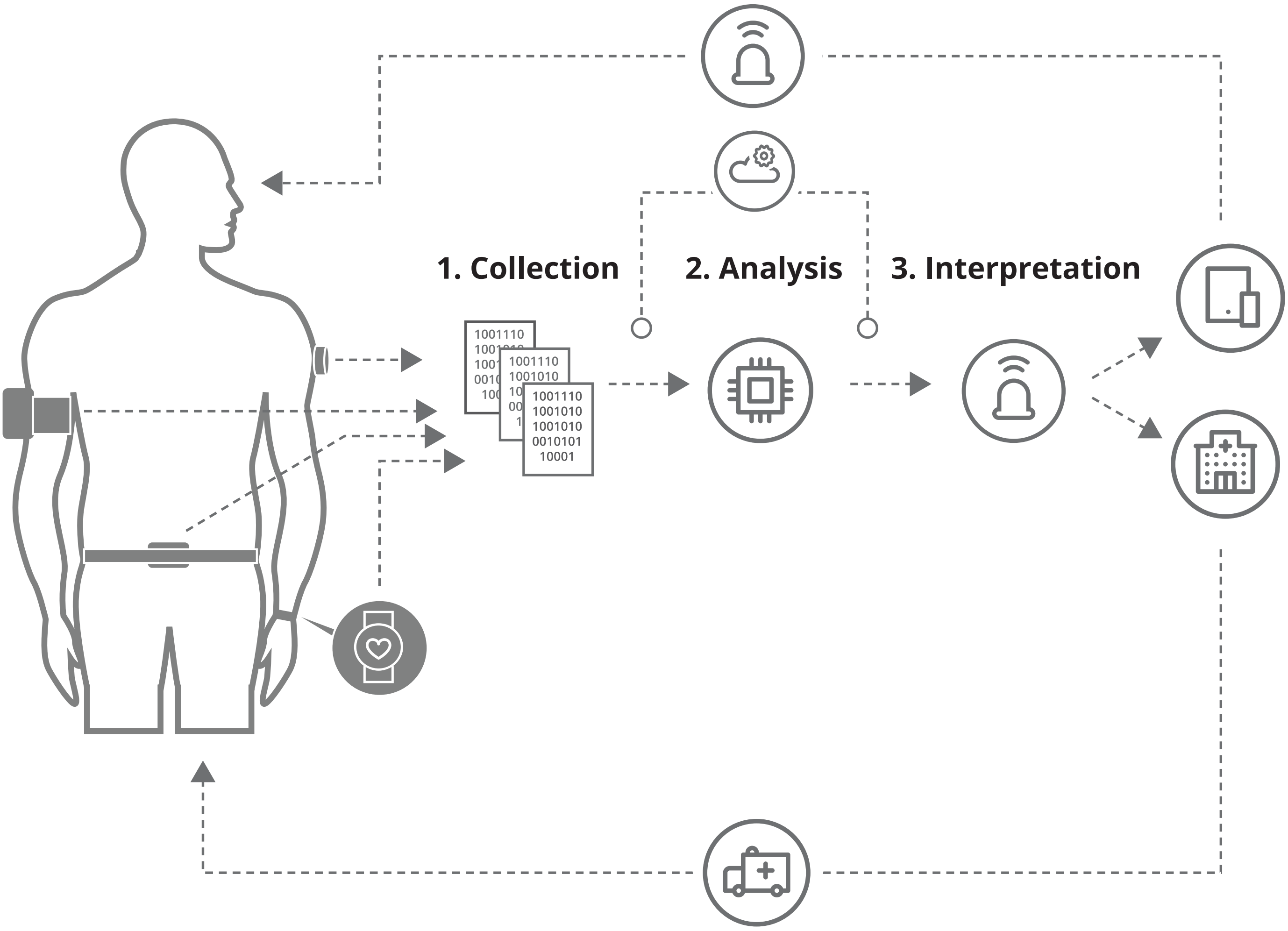
AI-enabled wearables show much promise in fall prevention for the elderly. **Accelerometer bracelets** or smart belts combined with an AI algorithm allow the accurate prediction of fall events pre- and post-impact. This application has the potential to help save 1,800 lives a year and decrease fall-related costs by as much as €3.8 billion.

AI applications in cardiology are also skyrocketing, especially in the diagnosis of cardiovascular diseases, such as heart failure. Atrial fibrillation and cardiac arrhythmias, important indicators of heart failure, can now be detected by a combination of **smart watches**[9] with electrocardiograms and AI algorithms. This has the potential to significantly reduce hospitalisations and save up to €36.9 billion.

Diabetes treatment will also be quite significantly impacted by AI in the next ten years. AI-enabled **continuous glucose monitors**[10], wearable devices that track blood sugar levels day and night, can predict highs and lows, and provide tailored health advice to patients. This not only improves quality of life, it also increases the accuracy of glucose measurements by as much as 40% compared to traditional (manual) tests.[11,12]

While wearables can be used by patients themselves, many opportunities arise for healthcare professionals as well. A wearable remote monitoring arm strap, for instance, can continuously track patients' vital signs, and send them for analysis by AI technologies. Nurses are automatically alerted if there is any deterioration, instead of having to check on their patients with daily home visits, potentially saving up to 301.8 million hours and €6.1 billion. Healthcare professionals can also use wearable activity trackers before and after surgery to monitor patient recovery. By analysing step counts, AI technologies can reduce the risk of re-admissions.

Figure 2: Data flows for AI-enabled wearables and related actions in case of deterioration



2. Imaging

Staff shortages in European radiology departments are not new and, according to industry experts, have been worsening in recent years. However, AI applications are already starting to fill in the gaps, among others, by analysing medical images, detecting pathologies and supporting healthcare professionals in the decision-making process

Many AI applications in medical imaging are trained on large sets of medical images. It enables them to detect clinical abnormalities, such as cancer, often faster and with the same or greater accuracy than specialists. This could have a high impact on health outcomes by saving lives with improved and more timely diagnosis, and through related cost savings. The potential impact on healthcare professionals is also significant, especially with regards to doctors' time.

36,000 - 41,000
lives saved per year

€16.1 - 18.6
billion in savings (including opportunity costs)

15.1 – 32.7
million hours freed up

AI is poised to have a tremendous impact on the interpretation of medical images in digital pathology: detecting, diagnosing and monitoring multiple pulmonary, cardiac and oncological pathologies. Furthermore, it can play a role in image acquisition and reconstruction, as well as in video processing to guide surgeons during procedures and 3D imaging.

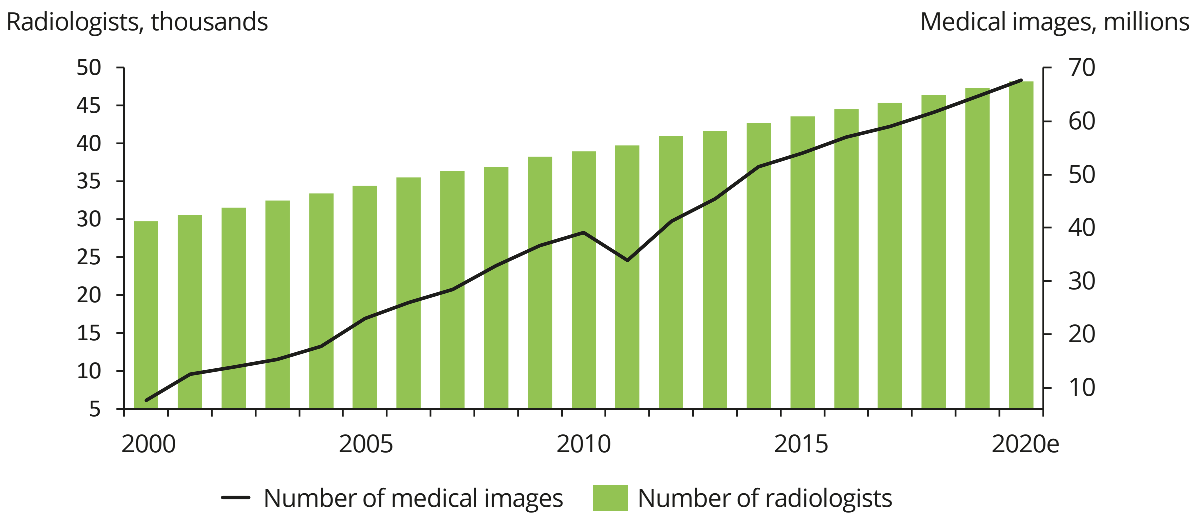
A chest X-ray is currently the best available medical imaging method for detecting multiple pulmonary pathologies, pneumonia among others. The images are analysed by expert radiologists to provide a diagnosis. Digital pathology algorithms can support this process by screening the images and autonomously detecting pathologies. In some cases, AI algorithms[13] outperform radiologists with regards to the accuracy of diagnosis. This has the potential to save up to 1,900 lives per year.

Another AI application in medical imaging is the early detection of coronary artery diseases (CAD). Combining coronary computed tomographic angiography images and clinical data, a machine learning algorithm was able to predict five-year mortality rates for patients at risk of CAD with greater accuracy than standard techniques. This could lead to improved treatment and care for patients, and potential cost savings of €7 billion for the healthcare system.

A promising combination of AI and medical imaging concerns the screening, diagnosis and treatment of breast cancer. Breast cancer continues to be one of the leading causes of death among women in the EU, with approximately 85,000 deaths per year.4 However, it can be successfully treated if detected early. Studies show that AI can significantly decrease the number of false positives and negatives during mammography screening.[14] It has been demonstrated that AI software was able to interpret mammogram results up to 30 times faster than doctors, with a 99% accuracy.[15] Moreover, when double reading of mammograms is necessary, AI can take the role of second reader. This can be especially useful in areas where there are not enough trained radiologists. Combined, these AI applications have the potential to save up to 16,000 lives and €7.4 billion annually.

AI can also have an impact upstream in the clinical radiology workflow. The first step concerns image acquisition through specific hardware, a CT scanner for instance. The reduction in radiation during image acquisition can have important benefits for patients. The second step is image reconstruction, done with software. The software has barely evolved in the last 25 years[16,17], and experts are currently looking into AI to enhance it. The objective is to improve the overall quality of the medical images, and subsequently decrease the radiation levels needed during image acquisition. These two elements have the potential to save 11,600 lives and close to €1 billion.

Figure 3: 62% more radiologists vs. 792% more medical images: PET, MRI, CT (EU 2000-2020)



Source: Eurostat, Deloitte analysis

Case Study – AI response to COVID-19[18]

AI can be used in the fight against COVID-19. An AI solution was developed to automatically detect and quantify suspected COVID-19 findings on chest CT-scans. Scans of patients diagnosed with COVID-19 were uploaded to the solution analytics engine, teaching the algorithm to detect specific visual fingerprints. By comparing the percentage of affected lung volume to the entire lung volume, the algorithm can detect COVID-19 rapidly. Moreover, it can help with triaging and monitoring COVID-19 patients by segmenting the suspected findings and quantifying the disease burden.

3. Labs

The lab of the future is set to transform the healthcare sector. AI will play an important role by enabling the rapid processing of large sets of scientific data and automating data workflows

AI-enabled laboratory applications can have a substantial impact on the workforce, partly by alleviating the work burden, especially for repetitive and routine tasks, and optimizing the duration of certain tasks.

€834.4 – 883.5
billion in savings (including opportunity costs)

50.4 – 53.4
million hours freed up

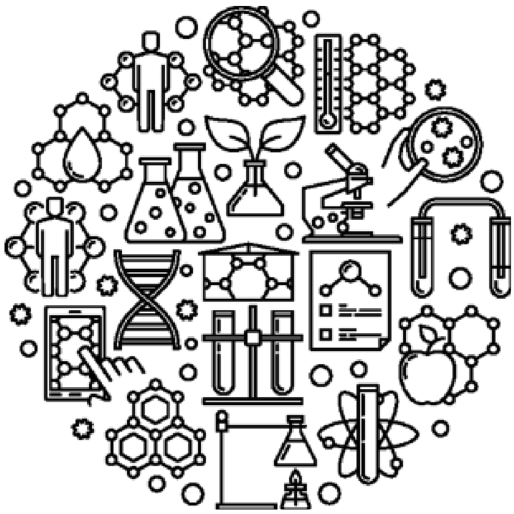
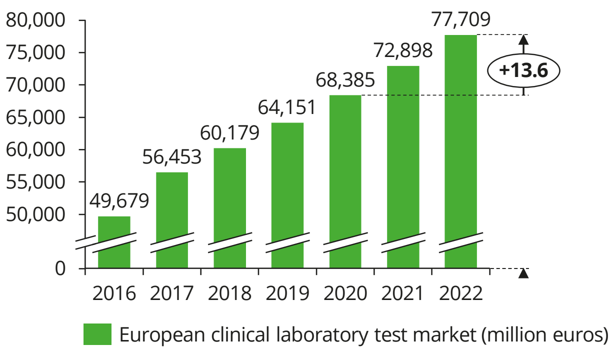


Figure 4: AI innovations can help sustain the growing European market in clinical laboratory tests



Source: https://www.marketresearchfuture.com/statistical-reports/europe-clinical-laboratory-test-market-3650

AI-enabled laboratory applications can be used in diagnosis, treatment and care management, and R&D. They have the potential to increase the understanding of disease pathology through better detection of infections, optimising database workflows in the laboratory, and improving prescriptions of treatment.

AI-enabled infection testing is the laboratory application with the largest potential to impact the healthcare sector. To analyse viral infections, microbiology techniques are used, such as quantitative polymerase chain reaction (qPCR) for analysing genome evolution. Test results are traditionally interpreted manually by clinical technicians with microscopes. Some AI algorithms can automate and standardise this process.[19,20,21] The algorithm analyses the progression of the viral genomes and compares it with historical data it has been trained on. Through pattern recognition, it can detect infections, taking on the role of clinical technician and reducing the lab workload. As a result AI could save up to 53 million hours of routine analyses for clinical technicians, linked to potential savings up to €883 million per year.

AI laboratory databases can improve R&D by enhancing the data quality from labs. For instance, some AI solutions automate laboratory data workflows for scientific discoveries.[22,23] The algorithm unifies different data streams from every piece of lab equipment by using image and language recognition. This ensures that every scientific discovery can be replicated and accessed on a centralised and secure cloud.

Case Study – Genomic sequencing and AI [24,25]

Patient treatment can potentially be improved by combining genomic sequencing with AI. An algorithm that captures variations in different genetic codes has been developed. Comparing these gene mutations with historical data, the algorithm can characterise the genomic variants associated with cancers and hereditary disorders. The algorithm can then predict an individual therapy response. This could help health providers treat patients with an optimal, personalised drug combination..

4. Physiological monitoring

Thanks to a wide variety of AI applications, patients can be followed remotely without having to be in a healthcare facility. This could enable the detection of health issues 24/7 and trigger a timely response when needed. For those in healthcare facilities, predictive monitoring can detect health events in advance

AI-enabled monitoring can have a positive impact on health outcomes, quantified in terms of lives saved per year. Additionally, monitoring can optimise resource utilisation, bringing substantial cost reductions.

39,000 – 42,000
lives saved per year

€43.6 – 45.7
billion in savings (including opportunity costs)

323.8 – 375.4
million hours freed up

Physiological monitoring can be used for a variety of purposes, including cardiovascular conditions, medication adherence, treatment decisions, diabetic retinopathy screening, sleep apnoea, and predicting health events (heart failure, seizures, hypotension, etc.).

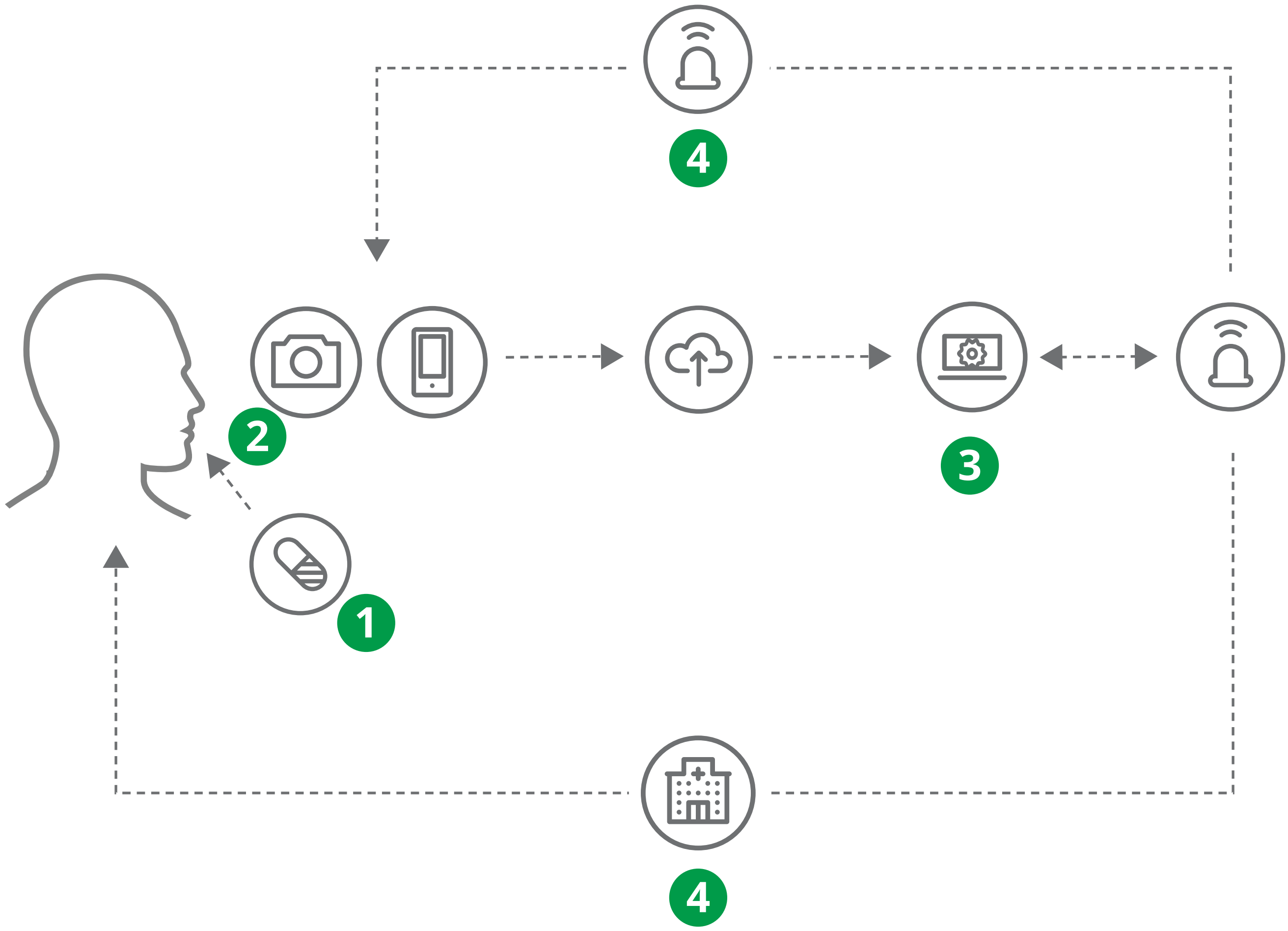
AI-enabled applications have the potential to monitor **medication adherence** and ensure continuity of care between visits, encouraging patients to take treatments as prescribed. Patients send selfies while taking their medication. An AI system analyses the images to make sure the medication was taken correctly and sends an alert if it was not. Lack of medication adherence is a critical issue for the European healthcare system, which could be partly solved with AI monitoring. Up to 20,000 lives per year could be saved and related costs could be reduced by as much as €45.6 billion.

AI monitoring could also support **treatment decision** by predicting health events (seizures, heart failure, etc.) before they occur, by analysing a patient's brain activity through a combination of an electroencephalogram and an AI algorithm. As another example, AI-based solutions can already predict health events such as intraoperative hypotension, by detecting rapid physiologic changes in critically ill patients ahead of time. Treatment decisions could thus be made in a more-timely manner, improving outcomes. Such predictive applications have the potential to help save about 22,000 lives yearly.

Doctors analyse patients' eye movement to assess brain health. Recently, AI monitoring applications, such as **eye-tracking technologies** linked to machine learning, have helped predict neurological impairment faster and with more precision by analysing the retina of the patient. As a result, patients do not require eye drops for dilation. Such retinal scan applications can be used for monitoring multiple sclerosis. This has the potential to free up 375,000 hours of HCP time and save €27.4 million.

In addition, AI applications combined with machine learning could help decrease the screening cost of detecting **diabetic retinopathy.** Using semi- or fully-automated screening models based on AI is significantly faster and as accurate as human-based processes. Such applications have the potential to save up to €59 million.

Figure 5: Non-adherence in Europe causes approximately 200,000 deaths and 102.5 billion in



- **1** Doctor prescribes medication
- **2** Patient sends selfie taking medication
- **3** AI analyses image
- **4** If non-adherence detected:
  - send notification to patients
  - Or send alert to doctor

5. Real world data

The increasing impact of smart technologies on everyday activities, including those directly related to healthcare services, generates huge amounts of real world data (RWD). Using RWD with predictive AI models can unlock major evolutions in the healthcare sector by generating insights through linking multiple data sources

AI-generated insights via RWD can reduce R&D costs and improve disease prevention and diagnosis. Indirectly, this can lead to greater benefits for healthcare systems and patients, thanks to faster and less costly innovation.

between
€14.0 - 38.0
billion in savings (including opportunity costs)

WD is derived from data routinely collected from a variety of sources[27,] including:

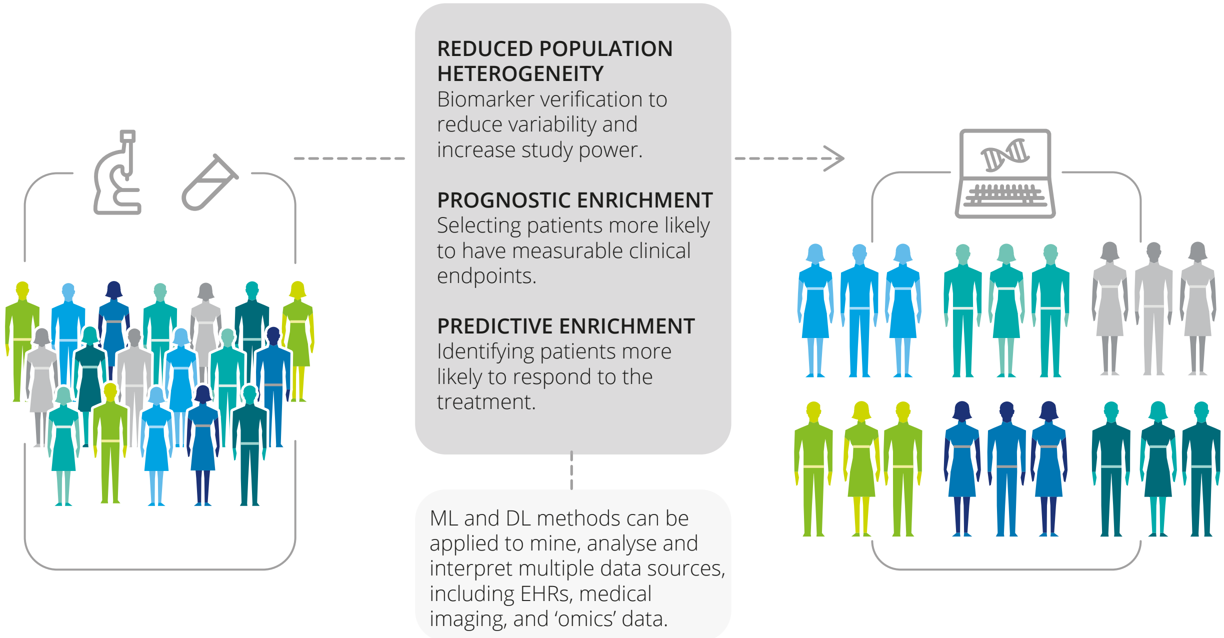
- Electronic health records (EHRs)
- Claims and billing activities
- Product and disease registries
- Patient-generated data, including at home
- Health-status data from other sources, such as mobile devices

AI applied to RWD can identify meaningful patterns to help improve prevention and population health management. Currently, RWD is widely used to design clinical trials, mainly in the patient recruitment stage. For instance, some oncology applications use AI tools in to organise RWD into patient journeys aligned to specific treatments. By correctly matching eligible patients to the right trials, this can speed up the patient identification process and increase patient enrolment in clinical trials by 20-50%.[28] Finally, it has the potential to reduce the dropout rate[29] (Figure 6). This leads to accelerated clinical development timelines and can result in a 34%[30] decrease in clinical trial costs (Figure 7), potentially saving €38 billion per year.

Additionally, AI and RWD can predict **drug effectiveness**. Analysis of RWD can lead to clinical evidence regarding the use and potential effects of medical products, known as real world evidence (RWE). For instance, some AI solutions[31,32] have the potential to predict a patient's response to possible drug treatments. The algorithms leverage genomics and genetics data found in medical claims, lab results and electronic health records, searching for combinations of elements that affect the patient's response to drug treatment and compare these elements with the patient's case.[33,34] Valid conclusions on the effectiveness of specific drugs can then be extrapolated.

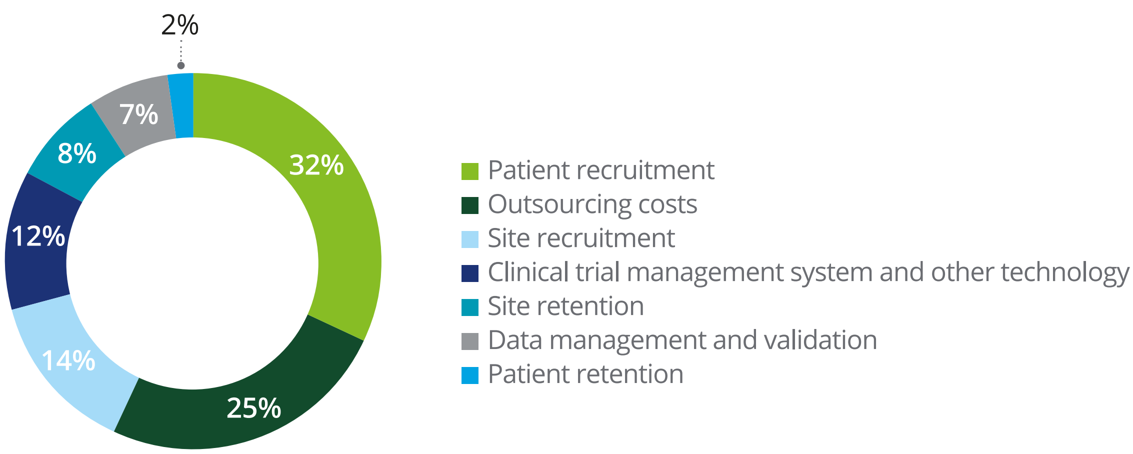
Finally, AI applied to RWD has the potential to become crucial for pharmacovigilance. Drug safety is designed to assess and report the undesired effects of pharmaceutical products. The safety process is traditionally done manually, based on analysing information from patients and healthcare providers. AI can automate this process by extracting and reporting information on undesired effects automatically based on historical data.[35] Taken together, these advancements in RWE have the potential to deliver a significant efficiency boost to the current pharmacovigilance operating model.

Figure 6: AI can improve patient selection by organising RWD into patient journeys aligned to specific treatments



Source: https://www2.deloitte.com/content/dam/insights/us/articles/22934_intelligent-clinical-trials/DI_Intelligent-clinical-trials.pdf

Figure 7: Patient recruitment: main cost driver in clinical trials



Source: https://www2.deloitte.com/content/dam/insights/us/articles/22934_intelligent-clinical-trials/DI_Intelligent-clinical-trials.pdf

6. Virtual health assistance

AI applications are emerging to reduce the burden of administrative tasks on doctors and medical personnel. This will enable a higher quality of care by improving access, thanks to shorter waiting times

AI-enabled virtual health-assistance applications can lead to large reductions in the workload of healthcare professionals. Along with decreasing the work burden of administrative tasks, costs can be significantly reduced.

€32.0 - 36.8
billion in savings (including opportunity costs)

961.1 - 1,154.0
million hours freed up

Virtual health assistance can be used for a variety of purposes, including reducing transcription burdens, extracting medical information, helping doctors with general administrative tasks, and answering patient questions.

AI-enabled transcription assistance shows much promise in the automation of medical transcription. **Virtual scribes** – linked to machine learning or smart speaker devices and combined with an AI algorithm – are able to completely transcribe clinical data recorded between patients and physicians. These voice-to-text applications can be used to take notes about symptoms, write prescriptions, order additional tests, arrange follow-up appointments and classify into categories and enter everything into the patient's electronic health record. This could reduce the burden on healthcare professionals by up to 507.2 million hours, translated into a yearly opportunity cost of about €7.9 billion.

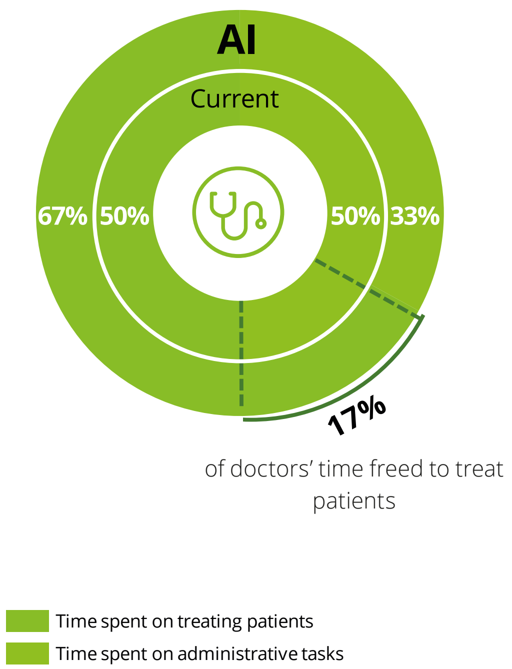
AI-powered solutions can augment human workers by helping them answer patient questions more efficiently and accurately. These applications can quickly extract information from individual electronic health records and provide personalised answers based on the patient's current medical condition. This has the potential of freeing up 147.1 million hours of HPC time, representing savings of up to €1.6 billion.

Next, several similar AI applications designed to specifically support doctors with **administrative tasks** have come to market. For instance, AI-enabled chatbots can engage with patients to answer their questions. These applications could save doctors a considerable amount of time, potentially up to 499.8 million hours and €27.3 billion.

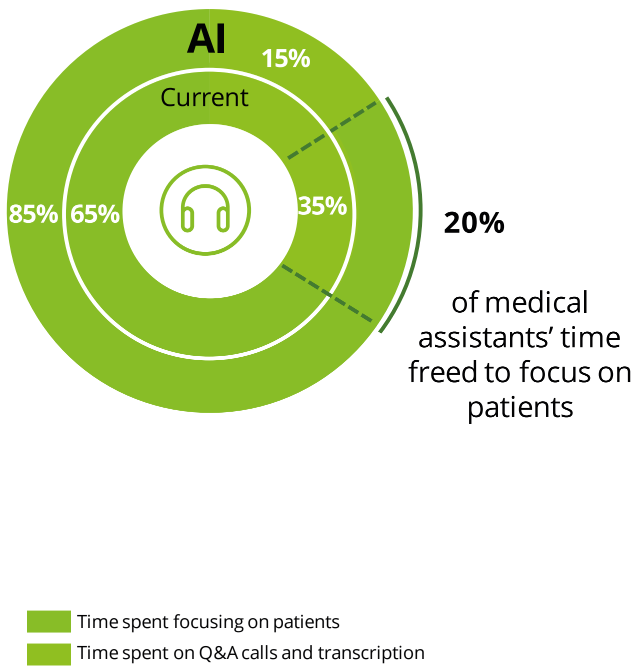
Last, virtual health assistance is also about providing virtual care and help to patients. AI-based **chatbots** focused on specific diseases can answer patient calls, provide complete answers to their questions and recognise their symptoms.

Figure 8: Use of AI to reduce burden of administrative tasks to healthcare professionals

Administrative burden on physicians



burden on medical assistants of Q&A calls and transcription



7. Personalised apps

More and more patients are discovering the possibilities of having a better understanding of their own health conditions thanks to personalised apps. Personal health and lifestyle management will be impacted in major ways by AI. The field is a hotbed of innovation.

Personalised apps and AI could play a significant role in improving health outcomes, quality and care. This can be reflected in a potentially significant number of lives saved per year. Another important impact could be improved use of financial resources, mostly from large cost reductions in metabolism pathology areas.

6,000 – 7,000
lives saved per year

€1.5 – 1.6
billion in savings (including opportunity costs)

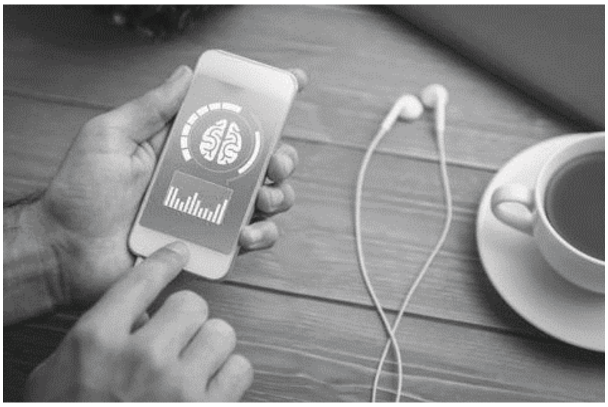
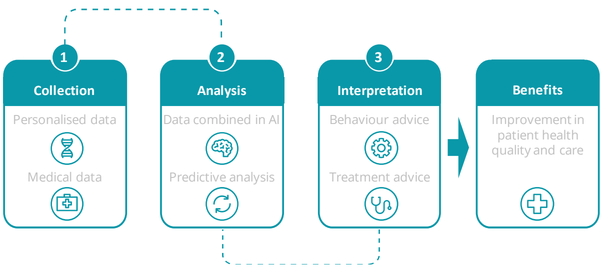


Figure 9: Personalised advice via personalised apps improves health quality and care



AI-enabled personalised apps could have a great effect on both patients and health professionals. Different applications in the fields of prevention and care management demonstrate their potential in treating metabolism pathologies and in supporting nurses.

The largest potential lies in **metabolism pathologies**, such as obesity. Treatment can be improved with an AI-enabled personalised app that provides intensive ad-hoc behavioural counselling to help change health-related behaviour. For instance, some AI nutrition apps[36] provide personalised eating plans by analysing data about a person's unique gut microbes and dietary inflammation. Enabling weight loss, these apps have the potential to annually save up to €1.6 billion in healthcare costs and save 7,000 lives. Other AI-enabled personalised apps[37] give notification alerts based on the patient's health history and the geolocation available in their smartphone. The proximity of fast-food outlets or bars, for instance, can activate the app to send motivational messages to keep the patient following a healthy lifestyle.

AI-powered personalised apps can also be used in **care provision**. For example, nurse applications[38] can improve treatment for chronic diseases via a virtual nurse assistant for personalised monitoring and follow-up care. The patient is guided by an avatar through the treatment process, receiving instant feedback. The app monitors health conditions, keeps track of doctor appointments and predicts follow-up treatments. Additionally, it can support patients with notification alerts, ensuring they adhere to their medication. Other applications[39] can answer patient questions, thanks to AI based on personal health records and medical-question history. Finally, AI-enabled personalised apps can gather feedback, patient-reported outcome measures and patient-reported experience measures, predicting adjustments to the treatment plan based on medical history.

8. Robotics

Although not widely used in healthcare currently, robotics in combination with AI has the potential to disrupt the way care is provided. Healthcare providers could save more lives and improve patient outcomes, thanks to greater accuracy and the optimisation of human-driven decisions and actions

Robotics has the potential to lead to important cost reductions improving financial resources of hospitals. Additionally, robotics could take away some workload from the medical staff enabling them to focus more on valuable activities like patient interactions.

€16.4 – 20.4
billion in savings (including opportunity costs)

330.8 – 367.5
million hours freed up

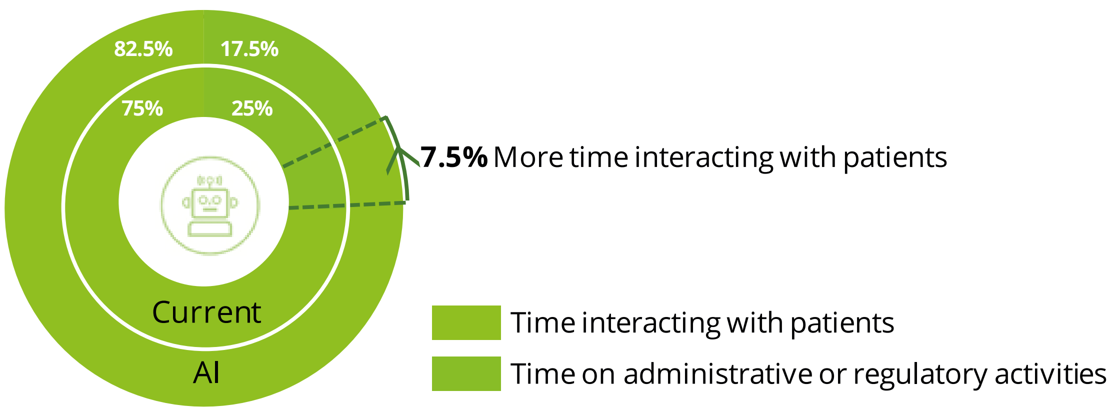
Case Study – Robot pillow[44, 45]

A robot pillow uses AI to improve the sleep of its users. It simulates a personalised optimal breathing rhythm based on data captured by sensors. Furthermore, its integrated stereo provides the user with relaxing music. This has a positive impact on patient health outcomes, resulting in a decrease of 21 minutes36, or approximately 70%, to fall asleep.

Such technologies include control, perception, sensors, and actuators, as well as the integration of other techniques into cyber-physical systems. These technologies can be applied at every step of the patient journey.

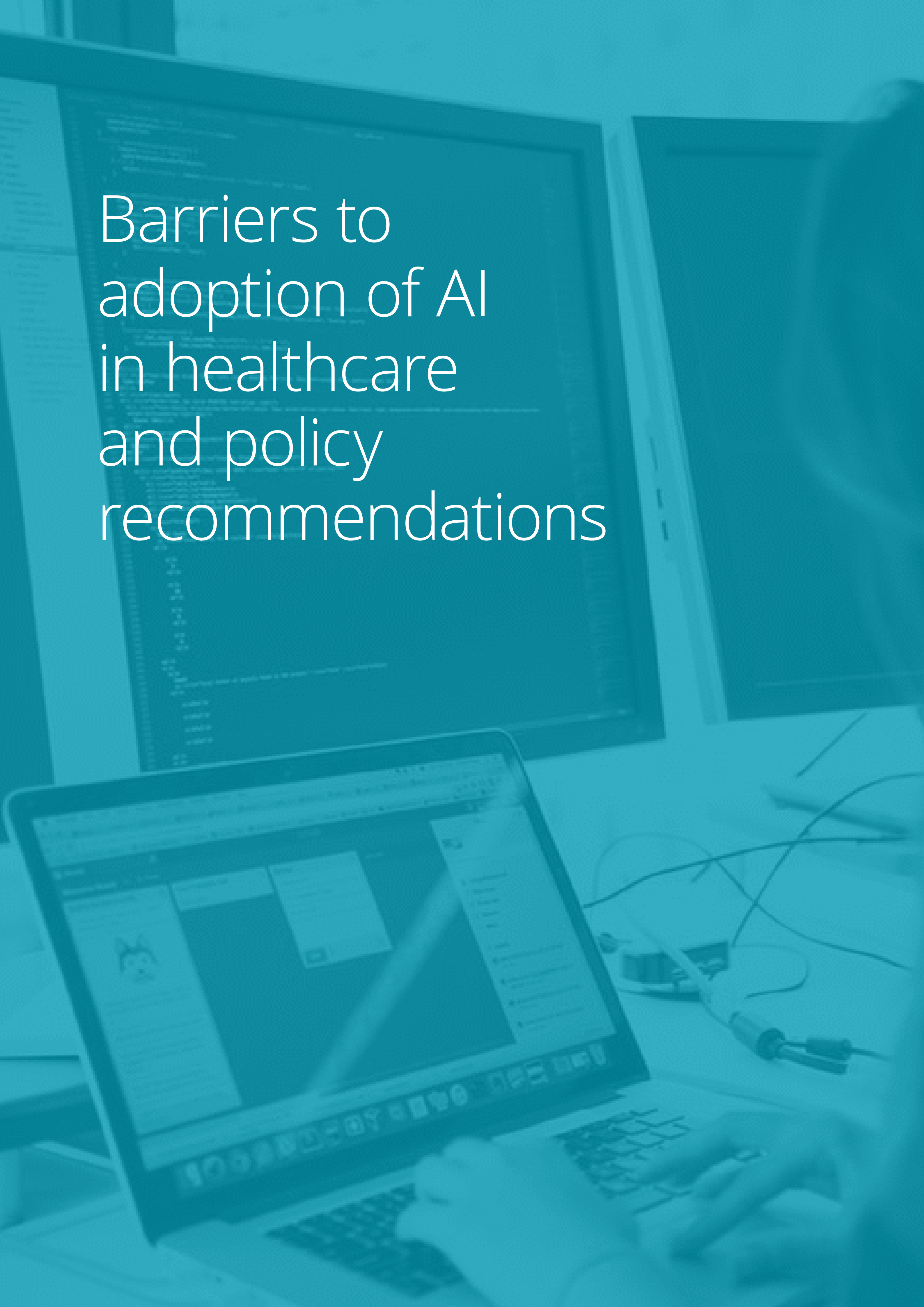
One of the most promising is robot-assisted surgery powered by AI software. For instance, AI-enabled robot hands[40] can use data from past operations to perform new surgical techniques, reducing the risk of human error. Such applications could potentially save up to 35.9 million days of hospital stay, leading up to €12.9 billion of savings per year. And post-surgery hospital stays could be reduced up to 21%.[41] Another impact of robot-assisted surgery is a 52% increase in the success rate of nephrectomy operations.[42] Additionally, robot assisting-nurses can have major benefits for medical staff, reducing their work burden by taking care of repetitive tasks. For instance, auxiliary robots[43] can take care of restocking supplies, transporting medical equipment, and cleaning and disinfecting patient rooms. Via cameras and sensors they can capture key information, such as weight, colour and sound. These robots have the potential to handle approximately 30%[44] of clinical nurse tasks that do not involve interacting with patients. Hence, nurses can save up to 368 million hours per year, representing up to €7.4 billion in potential savings annually.

Figure 10: Nurse interaction time with patients



Source: https://www.fastcompany.com/90372204/a-hospital-introduced-a-robot-to-help-nurses-they-didnt-expect-it-to-be-so-popular

Barriers to adoption of AI in healthcare and policy recommendations



AI in healthcare: barriers to adoption and policy recommendations

AI has the potential to have a significant socioeconomic impact on healthcare in Europe by improving patient outcomes and access to healthcare, as well as optimising the use of resources. However, in order to reach its full potential a number of barriers must be addressed by public policy

Potential barriers to the adoption of AI in European healthcare can be grouped into four domains: data challenges, legal and regulatory challenges, organisational and financial challenges, and social challenges.

Data challenges

AI relies on data, and it is crucial that the type, quality and sensitivity of the data is carefully considered, especially in healthcare. Good data is the key to training unbiased, robust and safe AI.

1. **Fragmented data landscape and interoperability.** In our digital world large amounts of data are continuously generated. AI applications can benefit from this rich information provided it can be accessed and processed. With most data currently is held in silos, different stakeholders are not always able to transfer or compare it. This hinders its use and reduces the potential that AI can deliver. The European Health Data Space project promises to address these challenges.
2. **Data quality**. As with any medical practice, AI in healthcare requires access to high quality, accurate, representative and interpretable data in order to deliver meaningful insights. Existing data must be carefully evaluated to ensure it meets the requirements for a medical AI solution.
3. **Data privacy and protection**. Healthcare data is subject to strict privacy and data protection regulations. As AI applications multiply, it is important to establish which information can be used where, by whom and for what purposes. This will ensure a fair balance between data privacy and the benefits that data-driven insights can generate. More consistent interpretation and implementation of existing data-protection legislation would help to foster the data access and connectivity that empowers AI solutions, while preserving the right to privacy.
4. **Cybersecurity.** Healthcare data is an increasingly attractive target for cybercriminals. The IT systems of some hospitals and clinics might not meet the latest cybersecurity standards. To fully benefit from AI solutions, all stakeholders must update and maintain secure IT systems and infrastructure, and train patients and staff in safe-data protocols

Legal and regulatory challenges

AI technology can be subject to different legal frameworks depending on its characteristics and use. AI in healthcare is mainly regulated via the Medical Devices Regulation (Regulation 93/42/EEC) and the In-vitro Diagnostics Regulation (EU Regulation 2017/745). This is because medical devices are often either developed using AI or they have an AI component. Other relevant legislative frameworks are the General Data Protection Regulation (EU Regulation 2016/679) the Product Liability Directive (Directive 85/374/EEC).

While current legislative frameworks function adequately, as innovation rapidly progresses, more clarity, guidance and rules are needed. Flexible legislation that allows novel approaches to meeting requirements can ensure legal certainty for future technologies.[45] The medical technology industry believes this would promote innovation and competitiveness, enabling developers to more readily navigate the highly regulated European medical technology sector.

AI applications should not only be consistent with the law. They must also adhere to ethical principles and ensure their implementations avoid unintended harm. This was highlighted in Ethics Guidelines for Trustworthy AI, published by the European Commission in 2019.[46]

Organisational and financial challenges

Digitalisation and AI inclusion in European health systems will require substantial investments in several areas. Infrastructure. The European Health Data Space project will go a long way to ensuring data is compatible and easily transferred. To fully benefit from AI, some hospitals and clinics might need to update their IT systems to facilitate the inclusion of AI in current care delivery processes.

1. **Digitalisation adaption**. As healthcare systems shift towards a more digital world, healthcare professionals have to adapt their clinical pathways. This will impose an implementation burden before AI fully delivers its efficiencies. Of course, AI technologies will be adopted more rapidly if they are cost-efficient.

2. **Technologies**. AI technologies come at a cost. Current pricing and reimbursement mechanisms are not necessarily suitable for covering the use and adoption of AI technologies, despite the advantages they bring. Some centres of excellence are already conducting cost-benefit studies to assess the value of introducing AI into their care pathways. But this is not being done consistently across Europe.

3. **Skills and training**. Introducing AI applications will revolutionise hospital operational models. Healthcare workers will need training in the use of these novel technologies. At the same time, new job profiles must be created to train and recruit individuals with the right mix of IT and medical skills.

4. **Shift from care to prevention**. AI has the potential to improve disease prevention and early detection. This requires a shift in the way care provision is organised and the way the workload is allocated across the different healthcare disciplines.

AI will be difficult to fit into traditional financing/reimbursement models. Consequently, the broader adoption of AI in healthcare will require novel approaches to funding, evaluating and reimbursing technologies. This will ensure a clear route-to-market for digital innovations and provide guidance for rewarding them.

Social challenges

Along with organisational and financial challenges, the social aspects of AI adoption will need to be addressed.

1. **Trust and explanation**. Most users lack proficiency in managing data and digital technologies. Add to this a lack of trust in data management and use. There is a need for relevant training, as well as clear and convincing explanations about AI-generated insights and their benefits.

2. **Governance**. Successful use of AI will require stakeholders at multiple levels to cooperate and clearly define their roles and responsibilities. Participants include governments, healthcare professionals, academia and industry, as well as society at local, national and European levels.

3. **Patient empowerment**. Maximising the shift from care to prevention and the adoption of new digital solutions will require a change in mindset and a higher level of digital health literacy among citizens, especially patients.

Although the adoption of AI in European healthcare will face challenges, these can be mitigated by focusing on key areas. They include making AI trustworthy, carefully managing data, making it usable for AI applications, communicating the benefits of AI, providing guidance on applying regulations to AI technologies, and finally, funding their adoption.

Policy recommendations

In order to unlock the full potential of AI in healthcare, European health systems and the broader ecosystem will need to make improvements in a range of areas. These include how such technologies are evaluated and reimbursed, workforce skills and training, data access and control, connectivity and interoperability, and empowerment.

As the dialogue on the future of AI in healthcare progresses, our analysis has identified some policy priorities to address the barriers discussed in the previous section.

The recommendations presented below are overarching and intended for a wide range of national and EU stakeholders that might play a role in successfully integrating AI technologies in European health systems. These recommendations can help accelerate the benefits of AI and ensure they are harmonised across all EU Member States.

- Develop policy frameworks to build trust and foster the adoption of AI in healthcare.
- Build and maintain a balanced regulatory environment, based on existing applicable regulations, that enables and stimulates future technological innovation and evolution.
- Build data policies and infrastructure (in line with the European Health Data Space project) to foster seamless access, connectivity and sharing of high-quality, harmonised data.
- Define clear governance and partnerships across healthcare professionals, academia, decision-makers and industry.
- Ensure appropriate commercial incentives and reimbursement mechanisms to foster innovation in Europe and support patient access.
- Advance data interoperability by defining data format standards, so data is generated and transferred in a more consistent way across market participants and Members States.
- Advance AI skills among HCPs, and digital health literacy among citizens (especially patients) to ensure the benefits will be achieved equitably across the EU regardless of proximity to a centre of excellence.

Conclusion

Conclusion

The analysis demonstrated that AI technologies have the potential to deliver great benefits for European health systems and EU citizens. Current use of AI to assist healthcare organisations in providing more efficient and accurate care provides a basis for increased adoption, allowing the benefits to be harmonised across all EU Member States.

This report aims at mapping the potential impact and barriers that could hinder the full achievement of AI's potential. The insights should be used to understand the size of the potential rather than net benefits, since the analysis does not estimate the cost of implementing and adopting AI.[47]

The European AI strategy and the coordinated plan developed by the European Commission make trust a prerequisite for ensuring a human-centric approach to AI. It should not be seen as a solution to all challenges that healthcare systems face, but as a tool with the potential to serve HCPs and individuals, with the ultimate objective of improving human well-being. Moreover, a shift to proactive disease prevention could empower patients and further engage them in care decisions. At the same time, a fair balance must be made between data privacy and the benefits that data-driven insights can generate.

To unlock the full potential of AI in healthcare, European health systems and the broader ecosystem need to make improvements in a number of areas, including the ways such technologies are evaluated and reimbursed, workforce skills and training, and data interoperability and ownership.

As the number of AI applications grows and the technology develops, applying it without due care could lead to problematic outcomes, as well as public reluctance to accept or use it.[48] As devices get smarter, they rely more on algorithms to make suggestions (e.g. showing the links between behaviour, biometrics and disease) and take actions (e.g. surgery-assisting robots). This could result in ineffective actions if the data that decisions are based on is: incomplete and thus unreliable, vulnerable to tampering by cyber-attackers, possibly biased, or simply incorrect. This requires a fresh look at how we make sure these approaches will have the intended effects. It therefore becomes essential that such algorithms are subjected to transparent standards in approval procedures.

These barriers can be overcome with the collaboration of all stakeholders in the ecosystem: policy makers at all levels (EU, national and regional), healthcare providers, academia, industry and citizens. With this broad partnership, AI innovation and adoption can help ensure high-quality care for European citizens and put the EU at the forefront of a very innovative industry.

Appendix

Assumptions

Main assumptions used per category in this report are:

- Results are presented as a range and the upper and lower values of the interval reflect the multiple sources available on the impact of a given AI application.
- Extrapolation for EU 27 is based on EU population data and GDP data (Eurostat) when EU figures are not available.
- Monetary savings do not include the investment required to introduce the technology, i.e. cost of the technology, infrastructure and HCPs training.
- Health outcomes are characterised via impact on hospitalisation and mortality.
- HCPs time saved is based on average working hours in the EU.
- The salaries of HCP's (neurologists, doctors, nurses, radiologists, laboratory workers, ophthalmologists, physicians and medical assistants) in Europe are based on the average of national data.
- The number of surgeries in Europe is based on WHO data.
- The R&D investments in Europe are extrapolated from the R&D investments in Belgium.
- The number of breast cancer tests is based on the proportion of women aged between 50 and 69 years in Europe that had one breast cancer test in 2019 multiplied by the total population of women aged between 50 and 69 years in Europe that year.

To calculate the impact of a given AI application, baseline data to AI applications data are compared by calculating the variation on a given variable related to the use of AI. This is then used to estimate the impact on resources utilisation and health outcomes. Results are per year and extrapolated to represent EU 27 for each AI application.

For example:

- Auxiliary robots assisting nurses can reduce time spent on tasks that do not involve patients' interactions by 30%. Hence, as
- nurses spend 25% of their time on administrative/regulatory activities
- there are 3 millions nurses in Europe
- The average salary of a nurse in Europe is €34,646 per year

We can determine that auxiliary robots assisting nurses could save up to €7.8 Billion per year in Europe (30%*3M*25%*€34,646).

Key References

- *Artificial Intelligence in Medical Technology: Delivering on the Promise of Better Healthcare in Europe;* **MedTech Europe** (https://www.medtecheurope.org/wp-content/uploads/2019/11/MTE_Nov19_AI-in-MedTech-Delivering-on-the-Promise-of-Better-Healthcare-in-Europe.pdf)

- *The future of artificial intelligence in health care - How AI will impact patients, clinicians, and the pharmaceutical industry;* **Deloitte** (https://www2.deloitte.com/us/en/pages/life-sciences-and-health-care/articles/future-of-artificial-intelligence-in-health-care.html)

- *Artificial Intelligence in Medicine and Healthcare: applications, availability and societal impact;* **Joint Research Centre** (https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120214/jrc120214_ai_in_medicine_and_healthcare_report-aiwatch_v50.pdf)

- *White Paper on Artificial Intelligence A European approach to excellence and trust;* **European Commission** (https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf)

- *Transforming healthcare with AI The impact on the workforce and organisations* **EIT Health** (https://eithealth.eu/wp-content/uploads/2020/03/EIT-Health-and-McKinsey_Transforming-Healthcare-with-AI.pdf)

- *Artificial Intelligence in Healthcare;* **Adam Bohr & Kaveh Memarzadeh** (https://www.elsevier.com/books/artificial-intelligence-in-healthcare/bohr/978-0-12-818438-7)

- *AI in Health A Leader's Guide to Winning in the New Age of Intelligent Health Systems;* **Tom Lawry** (https://books.google.nl/books/about/AI_in_Health.html?id=wswhywEACAAJ&redir_esc=y)

References used for the impact estimation

	Category	Main sources
A.	**Wearables**	
1	Prediction of falls	• Wearable Technology Applications in Healthcare: A Literature Review, 2019, Online Journal of Nursing Informatics Contributors, Min Wu, PhD and Jake Luo; Available from: https://www.himss.org/resources/wearable-technology-applications-healthcare-literature-review
		• Falls among older adults in the EU-28: Key facts from the available statistics, 2015, EuroSafe, Samantha Turner, Rupert Kisser, Wim Rogmans; Available from https://eupha.org/repository/sections/ipsp/Factsheet_falls_in_older_adults_in_EU.pdf
		• https://www.jnj.com/johnson-johnson-launches-heartline-the-first-of-its-kind-virtual-study-designed-to-explore-if-a-new-iphone-app-and-apple-watch-can-help-reduce-the-risk-of-stroke accessed on 12/10/2020
2	Prediction of heart failure	• Artificial Intelligence (AI) and Cardiovascular Diseases: An Unexpected Alliance, 2020, Cardiology Research and Practice, Silvia Romiti, Mattia Vinciguerra, Wael Saade , Iñaki Anso Cortajarena, and Ernesto; Available from: https://www.hindawi.com/journals/crp/2020/4972346/
		• https://www.bostonscientific.com/en-US/medical-specialties/electrophysiology/heartlogic-heart-failure-diagnostic/clinical-data.html accessed on 14/09/2020
		• Efficient Epileptic Seizure Prediction Based on Deep Learning, 2019, IEEE, Hisham Daoud and Magdy A. Bayoumi; Available from: https://ieeexplore.ieee.org/document/8765420/authors#authors
		• https://academic.oup.com/eurheartjsupp/article/6/suppl_D/D57/364381 accessed on 14/09/2020
3	Continuous glucose monitoring	• The Rationale for Continuous Glucose Monitoring-based Diabetes Treatment Decisions and Non-adjunctive Continuous Glucose Monitoring Use, 2016, US National Library of Medicine, David Price and Tomas Walker; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5813454/
		• https://www.uhs.nhs.uk/ClinicalResearchinSouthampton/Research/News-and-updates/Articles/Doctors-trial-device-that-monitors-glucose-levels-in-children-with-diabetes.aspx, accessed on 14/09/2020
		• Variability of Diabetes Alert Dog Accuracy in a Real-World Setting, 2017, Journal of Diabetes Science and Technology, Linda A. Gonder-Frederick, Jesse H. Grabman, Jaclyn A. Shepard, Anand V. Tripathi, Dallas M. Ducar, and Zachary R. McElgunn; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5588823/
		• https://www.medtronicdiabetes.com/treatments/continuous-glucose-monitoring accessed on 14/09/2020
		• https://ec.europa.eu/health/sites/health/files/state/docs/2018_healthatglance_rep_en.pd accessed on 14/09/2020
		• https://www.diabetes.org.uk/guide-to-diabetes/managing-your-diabetes/testing#Howtotest accessed on 14/09/2020
4	Remote monitoring with arm straps	• https://www.digitalhealth.net/2019/11/remote-monitoring-saves-nurses-time/ accessed on 14/09/2020
		• https://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_personnel_statistics_-_nursing_and_caring_professionals accessed on 14/09/2020
		• https://www.researchgate.net/figure/Percentage-of-long-term-care-services-providers-that-provide-mental-health-or-counseling_fig7_279301309 accessed on 14/09/2020

	Category	Main sources
5	Pre/post-surgery monitoring with activity trackers	• Fitbit step counts during inpatient recovery from cancer surgery as a predictor of readmission, 2018, US National Library of medicine, Carissa A Low, Dana H Bovbjerg, Steven Ahrendt, M Haroon Choudry, Matthew Holtzman, Heather L Jones, James F Pingpank, Lekshmi Ramalingam, Herbert J Zeh, III, Amer H Zureikat, and David L Bartlett; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6051699/
		• https://www.yumpu.com/en/document/read/14608448/hospital-readmissions-in-europe accessed on 14/09/2020
6	Patient's recovery monitoring in neurology	• https://www.synphne.com/ accessed on 14/09/2020
		• Country resources for neurological disorder, 2004, WHO Library, Dr L. Prilipk; available from https://www.who.int/mental_health/neurology/neurogy_atlas_lr.pdf?ua=1
7	Pill-cam	• https://www.medtronic.com/covidien/en-us/products/capsule-endoscopy/pillcam-sb-3-system.html#pillcam-recorder-3 accessed on 14/09/2020
B.	**Imaging**	
1	Detection of pulmonary pathologies with chest X-rays	• CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning, 2019, Article, Pranav Rajpurkar, Jeremy Irvin, Kaylie Zhu, Brandon Yang, Hershel Mehta, Tony Duan, Daisy Ding, Aarti Bagul, Robyn L. Ball, Curtis Langlotz,Katie Shpanskaya, Matthew P. Lungren, Andrew Y. Ng; Available from: https://arxiv.org/pdf/1711.05225v3.pdf
		• AI in medical imaging may make the biggest impact in healthcare, 2017, Healthmanagement, Margaretta Colangelo, Dmitry Kaminskiy; Available from: https://healthmanagement.org/c/hospital/issuearticle/ai-in-medical-imaging-may-make-the-biggest-impact-in-healthcare
		• Pneumonia in adults, 2016, National Institute for Health and Care Excellence, Nick Baillie , Karen Slade, Stephanie Birtles, Sabina Keane, Esther Clifford, Jenny Mills, Julia Sus; Available from: https://www.nice.org.uk/guidance/qs110/resources/pneumonia-in-adults-75545291391685
		• Pneumonia in adults, 2016, National Institute for Health and Care Excellence, Nick Baillie , Karen Slade, Stephanie Birtles, Sabina Keane, Esther Clifford, Jenny Mills, Julia Sus; Available from: https://www.nice.org.uk/guidance/qs110/resources/pneumonia-in-adults-75545291391685
		• Deaths from pneumonia in EU regions, 2019, Eurostat; Available from: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20191112-1#:~:text=In%202016%2C%20131%20450%20people,of%20all%20deaths%20in%202016
2	Detection of coronary artery diseases	• Machine learning for prediction of all-cause mortality in patients with suspected coronary artery disease: a 5-year multicentre prospective registry analysis, 2017, National Library of Medicine, Manish Motwani, Damini Dey, Daniel S Berman, Guido Germano, Stephan Achenbach, Mouaz H Al-Mallah, Daniele Andreini, Matthew J Budoff, Filippo Cademartiri, Tracy Q Callister, Hyuk-Jae Chang, Kavitha Chinnaiyan, Benjamin J W Chow, Ricardo C Cury, Augustin Delago, Millie Gomez, Heidi Gransa, Martin Hadamitzky, Joerg Hausleiter, Niree Hindoyan, Gudrun Feuchtner, Philipp A Kaufmann, Yong-Jin Kim, Jonathon Leipsic, Fay Y Lin, Erica Maffei, Hugo Marques, Gianluca Pontone, Gilbert Raff, Ronen Rubinshtein, Leslee J Shaw, Julia Stehli, Todd C Villines, Allison Dunning, James K Min, Piotr J Slomka ; Available from: https://pubmed.ncbi.nlm.nih.gov/27252451/
		• Precision Medicine could have a major impact on healthcare outcomes and costs, 2018, Harvard Business Review, Siemens Healthineers; Available from: https://hbr.org/sponsored/2018/12/precision-medicine-could-have-a-major-impact-on-healthcare-outcomes-and-costs
		• Artificial Intelligence (AI) and Cardiovascular Diseases: An Unexpected Alliance, 2020, Cardiology Research and Practice, Silvia Romiti, Mattia Vinciguerra, Wael Saade , Iñaki Anso Cortajarena, and Ernesto; Available from: https://www.hindawi.com/journals/crp/2020/4972346/
3	Detection of breast cancer	• AI in medical imaging may make the biggest impact in healthcare, 2017, Healthmanagement, Margaretta Colangelo, Dmitry Kaminskiy; Available from: https://healthmanagement.org/c/hospital/issuearticle/ai-in-medical-imaging-may-make-the-biggest-impact-in-healthcare

	Category	Main sources
		• Correlating Mammographic and Pathologic Findings in Clinical Decision Support Using Natural Language Processing and Data Mining Methods, 2017, Article, Tejal A. Patel, Mamta Puppala, Richard O. Ogunti, Joe E. Ensor, PhD, Tiancheng He, PhD, Jitesh B. Shewale, Donna P. Ankerst, PhD, Virginia G. Kaklamani, Angel A. Rodriguez, Stephen T. C. Wong, PhD, and Jenny C. Chang; Available from: https://pubmed.ncbi.nlm.nih.gov/27571243/
		• Artificial Intelligence: Power for Civilisation – and for Better Healthcare, 2019, Public Health Genomics, Horgan D., Romao M., Morré S.A, Kalra D; Available from https://www.karger.com/Article/FullText/504785
		• Comparison of digital mammography alone and digital mammography plus tomosynthesis in a population-based screening program, 2013, National Library of Medicine, Per Skaane, Andriy I Bandos, Randi Gullien, Ellen B Eben, Ulrika Ekseth, Unni Haakenaasen, Mina Izadi, Ingvild N Jebsen, Gunnar Jahr, Mona Krager, Loren T Niklason, Solveig Hofvind, David Gur; Available from https://pubmed.ncbi.nlm.nih.gov/23297332/
		• International evaluation of an AI system for breast cancer screening, 2020, Article, Scott Mayer McKinney, Marcin Sieniek, Varun Godbole, Jonathan Godwin, Natasha Antropova, Hutan Ashrafian, Trevor Back, Mary Chesus, Greg C. Corrado, Ara Darzi, Mozziyar Etemadi, Florencia Garcia-Vicente, Fiona J. Gilbert, Mark Halling-Brown, Demis Hassabis, Sunny Jansen, Alan Karthikesalingam, Christopher J. Kelly, Dominic King, Joseph R. Ledsam, David Melnick, Hormuz Mostofi, Lily Peng, Joshua Jay Reicher, Bernardino Romera-Paredes, Richard Sidebottom, Mustafa Suleyman, Daniel Tse, Kenneth C. Young, Jeffrey De Fauw & Shravya Shetty; Available from https://www.nature.com/articles/s41586-019-1799-6
		• National Expenditure For False-Positive Mammograms And Breast Cancer Overdiagnoses Estimated At $4 Billion A Year; 2015, Research Article, Mei-Sing Ong and Kenneth D. Mandl; Available from https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2014.1087
4	Image acquisition and reconstruction	• Radiation dose reduction in computed tomography: techniques and future perspective, 2012, US National Library of Medicine, Lifeng Yu, Xin Liu, Shuai Leng, James M Kofler, Juan C Ramirez-Giraldo, Mingliang Qu, Jodie Christner, Joel G Fletcher, and Cynthia H McCollough; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3271708/
		• The cost of cancer in Europe 2018, 2020, European Journal of Cancer, Thomas Hofmarcher, Peter Lindgren, Nils Wilking, Bengt Jönsson; Available from https://www.ejcancer.com/article/S0959-8049(20)30026-5/fulltext
		• https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Causes_of_death_%E2%80%94_malignant_neoplasms,_residents,_2016_Health2019.png accessed on 14/09/2020
		• https://www.visiblepatient.com/en/professionnals/ accessed on 12/10/2020
		• https://www.csats.com/ accessed on 12/10/2020
5	Detection of COVID-19	• https://www.zebra-med.com/covid-19 accessed on 14/09/2020
6	Diagnosis of dermatological conditions	• Melanoma Treatment Costs, 2015, US National Library of Medicine, Gery P. Guy, Donatus U. Ekwueme,, Florence K. Tangka and Lisa C. Richardson; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4495902/
		• https://www.skinvision.com/service/ accessed on 14/09/2020
		• http://www.melanomapatientnetworkeu.org/melanoma.html accessed on 14/09/2020
7	Preparation time for radiation	• Radiotherapy staffing in the European countries: Final results from the ESTRO-HERO survey, 2014, US National Library of medicine, Yolande Lievens, Noémie Defourny, Mary Coffey, Josep M.Borras, Peter Dunscombe, Ben Slotman, Julian Malickig, Marta Bogusz, Chiara Gasparotto, Cai Grau; https://www.sciencedirect.com/science/article/pii/S0167814014003648
		• https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/transforming-healthcare-with-ai accessed on 14/09/2020

	Category	Main sources
		• https://www.philips.com/a-w/about/news/archive/standard/news/press/2018/20180228-philips-launches-digital-ingenia-elition-mr-solution-delivering-premium-digital-image-quality-up-to-50-per-cent-faster.html accessed on 14/09/2020
8	Skin cancer self-scanning solutions	• Assessment of Accuracy of an Artificial Intelligence Algorithm to Detect Melanoma in Images of Skin Lesions, 2019, JAMA Network, Michael Phillips,Helen Marsden, Wayne Jaffe; Available from https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2752995
		• https://www.skincancer.org/skin-cancer-information/skin-cancer-facts/, accessed on 14/09/2020
		• http://www.melanomapatientnetworkeu.org/melanoma.html accessed on 14/09/2020
C.	**Labs**	
1	Detection of pathogens	• https://pcr.ai/ accessed on 14/09/2020
		• Laboratory medicine in the European Union, 2015, Clin Chem Lab med Review, Wytze P. Oosterhuis and Simone Zerah; Available from: https://www.eflm.eu/files/efcc/1%20CCLM%202015%20-%20Oosterhuis.pdf
2	Automation of data workflows in laboratory	• Dotmatics Acquires Biobright To Accelerate Laboratory Data Automation For The Lab Of The Future, 2020, Website, AIT News Desk; Available from: https://aithority.com/robots/automation/dotmatics-acquires-biobright-to-accelerate-laboratory-data-automation-for-the-lab-of-the-future/
		• https://www.dotmatics.com/, accessed on 10/09/2020
3	Characterization of genomic sequencing	• How AI and next-generation genomic sequencing is helping cancer patients, 2017, Website, Mary Shacklett; Available from: https://www.techrepublic.com/article/how-ai-and-next-generation-genomic-sequencing-is-helping-cancer-patients/
		• https://www.sophiagenetics.com/sophia-ai/genomics.html accessed on 10/09/2020
D.	**Physiological Monitoring**	
1	Medication adherence	• In small study, AiCure app led to 50 percent improvement in medication adherence, 2017, mobi health news, Jonah Comstock; Available from: https://www.mobihealthnews.com/content/small-study-aicure-app-led-50-percent-improvement-medication-adherence
		• Urging Europe to put non-adherence to inhaled respiratory medication higher on the policy agenda: a report from the First European Congress on Adherence to Therapy, 2017, European Respiratory Journal, Job F.M. van Boven, Federico Lavorini, P.N. Richard Dekhuijzen, Francesco Blasi, David B. Price, Giovanni Viegi; Available from https://erj.ersjournals.com/content/49/5/1700076
		• The Impact of Medication Non-Adherence on the Relationship Between Mortality Risk and Depression in Heart Failure, 2018, US National Library of Medicine, Emily C. Gathright, Mary A. Dolansky, John Gunstad, Joseph D. Redle, Richard Josephson, Shirley M. Moore and Joel W. Hughes; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5573609/
		• https://www.mobihealthnews.com/content/small-study-aicure-app-led-50-percent-improvement-medication-adherence Accessed on 14/09/2020
2	Prediction seizures and early detections health abnormalities	• New AI System Predicts Seizures With Near-Perfect Accuracy, 2019, Website, Michelle Hampson; Available from: https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/this-new-ai-system-can-predict-seizures-with-nearperfect-accuracy
		• https://www.ibe-epilepsy.org/european-epilepsy-report/ accessed on 14/09/2020
3	Retinal scan for monitoring Multiple Sclerosis	• This eye-tracking system uses AI to monitor multiple sclerosis, 2020, Engadget Website, Christine Fisher; Available from: https://www.engadget.com/2020-02-12-eye-tracking-ai-spots-mulitple-sclerosis.html?guccounter=2

	Category	Main sources
4	Screening of diabetic retinopathy	• Artificial intelligence for teleophthalmology-based diabetic retinopathy screening in a national programme: an economic analysis modelling study, 2020, The Lancet Digital health, Yuchen Xie, Quang D Nguyen, Haslina Hamzah, Gilbert Lim, Valentina Bellemo, Dinesh V Gunasekeran, Michelle Y T Yip, Xin Qi Lee, Prof Wynne Hsu, Prof Mong Li Lee, Colin S Tan, Hon Tym Wong, Prof Ecosse L Lamoureux, Gavin S W Tan, Prof Tien Y Wong, Prof Eric A Finkelstein, Prof Daniel S W Ting; Available from: https://www.thelancet.com/journals/landig/article/PIIS2589-7500(20)30060-1/fulltext
E.	**Real World Data**	
1	Patient recruitment and retention for clinical trials	• Intelligent clinical trial: Transforming through AI-enabled engagement, 2020, Deloitte Insights, Sara Sikora, Colin Terry, John Haughey, Peter Wallace, Vicky Levy, Hanno Ronte, Niel Lesser, Amy Cheung, Aditya Kudumala; Available from: https://www2.deloitte.com/content/dam/insights/us/articles/22934_intelligent-clinical-trials/DI_Intelligent-clinical-trials.pdf
		• https://www.efpia.eu/about-medicines/development-of-medicines/regulations-safety-supply/clinical-trials/ accessed on 14/09/2020
2	Prediction of drug effectiveness	• https://www.gnshealthcare.com/, accessed on 11/09/2020
		• Artificial Intelligence in the Pharmaceutical Industry – An Overview of Innovations, 2019, Website, Ayn de Jesus; Available from: https://emerj.com/ai-sector-overviews/artificial-intelligence-for-pharmacies-an-overview-of-innovations
		• Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine, 2020, The Journal of Biological Database and Curation, Zeeshan Ahmed, Khalid Mohamed, Saman Zeeshan and XinQi Dong;
		• Opportunities of Artificial Intelligence, 2020, Study, James Eager, Mark Whittle, Jan Smit; Available from: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652713/IPOL_STU(2020)652713_EN.pdf
3	Automation of pharmacovigilance	• How AI is Transforming Pharmacovigilance, 2019, Pharma Boardroom, Michael Levy; Available from: https://pharmaboardroom.com/articles/how-ai-is-transforming-pharmacovigilance/
F.	**Virtual Health Assistance**	
1	Automation of medical records transcription	• Orbita debuts OrbitaASSIST, an AI-powered virtual health assistant, 2019, Healthcare IT News, Nathan Eddy; Available from https://www.healthcareit.com.au/article/orbita-debuts-orbitaassist-ai-powered-virtual-health-assistant
		• AI for Virtual Medical Assistants – 4 Current Applications, 2019, Emerj Website, Kumba Sennaar; Available from: https://emerj.com/ai-sector-overviews/virtual-medical-assistants/
		• https://www.amberscript.com/en/transcription-healthcare, accessed on 14/09/2020
		• https://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_personnel_statistics_-_physicians accessed on 14/09/2020
2	Extraction of information to answer patients questions	• Better health outcomes with AI-powered virtual assistants, 2019, Expert Insigts IBM, John Murtha, John Tarcson, Anita Nair-Hartman; Available from: https://www.ibm.com/downloads/cas/KWQKA5LV
		• https://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_personnel_statistics_-_nursing_and_caring_professionals accessed on 14/09/2020
3	Administrative timesaving	• https://www.accenture.com/_acnmedia/PDF-49/Accenture-Health-Artificial-Intelligence.pdf, accessed on 10/09/2020
		• https://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_personnel_statistics_-_physicians accessed on 14/09/2020

	Category	Main sources
G.	**Personalized Apps**	
1	Behavioral counselling for metabolism pathologies	• A Fully Automated Conversational Artificial Intelligence for Weight Loss: Longitudinal Observational Study Among Overweight and Obese Adults, 2017, US National Library of Medicine, Gunther Eysenbach, Sheyu Li, Hammad Akram, Tanushree Bose, Natalie Stein and Kevin Brooks; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6238835/ • Savings in Medical Expenditures Associated with Reductions in Body Mass Index Among US Adults with Obesity, by Diabetes Status, 2014, US National Library of Medicine, John Cawley,corresponding author Chad Meyerhoefer, Adam Biener, Mette Hammer, and Neil Wintfeld; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4486410/ • Morbidity and mortality associated with obesity, 2017, US National Library of Medicine, Mahmoud Abdelaal, Carel W. le Roux, and Neil G. Docherty; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5401682/
2	Personalized monitoring by a virtual nurse assistant	• Top 10 AI apps and solutions that are changing the healthcare industry, 2019, Website, Ankit Shrivastav; Available from: https://bigdata-madesimple.com/top-10-ai-apps-and-solutions-that-are-changing-the-healthcare-industry/
H.	**Robotics**	
1	Robot-assisted surgeries	• AI in healthcare – benefits, challenges & risks, 2018, Impact brief, Insightbrief; Available from https://www.insightbrief.net/wp-content/uploads/AI-in-Healthcare-Benefits-Challenges-Risks-InsightBrief.pdf?tagged= • Robotic surgery: finding value in 2019 and beyond, 2019, ALES, Rafael E. Perez, Steven D. Schwaitzberg; Available from: https://ales.amegroups.com/article/view/5205/html • https://hbr.org/2018/05/10-promising-ai-applications-in-health-care accessed on 14/09/2020 • https://www.statista.com/statistics/312022/cost-of-hospital-stay-per-day-by-country/, accessed on 14/09/2020 • Analysis of length of hospital stay using electronic health records: A statistical and data mining approach, 2018, US National Library of Medicine, Hyunyoung Baek, Minsu Cho, Seok Kim, Hee Hwang, Minseok Song and Sooyoung Yoo; Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5898738/
2	Auxiliary robot assisting nurses	• A hospital introduced a robot to help nurses. They didn't expect it to be so popular, 2019, Website, Katharine Schwab; Available from: https://www.fastcompany.com/90372204/a-hospital-introduced-a-robot-to-help-nurses-they-didnt-expect-it-to-be-so-popular
3	Sleep assistant	• https://meetsomnox.com/ accessed on 14/09/2020

Report references

1. **Artificial Intelligence in Medicine and Healthcare: applications, availability and societal impact**, 2020, Joint Research Centre, *Dr. Emilio Gómez-González, Dr. Emilia Gómez*; Available from: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120214/jrc120214_ai_in_medicine_and_healthcare_report-aiwatch_v50.pdf
2. **Artificial Intelligence A European approach to excellence and trust**, 2020, White Paper, *European Commission*; Available from: https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf
3. **Transforming healthcare with AI The impact on the workforce and organisations**, 2020, EIT Health research, *Jorge Fernández García, Dr. Angela Spatharou*; Available from: https://eithealth.eu/wp-content/uploads/2020/03/EIT-Health-and-McKinsey_Transforming-Healthcare-with-AI.pdf
4. **Artificial Intelligence in Healthcare**, 2020, Elsevier ebook, *Adam Bohr and Kaveh Memarzadeh*; Available from: https://www.elsevier.com/books/artificial-intelligence-in-healthcare/bohr/978-0-12-818438-7
5. **AI in Health A Leader's Guide to Winning in the New Age of Intelligent Health Systems**, 2020, *Tom Lawry* ; Available from: https://books.google.nl/books/about/AI_in_Health.html?id=wswhywEACAAJ&redir_esc=y
6. **Artificial Intelligence in Medical technology: Delivering on the Promise of better Healthcare in Europe**, 2019, Medtech Europe Position Paper, *Michael Strübin*; Available from: https://www.medtecheurope.org/wp-content/uploads/2019/11/MTE_Nov19_AI-in-MedTech-Delivering-on-the-Promise-of-Better-Healthcare-in-Europe.pdf
7. **The future of artificial intelligence in health care - How AI will impact patients, clinicians, and the pharmaceutical industry**, 2019, Deloitte Perspectives, *Ken Abrams, Bill Fera*; Available from: https://www2.deloitte.com/us/en/pages/life-sciences-and-health-care/articles/future-of-artificial-intelligence-in-health-care.html
8. **https://ec.europa.eu/info/sites/info/files/better-regulation-guidelines-impact-assessment.pdf** accessed on 14/09/2020
9. **Continuous Glucose Monitoring**. 2020, Website, *Medtronic*; Available from: https://www.medtronicdiabetes.com/treatments/continuous-glucose-monitoring
10. **Variability of Diabetes Alert Dog Accuracy in a Real-World Setting**, 2017, Journal of Diabetes Science and Technology, *Linda A. Gonder-Frederick, PhD, Jesse H. Grabman, Jaclyn A. Shepard, PsyD, Anand V. Tripathi, Dallas M. Ducar and Zachary R. McElgunn*; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5588823/
11. **Wearable Technology Applications in Healthcare**: **A Literature Review**, 2019, Online Journal of Nursing Informatics Contributors, *Min Wu, PhD and Jake Luo*; Available from: https://www.himss.org/resources/wearable-technology-applications-healthcare-literature-review
12. **Large-Scale Assessment of a Smartwatch to Identify Atrial Fibrillation** 2019, National Library of Medicine, *Marco V Perez, Kenneth W Mahaffey, Haley Hedlin, John S Rumsfeld, Ariadna Garcia, Todd Ferris, Vidhya Balasubramanian, Andrea M Russo, Amol Rajmane, Lauren Cheung, Grace Hung, Justin Lee, Peter Kowey, Nisha Talati, Divya Nag, Santosh E Gummidipundi, Alexis Beatty, Mellanie True Hills, Sumbul Desai, Christopher B Granger, Manisha Desai, Mintu P Turakhia, Apple Heart Study Investigators*; Available from: https://pubmed.ncbi.nlm.nih.gov/31722151/
13. **CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning**, 2017, Article, *Pranav Rajpurkar, Jeremy Irvin, Kaylie Zhu, Brandon Yang, Hershel Mehta, Tony Duan, Daisy Ding, Aarti Bagul, Robyn L. Ball, Curtis Langlotz,Katie Shpanskaya, Matthew P. Lungren, Andrew Y. Ng*; Available from: https://arxiv.org/pdf/1711.05225v3.pdf
14. **World Cancer Day: 1 in 4 deaths caused by cancer**, 2020, Eurostat, *European Commission*; Available from: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20200204-1
15. **International evaluation of an AI system for breast cancer screening**. 2020, Nature Research Journal, *Scott Mayer McKinney, Marcin Sieniek, Varun Godbole, Jonathan Godwin, Natasha Antropova, Hutan Ashrafian, Trevor Back, Mary Chesus, Greg C. Corrado, Ara Darzi, Mozziyar Etemadi, Florencia Garcia-Vicente, Fiona J. Gilbert, Mark Halling-Brown, Demis Hassabis, Sunny Jansen, Alan Karthikesalingam, Christopher J. Kelly, Dominic King, Joseph R. Ledsam, David Melnick, Hormuz Mostofi, Lily Peng, Joshua Jay Reicher, Bernardino Romera-Paredes, Richard Sidebottom, Mustafa Suleyman, Daniel Tse, Kenneth C. Young, Jeffrey De Fauw and Shravya Shetty*; Available from: https://www.nature.com/articles/s41586-019-1799-6
16. **Correlating Mammographic and Pathologic Findings in Clinical Decision Support Using Natural Language Processing and Data Mining Methods**, 2017, Article, *Tejal A. Patel, Mamta Puppala, Richard O. Ogunti, Joe E. Ensor, PhD, Tiancheng He, PhD, Jitesh B. Shewale, Donna P. Ankerst, PhD, Virginia G. Kaklamani, Angel A. Rodriguez, Stephen T. C. Wong, PhD, and Jenny C. Chang*; Available from: https://acsjournals.onlinelibrary.wiley.com/doi/epdf/10.1002/cncr.30245
17. **Why do commercial CT scanners still employ traditional, filtered back-projection for image reconstruction?** 2010, National Library of Medicine, *Xiaochuan Pan, Emil Y Sidky and Michael Vannier*; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2849113/

18. **https://www.zebra-med.com/covid-19** accessed on 14/09/2020
19. **https://www.diagnostics.ai/#Impact** accessed on 10/09/2020
20. **https://pcr.ai/#solutions** accessed on 10/09/2020
21. **Automation and standardization of clinical molecular testing using PCR.Ai – A comparative performance study**, 2019, Journal of Clinical Virology, *A.R. MacLean, R. Gunson*; Available from: https://www.sciencedirect.com/science/article/pii/S138665321930174X
22. **Dotmatics Acquires Biobright To Accelerate Laboratory Data Automation For The Lab Of The Future**, 2020, Website, *AIT News Desk*; Available from: https://aithority.com/robots/automation/dotmatics-acquires-biobright-to-accelerate-laboratory-data-automation-for-the-lab-of-the-future/
23. **https://www.dotmatics.com**/ accessed on 10/09/2020
24. **How AI and next-generation genomic sequencing is helping cancer patients,** 2017, Website, *Mary Shacklett*; Available from: https://www.techrepublic.com/article/how-ai-and-next-generation-genomic-sequencing-is-helping-cancer-patients/
25. **https://www.sophiagenetics.com/sophia-ai/genomics.html**, accessed on 10/09/2020
26. **Urging Europe to put non-adherence to inhaled respiratory medication higher on the policy agenda: a report from the First European Congress on Adherence to Therapy**, 2017, European Respiratory Journal, *Job F.M. van Boven, Federico Lavorini, P.N. Richard Dekhuijzen, Francesco Blasi, David B. Price, Giovanni Viegi*; Available from: https://erj.ersjournals.com/content/49/5/1700076
27. **https://www.fda.gov/science-research/science-and-research-special-topics/real-world-evidence** accessed on 17/09/2020
28. **https://www.mendel.ai/** accessed on 11/09/2020
29. I**ntelligent clinical trial: Transforming through AI-enabled engagement,** 2020, Deloitte Insights, *Sara Sikora, Colin Terry, John Haughey, Peter Wallace, Vicky Levy, Hanno Ronte, Niel Lesser, Amy Cheung, Aditya Kudumala*; Available from: https://www2.deloitte.com/content/dam/insights/us/articles/22934_intelligent-clinical-trials/DI_Intelligent-clinical-trials.pdf
30. **Strategies to Measure and Improve Patient Adherence in Clinical Trials**, 2009, Researchgate, *Doreen Matsui*; Available from: https://www.researchgate.net/publication/233602962_Strategies_to_Measure_and_Improve_Patient_Adherence_in_Clinical_Trials
31. **https://www.gnshealthcare.com/** accessed on 11/09/2020
32. **Artificial Intelligence in the Pharmaceutical Industry – An Overview of Innovations**, 2019, Website, *Ayn de Jesus*; Available from: https://emerj.com/ai-sector-overviews/artificial-intelligence-for-pharmacies-an-overview-of-innovations/
33. **Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine**, 2020, The Journal of Biological Database and Curation, *Zeeshan Ahmed, Khalid Mohamed, Saman Zeeshan and XinQi Dong;*
34. **Opportunities of Artificial Intelligence**, 2020, Study, James Eager, Mark Whittle, Jan Smit; Available from: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652713/IPOL_STU(2020)652713_EN.pdf
35. **How AI is Transforming Pharmacovigilance**, 2019, Pharma Boardroom, *Michael Levy*; Available from: https://pharmaboardroom.com/articles/how-ai-is-transforming-pharmacovigilance/
36. **AI personalized nutrition: ZOE to launch app following twin investigation**, 2020, Nutrition Insight, *Katherine Durrell*; Available from: https://www.nutritioninsight.com/news/ai-personalized-nutrition-zoe-to-launch-app-following-twin-investigation.html
37. **Neura Enhances Medication Management Apps with AI, Enabling Personalized Experiences to Improve User Health**, 2017, *Businesswire, Neura*; Available from: https://www.businesswire.com/news/home/20170207005204/en/Neura-Enhances-Medication-Management-Apps-AI-Enabling
38. **https://www.sensely.com/** accessed on 14/09/2020
39. **https://medwhat.com/** accessed on 14/09/2020
40. **Early trials have demonstrated that AI-assisted surgery can help reduce variations in procedures and improve patient outcomes**, 2018, Robotics Business Review, *Phil Britt*; Available from: https://www.roboticsbusinessreview.com/health-medical/ai-assisted-surgery-improves-patientoutcomes
41. **Automation and standardization of clinical molecular testing using PCR.Ai – A comparative performance study**, 2018, Article, *Insightbrief*; Available from: https://www.insightbrief.net/wp-content/uploads/AI-in-Healthcare-Benefits-Challenges-Risks-InsightBrief.pdf?tagged=true
42. R**obotic surgery: finding value in 2019 and beyond**, 2019, ALES, *Rafael E. Perez, Steven D. Schwaitzberg*; Available from: https://ales.amegroups.com/article/view/5205/html
43. **A hospital introduced a robot to help nurses. They didn't expect it to be so popular**, 2019, Website, *Katharine Schwab*; Available from: https://www.fastcompany.com/90372204/a-hospital-introduced-a-robot-to-help-nurses-they-didnt-expect-it-to-be-so-popular

44. **Intelligent clinical trial: Transforming through AI-enabled engagement**, 2019, PCmag, *S. C. Stuart*; Available from: https://www.pcmag.com/news/when-nurses-are-busy-its-moxi-the-robot-to-the-rescue
45. **https://meetsomnox.com/science-research/** accessed on 15/09/2020
46. **https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai** accessed on 14/09/2020
47. **Communication: Building Trust in Human Centric Artificial Intelligence**, 2019, DG Connect, *European Commission*; Available from: https://ec.europa.eu/digital-single-market/en/news/communication-building-trust-human-centric-artificial-intelligence
48. **Artificial Intelligence in healthcare: is Europe ready?**, 2019, FEAM European Biomedical Policy Forum, *Dr Robin Fears*; Available from: https://www.feam.eu/wp-content/uploads/AI-Summary-report-15-Apr-2019-FV.pdf

Commissioned by

For more information please contact

Eliana Biundo
Senior Manager Health Economics and Outcomes Research
Monitor Deloitte Belgium
elibiundo@deloitte.com

Michael Strübin
Director Digital Health
MedTech Europe
m.strubin@medtecheurope.org