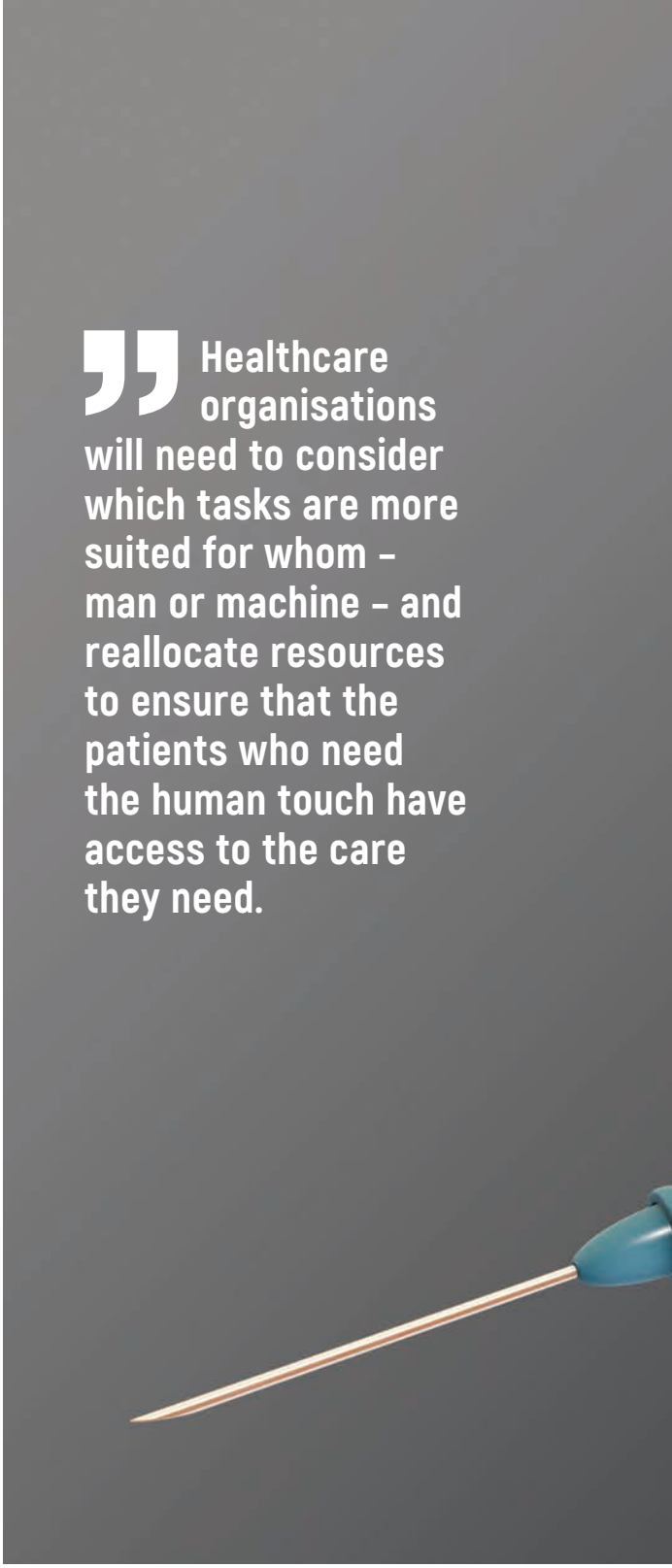


Artificial intelligence – AI – is getting increasingly sophisticated at doing what humans do, albeit more efficiently, more quickly, and more cheaply. While AI and robotics are becoming a natural part of our everyday lives, their potential within healthcare is vast.

Most of us are barely aware of it, but AI is everywhere we turn – it's in our cars, telling us when it's time for the engine to be serviced based on our driving patterns; it's in our everyday Google searches and the suggestions from Amazon that follow us around the web; it's the chatbot on the end of the telephone in call service centres. In homes, workplaces and clinical environments around the world, intelligent technologies such as AI and robots are supporting, diagnosing and treating people.

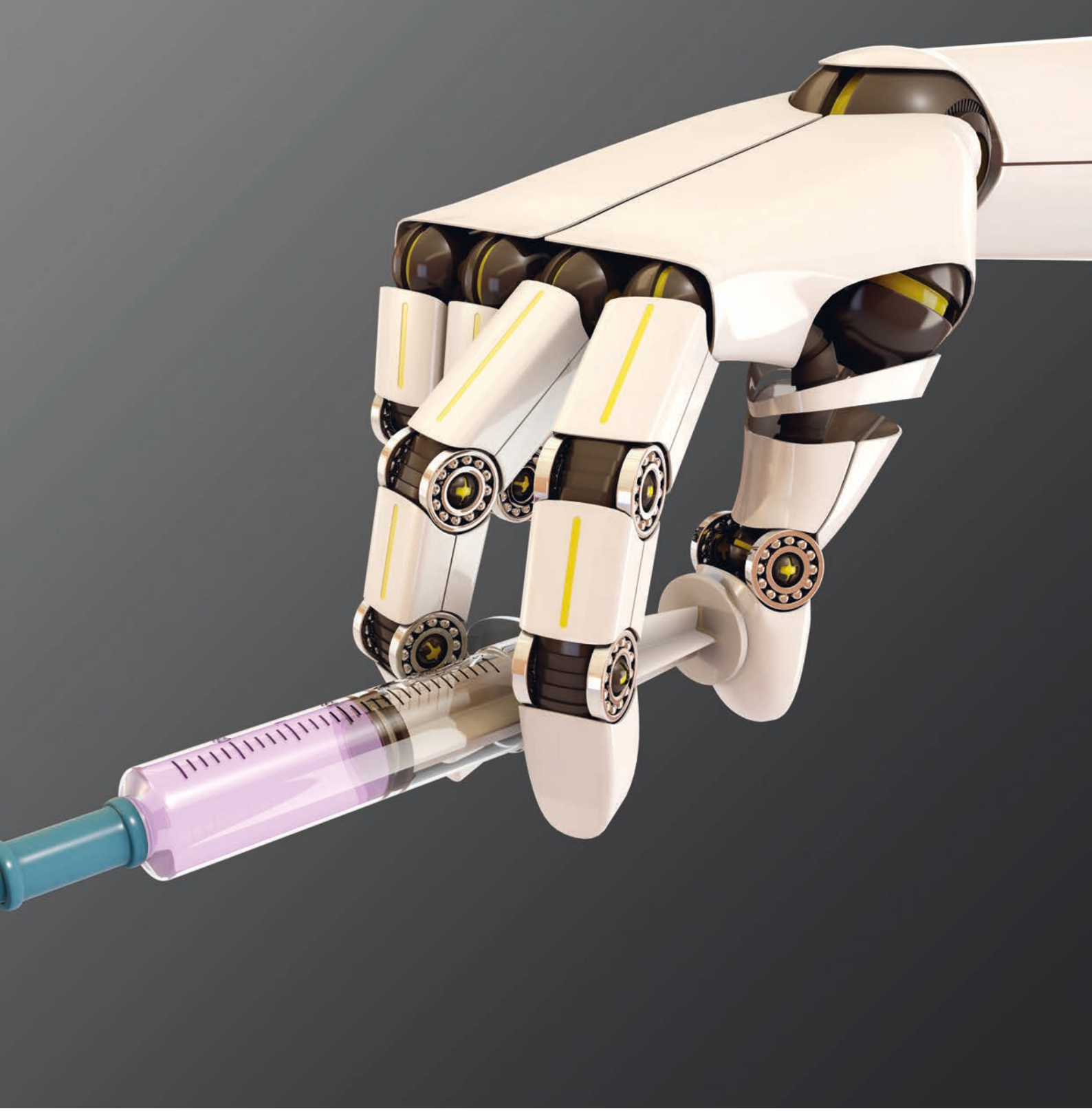
How we embrace AI and robotics to complement and enhance healthcare services today will define our ability to deliver more effective, efficient and responsive healthcare services that reap improved health outcomes, which enabling individuals to own and manage their daily health needs. Healthcare organisations will need to consider which tasks are more suited for whom – man or machine – and reallocate resources to ensure that the patients who need the human touch have access to the care they need.

No longer science fiction: **Artificial intelligence**

Megatrends in healthcare

There are a number of megatrends converging in healthcare that are setting the scene for the adoption of intelligent technologies.

The value challenge. In countries across the globe, not least Sweden, there is an escalating demand driven by long-term and chronic disease and rising healthcare costs, exacerbated by an ageing population and limited resources (finances, workforce specialists, etc.). Today, persons with one or more chronic diseases contribute to around 85% of total healthcare expenditure in Sweden.[1] Chronic disease will be a mounting challenge – the prevalence of chronic disease is naturally related to age and the population will continue to grow older, with the proportion of the Swedish population aged 85 years and above set to double by the year 2050.[2]



and robotics are transforming healthcare

Furthermore, due to demographic pressures, health workforce shortages will remain a major concern in Sweden and other European countries.

Changing patient attitudes and behaviours. Patient assertiveness has increased over the past two decades, partly due to the rising incidence of chronic diseases. Many of these diseases that were previously terminal are now managed over long periods and require continuous care. Patients are therefore inclined to take more control over their own health and challenging the traditional patient-doctor relationship, shifting care from hospitals into communities and homes. The increased democratisation of access facilitated by the rise in consumer health technologies is also providing patients and individuals with the data and information they need to proactively manage their own health and

Figure 1: AI and its subfields (non-exhaustive) (Source: PwC)

wellbeing, and to make better and more informed decisions in partnership with their healthcare providers.

Shift from volume to value. As patients move from passive healthcare recipients to active value seekers, the fee-for-service models of the past may not suffice in incentivising the improvement of value that patients are demanding. As the trend moves from volume to value in healthcare services, the need to have reliable, consistent and technology-based solutions will rise.

The data wave. Approximately 2.5 million new scientific papers are published annually;[3] for a skin specialist alone, there are 11,000 new dermatology articles published each year. International Data Corporation (IDC) estimates that the volume of healthcare data will grow to 2,314 exabytes (1018) by 2020 at an annual growth rate of 48 percent; IBM asserts that healthcare data doubles every 24 months.[4] Not only are health data volumes staggering, up to 80% of this data is unstructured, i.e. it is not contained in a database or some other type of data structure. Accessing and staying up to date with such data is clearly a challenge, if not impossible, for any human individual. As such, both healthcare and technologies industries are looking for tools and methods to integrate and analyse this unstructured data for use in diagnostics, treatments and the evaluation of new medicines.

Evolution and revolution of medicine. As the study of medicine evolves, new technologies are making a data-driven medicine revolution possible. Scientists are now able to analyse large amounts of relevant medical (e.g. diagnostic data, electronic health records, etc.) and non-medical (e.g. internet search history, social media profiles, etc.) data in a short amount of time, which promises to personalise medicine, and reduce healthcare errors and costs. For instance, it is already possible to personalise treatments based on the genetic features of a patients. The data revolution will allow us to better understand which treatments are truly effective.

For instance, it is already possible to personalise treatments based on the genetic features of a patients.

AI at work in healthcare

AI will undoubtedly have a profound influence on the healthcare industry. It can process information much faster than any human can, which can serve to increase efficiencies and decrease the likelihood of misdiagnosis and medical errors to a large extent. Not only will AI impact hospitals and healthcare professionals, it will revolutionise consumer health and wellbeing, for example with sensors that can detect symptoms early and predict a potential health incident ahead of time in order to prevent it.

The applications of AI are broad, ranging from sensors and Internet of Things (IoT) devices, to more complex systems that apply natural language processing and machine learning to reveal insights from large amounts of unstructured data (Figure 1).

While the healthcare industry might not be ready to exploit the full range of AI possibilities, such as autonomous

SOME DEFINITIONS	
Autonomous intelligence:	AI that is autonomous in decision making and acts with limited human intervention
Assisted intelligence:	AI that assists in decision making
Augmented intelligence:	AI that augments human capacity, for example in increasing the speed and accuracy of diagnosis
Machine learning:	AI that gives computers the ability to learn and act without being explicitly programmed
Natural language processing:	AI that understands human speech as it is spoken

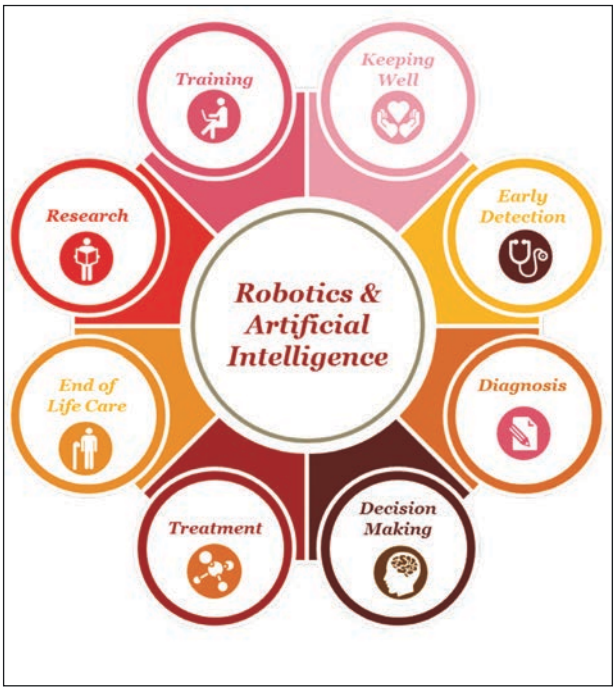


Figure 2: AI is transforming every aspect of healthcare delivery in innovative ways (Source: PwC)

intelligence due to its associated challenges, it is already on its way towards harnessing assisted intelligence and augmented intelligence to some extent. In addition, the subfields of machine learning and natural language processing are fast becoming transformative for the healthcare value chain.

AI applications across the healthcare value chain

Some of the applications developed using AI are having an impact across the care pathways, starting at prevention, to diagnosis, treatment and recovery (Figure 2).

Keeping well. The use of AI and the internet of medical things in consumer health applications can help people manage their own health and keep them well. Smart performance apparel offers real-time biometrics, personalised programming, and customised reporting to help athletes reach their goals faster. For instance, Under Armour will use IBM's Watson to power a 'cognitive coaching system' in an application that provides customised advice for sleep, fitness, activity and nutrition. The insights originate from Under Armour's 200 million-member Connected Fitness community, external academic research studies and institutions, and IBM Watson similarity analytics. Future new capabilities include behavioural and performance management, food intake tracking and overall nutrition management, as well as the effects of weather and environment on training. For the regular individual, Lumo Lift is a posture monitoring device that alerts the person when their posture changes, reminding the user to assume correct posture whether sitting or standing.

Early detection. AI and the use of wearables and other devices can be applied to detect diseases such as cancer, or monitor ailments such as cardiovascular disease at a very early stage, allowing doctors to closely monitor those patients and save lives. For example, according to the American Cancer Society, 12.1 million mammograms are performed annually in the US, but a high proportion of these mammograms yield false results, leading to 1 in 2 healthy women being told they have cancer. AI-enabled review and translation of mammograms is 30 times faster with 99% accuracy, reducing the need for unnecessary biopsies as well as reducing the uncertainty and stress of a misdiagnosis.[5] Another example is a device, developed by CardioDiagnostics, that remotely monitors its wearer for heart irregularities and is used to improve cardiac monitoring and rhythm management.

Diagnosis. AI is being implemented across different hospitals worldwide to solve issues of misdiagnosis given its ability to process large amounts of information more effectively, quickly and accurately than any human can. In 2016, IBM's Watson correctly identified a rare form of leukaemia suffered by a 60-year-old patient who had been previously misdiagnosed, by comparing her genetic changes across 20 million cancer research papers in just 10 minutes, thus saving her life.[6] Google's DeepMind Health has also begun working with UK hospitals in the same year, searching for early signs of diseases that lead to blindness and cancer, as well as developing new clinical mobile apps linked to electronic patient records.

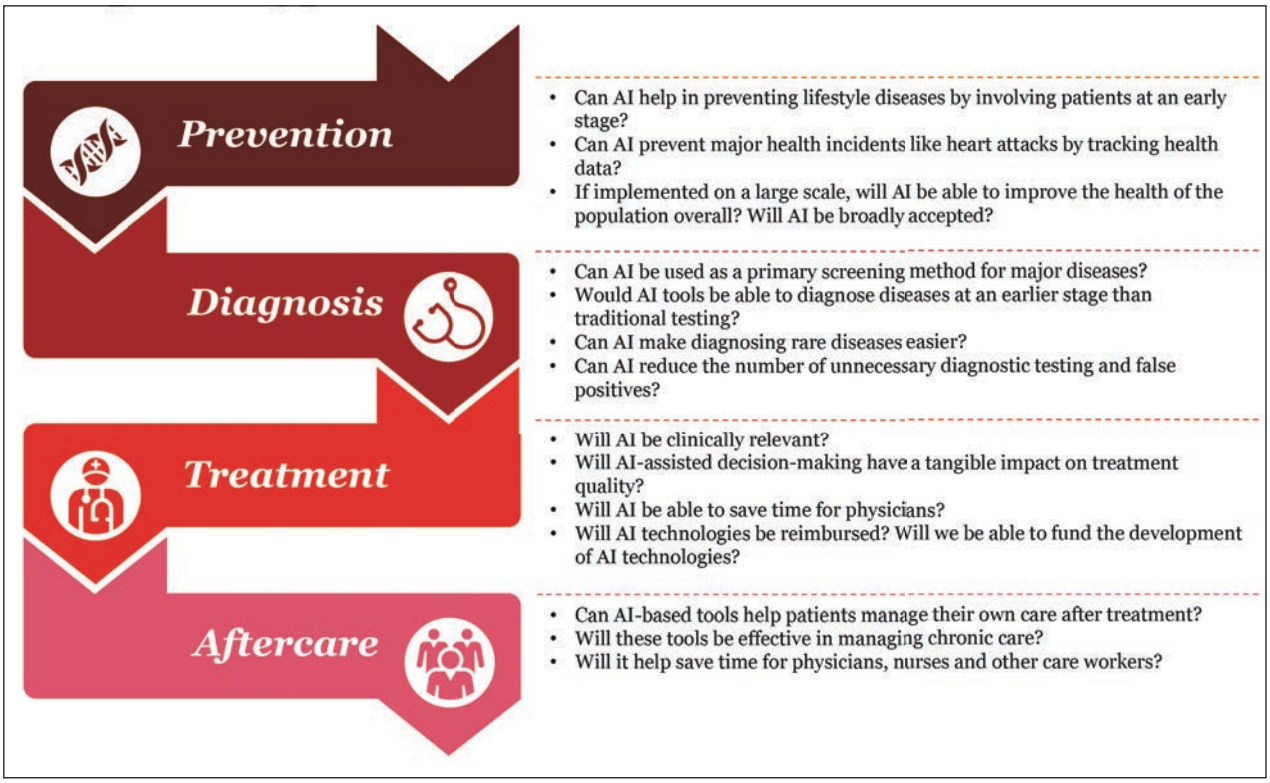


Figure 3: AI – hope or hype? (Source: PwC)

Decision making. Improving patient care requires aligning big health data with appropriate and timely decisions. Here, predictive analytics can support clinical decision-making and prioritise tasks. AI, via system dynamics driven pattern recognition, can also enable the identification of patients at risk of developing a certain condition or seeing it deteriorate due to lifestyle, environmental, genomic or other factors. Quest Diagnostics' Quanum platform, an integrated suite of healthcare information technology and predictive analytics tools, analyses patient test data alongside their medical data to help primary care physicians identify patients with early onset memory loss and dementia.

Treatment. Beyond patient identification, AI can assist clinicians in adopting a more comprehensive approach for disease management, better coordinate care plans and help patients to better manage and company with long-term treatment programmes. AiCure has developed an application to monitor patients with long-term conditions and help them adhere to medication intake. It uses a visual recognition system to identify the patient's face, the medication they are taking, and confirm ingestion. The related data is then sent back to the care provider or to the pharmaceutical company conducting a clinical trial. Robotics are also being widely adopted in healthcare to, for example, support the self-management of patients with long-term conditions, assist in surgeries, and do repetitive tasks. KASPAR is a child-sized humanoid robot designed to help teachers and parents support children with autism, while Aethon's TUG robots automate the delivery and transportation of vast amounts of materials such as food, laundry and prescriptions that move through a hospital each day, thus freeing staff to focus on patient care.

By directing the latest advances in AI to streamline the drug discovery and drug repurposing processes, there is the potential to significantly cut both the costs and time to market for new drugs.

End of life care. Robots have the potential to revolutionise end of life care in helping people remain independent longer and reducing the need for hospitalisation, caregivers and care homes through performing routine tasks such as monitoring vital signs and providing medication reminders. Going one step further, robots enabled by AI and improvements in humanoid design can possibly engage in 'conversations' and social interactions, thus keeping ageing minds sharp and mitigating problems of loneliness and isolation. For example, Robot Era is developing mobile robots with a friendly humanoid face. The robot's sensors and cameras gather and analyse real-time data that is wirelessly sent to the cloud to extrapolate advanced information such as

whether the person is showing early signs of dementia. These robots can also remind the elderly about daily tasks and important information, and track conditions over time.

Research. Drug research and discovery is one of the more recent applications for AI in healthcare. By directing the latest advances in AI to streamline the drug discovery and drug repurposing processes, there is the potential to significantly cut both the costs and time to market for new drugs. AstraZeneca has just entered into a collaboration with Berg, a specialist in using AI for drug discovery, with the aim to find and evaluate new and innovative ways of treating neurological disorders such as Parkinson's disease.[7] Additionally, AI provides the means to improve research into the diseases themselves. Meta, a startup that uses AI to analyse scientific papers and bring insights to researchers, was bought by the Chan Zuckerberg Initiative in early 2017 as part of the charitable foundation's mission to eradicate disease.

Training. The advent of the use of natural speech in technology and the ability of an AI-enabled computer to draw instantly from a large database of scenarios means that AI can create naturalistic simulations in a way that simple computer-driven algorithms cannot. AI-assisted mobile devices such as smartphones also provide the additional option of training on-the-go. AI can be further complemented with the use of virtual reality which has been shown to provide realistic and accurate simulations, thus improving comprehension and retention.

Hope, hype or real healthcare benefits?

While many developments in AI health applications are happening outside of Europe, the region has made progress in this field as well. Half of all professional service robots are produced in Europe, and many recent breakthroughs in AI were developed by European laboratories such as DeepMind's AI software.[8] In addition to the progress made in research, it is important to analyse the demand and potential benefits from AI applications in Europe, and distinguish between "hope" and "hype" (Figure 3). The consequences and implications of AI in healthcare – such as real benefits to citizens' health, long-term cost savings, and impact on healthcare structures – should be properly evaluated and established before AI adoption on a larger scale is to be considered.

Read related PwC publications in detail here:

What doctor? Why AI and robotics will define New Health (2017)
http://www.pwc.se/sv/pdf-reports/halso-sjukvard/what-doctor-why-ai-and-robotics-will-define-new-health.pdf

Robotar och AI har kommit för att stanna inom vården (2017)
http://www.pwc.se/sv/publikationer/halso-sjukvard/artificiell-intelligens-framtidens-storsta-livraddare.html

Sherlock in Health – How artificial intelligence may improve quality and efficiency, whilst reducing healthcare costs in Europe (2017)
http://www.pwc.de/de/gesundheitswesen-und-pharma/studie-sherlock-in-health.pdf

REFERENSER

1. Regeringskansliet (2016). Effektiv vård - Slutbetänkande av En nationell samordnare för effektivare resursutnyttjande inom hälso- och sjukvården. [ONLINE] http://www.regeringen.se/rattsdokument/statens-offentliga-utredningar/2016/01/sou-20162/

2. Regeringskansliet (2010). Den ljusnande framtid är vård – Delresultat från LEV-projektet. [ONLINE] http://www.regeringen.se/rapporter/2010/06/s2010.021/

3. Jinha, Arif. (2010). Article 50 million: An estimate of the number of scholarly articles in existence. Learned Publishing. 23. 258-263. 10.1087/20100308. [ONLINE] https://www.researchgate.net/publication/229062236_Article_50_million_An_estimate_of_the_number_of_scholarly_articles_in_existence

4. IBM (2017). http://www-07.ibm.com/hk/watson/health/

5. Wired (2016). http://www.wired.co.uk/article/cancer-risk-ai-mammograms

6. Engadget (2016). https://www.engadget.com/2016/08/07/ibms-watson-ai-saved-a-woman-from-leukemia/

7. Reuters (2017). https://www.reuters.com/article/us-astrazeneca-ai-berg-idUSKCN1B81G1

8 European Commission (2017). https://ec.europa.eu/digital-single-market/en/blog/future-robotics-and-artificial-intelligence-europe

JON ARWIDSON
Partner, Healthcare, PwC Sweden

JAN VON ZWEIGBERGK
Branch expert, Healthcare, PwC Sweden

SARAH LIDÉ
Branch specialist, Healthcare, PwC Sweden