What doctor?
Why AI and robotics will define New Health

Contents

Introduction

Would you allow a medical robot with artificial intelligence (AI) to examine, diagnose and prescribe a treatment plan for you or a member of your family with cancer? Would you accept a robot as your primary surgeon? And if you were to do so, what would the human clinician do?

AI and robots have long been a theme in fiction. From Isaac Asimov's 'I, Robot' in 1950 to Baymax, the care robot in 'Big Hero 6', we've long been fascinated with the possibilities for machines that can understand, reason and learn – and help us to make better use of information.

Just imagine that you had a hand-held scanner the size of your smartphone that could 'sense, compute and record' your daily health status just like the Star Trek medical 'tricorder'.

What if it could make recommendations so that you could achieve and maintain your 'optimal' physical or mental condition or detect anomalies early?

Robots like Baymax and tricorder scanners are not science fiction. AI and robots that support, diagnose and treat people are already in homes, workplaces and clinical environments all over the world. And how we embrace AI and robotics to complement and enhance current

healthcare services over the next ten years will define our ability to deliver a more responsive health service with improved health outcomes, while at the same time enabling people to take more control over their day-to-day health needs.

New Health

We are entering a new era of health – New Health

Health matters. It matters to each of us as individuals and to society as a whole. It lies at the heart of our economic, political, social and environmental prosperity and is one of the largest industries in the world.

Modern health systems can treat and cure more diseases than ever before. New technology is bringing innovation to old treatments. Yet significant quality, access and cost issues remain and our health systems are becoming increasingly unsustainable.

What doctor?

At the heart of this report is the emergence and increasing use of artificial intelligence (AI) and robotics within and throughout this New Health ecosystem. We chose 'What doctor' as our title for the report because during our research – and the response to that research – it has become increasingly clear that policy makers, payers, providers, educators and the public need to consider:t

- **What** is the role of the AI/ robot **doctor**?

- **What** is the role of the human **doctor**?

The answers to these two questions fundamentally impact clinicians and caregivers throughout healthcare. The answers will ultimately decide how we implement the use of AI and robots in developing our healthcare systems across the globe. We will specifically address these two questions in the next phase of our research initiative, but it is important to keep them in mind as we explore existing perceptions and attitudes towards AI and robotics in this report.

Five distinct trends are converging, which mean AI and robotics will come to define New Health:

1. First and foremost is the **value challenge** that all countries across the globe are facing – there is escalating demand from long-term, chronic disease, rising costs, often with an ageing population and limited resources (money, workforce specialists, etc). Yet we are continuing to invest in facilities and equipment that were built to solve a completely different set of healthcare needs and are not designed to cope with this demand. A hospital-centric system deals very well with serious health episodes that require days or weeks of acute care for very ill people. But it was never intended to deal with large numbers of people whose conditions are chronic, complex and require treatment for the longer term.

2. The past decade has seen an **explosion in the amount of health data** that is now available to us. For example, for a skin specialist there are 11,000 new dermatology articles published every year. In 2013, it was estimated that the volume of health-related data had reached over four zettabytes – that's four trillion gigabytes (10^{21}) – and there are those who project this exponential growth rate to reach ten times that by 2020, and, even beyond, to yottabyte (10^{24}) proportions[1]. Furthermore, fully 80% of this extraordinary amount of data is unstructured[2], meaning that it's not contained in a database or some other type of data structure. Staying current with and being able to access this data is simply beyond the scope of any human individual, no matter how capable or intelligent.

3. **Information technology** development in healthcare has been rapidly moving from products to services to solutions (Frost & Sullivan, 2016).

Past decades have focused on the innovation provided by medical **products** delivering historic and evidence-based care. The present decade is one of medical **platforms** focused on real-time, outcome-based care. The next decade is moving towards medical **solutions** – using AI, robotics, and virtual and augmented reality – to deliver intelligent solutions for both evidence- and outcome-based health, and focusing on collaborative, preventative care. This confluence of technology-based products, platforms and solutions is leading to a previously unimagined precision medicine, down to the familial and individual level, which one day may even be able to predict and thereby prevent disease.

4. Technology has, of course, had an impact far beyond the developments in healthcare. The explosion of technology – digitally enabled, wireless connectivity across increasingly mobile devices – has created an increasing **democratisation of access** for healthcare. Some of the most powerful AI tools are already embedded in Android or iOS. Harnessing this technology is providing consumers with the data and information they need to proactively manage their own health and wellness, and to make better, more informed decisions in partnership with their healthcare providers.

5. Finally, the **willingness of the general public** to be more active participants in their own health and wellness has now reached critical mass. As we reported in our 2016 survey Care Anywhere, the explosion of technology and the increasing ubiquity of the Internet of Things (IoT) is bringing about breakthroughs that are erasing healthcare boundaries and enabling care anywhere and everywhere[3]. And this willingness is extending into the areas of AI and robotics, which we explore in this report.

Last decade

Medical Products
Equipment, Hardware, Consumables

Differentiation is solely through product innovation. Focused on historic and evidence based-care.

Current decade

Medical Platforms
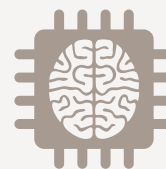Wearable, Big Data, Health Analytics

Differentiation by providing services to key stakeholders. Focused on real time outcome based-care.

Next decade

Medical Solutions
Robotics, AI, Augmented Reality

Differentiation via intelligent solutions for evidence/outcome based health. Focused on preventive care.

Source: Frost & Sullivan, 'Transforming healthcare through artificial intelligence systems', 2016

[1]The Medical Futurist (2016). http://medicalfuturist.com/artificial-intelligence-will-redesign-healthcare/

[2]Healthcare Data Institute (2015). http://healthcaredatainstitute.com/2015/02/18/big-unstructured-datas-contribution-to-healthcare/

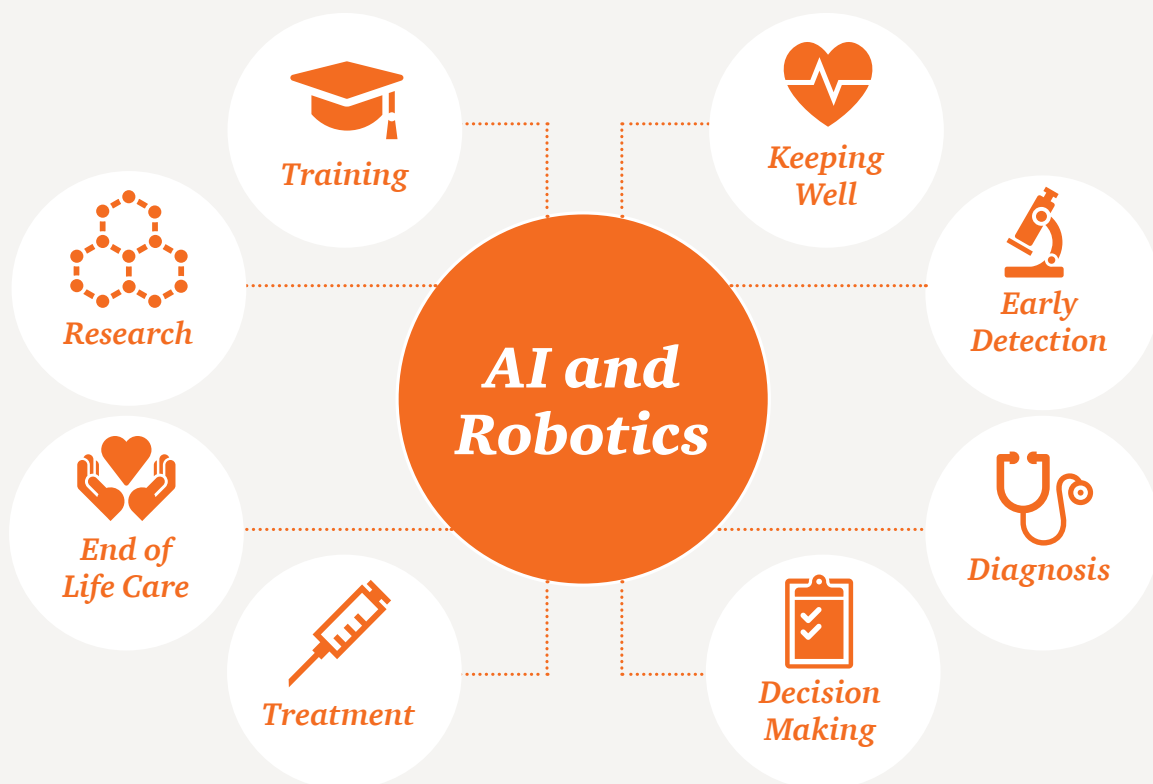[3]PwC (2016). Care Anywhere: Moving health and wellness out of the hospital and into the hands of the consumer. https://www.pwc.com/m1/en/publications/documents/care-anywhere.pdf

Transforming

No longer science fiction, AI and robotics are transforming healthcare

Most of us are barely aware of it, but AI is already a part of our lives – 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 on the web; it's the chatbot on the end of the telephone in call service centres. AI is becoming ubiquitous and most of us use it: Apple's Siri processes two billion natural-language requests a week[4], and 20% of requests on Android phones are made by voice alone[5].

AI is getting increasingly sophisticated at doing what humans do but more efficiently, more quickly and at a lower cost. The potential for both AI and robotics in healthcare is vast. Just like in our everyday lives, AI and robotics are increasingly a part of our healthcare ecosystem.

Throughout this section of the report, we highlight a range of products and existing or emerging technology in side-bars or boxes that we've found during our research for these eight areas. It is extraordinary, and hard to keep up with as new uses of AI and robotics are launched every week.

Training

Keeping Well

Research

Early Detection

AI and Robotics

End of Life Care

Diagnosis

Treatment

Decision Making

Keeping well

One of AI's biggest potential benefits is to help people stay healthy so they don't need a doctor, or at least not as often. The use of AI and the Internet of Medical Things (IoMT) in consumer health applications is already helping people to manage their own healthcare and to keep themselves well through healthier living. For example, the **Smart belt – welt** has a built-in mechanism that alerts the person when they overeat. It relies on a magnetic sensor to track waste size and tension to determine when the users may have over eaten and alerts the wearer. Further, **IBM** has announced three new consumer-focused partnerships, one of which is with **Under Armour** who will use Watson to power a 'cognitive coaching system'.

These applications and others (see Box-Out) all encourage healthier behaviour in individuals and help with the proactive management of a healthy lifestyle. It puts consumers in control of health and well-being. Additionally, AI increases the ability for healthcare professionals to better understand the day-to-day patterns and needs of the people they care for, and with that understanding they are able to provide better feedback, guidance and support for staying healthy – although, as we have noted, the sheer volume of data is increasingly difficult for humans to deal with, or make sense of.

Artificial Intelligence and Consumer Apps for keeping well

Smart Performance Apparel offers real-time biometrics, personalised programming, and customised reporting to help athletes reach their goals faster.

Samsung Electronics offers consumers devices such as smartwatches and activity trackers, as well as their Tizen open-source operating system, which gives users quick access to their mobile devices and help them track their fitness.

Lumo Lift is a posture monitoring device that alerts the person when their posture changes, thus providing the feedback necessary to ensure correct posture whether sitting or standing.

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 three sources: crunching data from Under Armour's 200 million-member Connected Fitness community, external academic research studies and institutions, and IBM Watson similarity analytics. Under Armour will be adding new capabilities including behavioural and performance management, food intake tracking and overall nutrition management as well as the effects of weather and environment on training.

Pathway Genomics is developing an application that will provide customised health advice based on a user's specific genetic makeup.

Early detection

AI is already being used to detect diseases, such as cancer, more accurately and in their early stages. 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. The use of AI is enabling review and translation of mammograms 30 times faster with 99% accuracy, reducing the need for unnecessary biopsies as well as reducing the uncertainty and stress of a misdiagnosis[6].

The proliferation of consumer wearables and other medical devices combined with AI is also being applied to oversee early-stage heart disease, enabling doctors and other caregivers to better monitor and detect potentially life-threatening episodes at earlier, more treatable stages.

On the horizon, Microsoft is developing computers programmed for use at a molecular level to start fighting cancerous cells as soon as they are detected. They are also doing research for using AI to interpret online search engine behaviour, for example, at the point where someone might research symptoms online long before they approach their physician.

AI and Wearables for early detection

Cyrcadia's iTBra™ is a wearable vest being used to screen for the detection of breast cancer at earlier stages.

CardioDiagnostics has developed a device that is able to remotely monitor its wearer for heart irregularities and is used to improve cardiac monitoring and rhythm management.

[4]The Ringer (2016). How Siri Got Left Behind. https://theringer.com/amp/p/2ffc86fe5dfa

[5]The Economist (2017). How voice technology is transforming computing. http://www.economist.com/news/leaders/21713836-casting-magic-spell-it-lets-people-control-world-through-words-alone-how-voice

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

Diagnosis

It's estimated that 80% of health data is invisible to current systems because it's unstructured[7]. IBM's Watson for Health uses cognitive technology to help healthcare organisations unlock vast amounts of health data and power diagnosis. Watson can review and store far more medical information – every medical journal, symptom, and case study of treatment and response around the world – exponentially faster than any human. And it doesn't just store data, it's capable of finding meaning in it. Unlike humans, its decisions are all evidence-based and free of cognitive biases or overconfidence, enabling rapid analysis and vastly reducing – even eliminating – misdiagnosis.

Google's DeepMind Health is working in partnership with clinicians, researchers and patients to solve real-world healthcare problems. The technology combines machine learning and systems neuroscience to build powerful general-purpose learning algorithms into neural networks that mimic the human brain.

Google's Deepmind

In 2016, Google's DeepMind stunned the Go-playing world by beating 18-time world champion Lee Se-dol, one of the highest ranked players in the world. It was the first time a computer programme took on a professional player of this ancient Chinese board game, which has long been considered impossible for computers to play at the international professional level. It's much more difficult than other games like chess, even though the rules are relatively simple, because of the almost infinite number of possibilities and the high levels of intuition required of a world-class player. Deepmind's programme displayed game-winning creativity, in some cases finding moves that challenged millennia of Go wisdom.

DeepMind Health began working with hospitals in the UK in 2016, searching for early signs of disease that lead to blindness and cancer, as well as developing new clinical mobile apps linked to electronic patient records.

Decision-making

Improving care requires the alignment of broad base data analysis with appropriate and timely decisions, and predictive analytics can support clinical decision-making and actions as well as prioritise tasks.

Using the system dynamics driven pattern recognition to identify patients at risk of developing a condition – or seeing it deteriorate due to lifestyle, environmental, genomic, or other factors – is another area where AI is beginning to take hold in healthcare. For example, in an extension and application of AI, **PwC's Bodylogical™** captures learnings in mechanistic modeling to digitally represent the physiology of the human body. This enables true-life simulations to predict the likely progression of chronic diseases in the future based on today's actions and interventions. These simulations help pharmaceutical companies, providers, payers, employers, researchers and consumers better understand how daily life choices and therapeutics impact individual patients or population health outcomes and associated costs.

AI and analytics platforms for decision-making

Quest Diagnostics' Quanum platform is an integrated suite of healthcare information technology and predictive analytics tools that analyses patient test data together with their medical data to help primary care physicians identify patients with early onset memory loss and dementia.

VitreosHealth has developed a predictive analytics platform that identifies people whose health is most likely to deteriorate and implements change protocols to prevent catastrophic health events.

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[7] Healthcare Data Institute (2015). http://healthcaredatainstitute.com/2015/02/18/big-unstructured-datas-contribution-to-healthcare/

Treatment

Beyond scanning health records to help providers identify chronically ill individuals who may be at risk of an adverse episode, AI can help clinicians take a more comprehensive approach for disease management, better coordinate care plans and help patients to better manage and comply with their long-term treatment programmes. **AiCure** has built an application to monitor patients with long-term conditions and help them adhere to medication intake. The application uses a visual recognition system to identify the patient's face, the medication they're taking, and confirm ingestion. The data is then sent back to the care provider or to a pharmaceutical company conducting a clinical trial.

Robots have been used in medicine for more than 30 years. From the first programmable universal machine for assembly (PUMA), used in urology surgery in the 1980s, to the da Vinci robot, the most widely used robotic system in clinical use today, robots have developed to perform a wide range of tasks and functions. They range from simple laboratory robots to highly complex surgical robots that can either aid a human surgeon or execute operations by themselves. In addition to surgery, they're used in hospitals and labs for repetitive tasks, in rehabilitation, physical therapy and in support of those with long-term conditions. **RoBear** is a nursing-care robot that is able to lift and move patients in and out of bed into a wheelchair, help those who need assistance to stand, and even turn patients in bed to prevent bedsores.

AI

Innovaccer's AI Assisted Care Coordination Platform addresses persistent issues in care and connectivity, and assures adherence to care plans by tracking deviations and staying updated on post-acute patient needs.

Sentrian is a remote patient intelligence service provider that delivers integrated remote patient monitoring and analytics to health plan members with complex pulmonary diseases.

Royal Philips delivers remote care options to proactively help patients at home. The services are powered by data analytics and connected sensors enabling 24/7 monitoring and delivery of an ongoing stream of monitoring data to a remote home-care team.

Google DeepMind is partnering with the University College London Hospitals' radiotherapy department. DeepMind will test the use of AI and machine learning to reduce the time it takes to plan radiotherapy treatment for hard-to-treat cancers of the head and neck.

IBM's Watson for Oncology gives treatment recommendations based on patients' medical records and is now being used around the world, including 21 hospitals across China and in Thailand and India.

Robotics

KASPAR is a child-sized humanoid robot designed to help teachers and parents support children with autism.

Giraff is a mobile communication robot that facilitates a chronically ill patients' contact with the outside world. It is remote-controlled, on wheels, and has a camera and monitor.

Bestic is a robotic-assisted dining appliance for people who are unable to move their arms or hands.

Toyota has created four robots that enable immobilized patients to walk or balance.

Xenex robots disinfect hospital facilities using UV light, destroying microorganisms that can be the cause of hospital acquired infections (HAIs).

Aethon's TUG robots automate the delivery and transportation of the immense amount of materials – including food, laundry and prescriptions – that move through a hospital every day, freeing staff to focus on patient care.

Veebot is a robot that can draw blood faster and more safely than a human.

End of life care

We are living much longer than previous generations, and as we approach the end of life, we are dying in a different and slower way, from conditions like dementia, heart failure and osteoporosis. It is also a phase of life that is often plagued by loneliness.

Robots have the potential to revolutionise end of life care, helping people to remain independent for longer, reducing the need for hospitalisation, caregivers and care homes by performing routine tasks such as taking vital signs and prompting for medication. AI combined with the advancements in humanoid design are enabling robots to go even further and have 'conversations' and other social interactions with the people that keep ageing minds sharp and solves problems of loneliness and isolation. **Kompai robots** talk, understand speech, remind people of meetings, keep track of shopping lists and play music.

Developed to assist the elderly in their own homes, they are able to monitor for falls and other health parameters, provide alerts, and connect via video-conference with healthcare providers as well as with friends and family.

End of life care

Paro Therapeutic Robots are advanced interactive robots that enable the documented benefits of animal therapy to be administered to patients in environments such as hospitals and extended care facilities where live animals present treatment or logistical difficulties. They've been found to reduce stress, stimulate interaction and improve socialisation.

Robot Era is developing robots that move around on wheels but have a friendly humanoid face. The robot's sensors and cameras are used to gather and analyse real-time data which is then sent to the cloud wirelessly where algorithms extrapolate such advanced information as whether someone is showing signs of dementia. They can also remind the elderly about daily tasks and important information, and track conditions over time.

Zora Robotics is building AI software into Zora Bots that have patient-facing roles in hospitals and are training humanoid robots to hold conversations with the elderly.

Research

Each and every one of us has most likely taken a medication prescribed by our doctors for a symptom or illness at some point in our lives. Those with chronic diseases often depend upon medication to manage what might otherwise be debilitating diseases. But the path from research lab to patient is a long and costly one.

According to the California Biomedical Research Association, it takes an average of **12 years** for a drug to travel from the research lab to the patient. Only five in 5,000, or .1%, of the drugs that begin pre-clinical testing ever make it to human testing and just one of these five is ever approved for human usage. Furthermore, on average, it will cost a company US $359 million to develop a new drug from the research lab to the patient[8].

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 time to market for new drugs and their costs, not only for the labs who develop the drugs, but for those people whose health depends upon them. **Pharma.AI** is the Pharmaceutical Artificial Intelligence division of Insilico Medicine, a bioinformatics company located at the Emerging Technology Centers at the Johns Hopkins University, launched in March 2016. They focus on drug discovery programmes for cancer, Parkinson's, Alzheimer's, and other ageing and age-related health issues.

However, medical research is not just about finding new drugs to combat disease. It also includes research into disease itself, with the ultimate goal being to inoculate against or completely eliminate disease. **Meta** is a Canadian start-up that uses AI to quickly read and comprehend scientific papers and then provide insights to researchers; it was bought by the Chan Zuckerberg Initiative in January 2017 as part of the charitable foundation's mission to eradicate disease.

Research

The **Japanese Government** has entered into a public-private alliance to develop a self-learning AI at the government-affiliated National Institutes of Biomedical Innovation, Health and Nutrition. The partnership will support researchers in streamlining the development of new drugs in order to boost the nation's competitive advantage.

BERG Health, a startup that uses an AI platform for drug discovery, initiated a phase II clinical trial in 2016 for a drug compound that could potentially treat pancreatic cancer.

Atomwise found two existing drugs – reportedly in one day using its AI technology – that may also work against the Ebola virus.

[8] California Biomedical Research Association. New Drug Development Process. http://www.ca-biomed.org/pdf/media-kit/fact-sheets/CBRADrugDevelop.pdf

Training

AI allows those in training to go through naturalistic simulations in a way that simple computer-driven algorithms cannot. The advent use of natural speech in technology and the ability of an AI computer to draw instantly on a large database of scenarios means AI can respond to questions, decisions or advice from a trainee and can challenge more effectively than a human can. And the training programme can learn from previous responses from the trainee, meaning that the challenges can be continually adjusted to meet their learning needs.

And training can be done anywhere with the power of AI embedded on a smartphone, for example, as quick catch up sessions, after a tricky case in a clinic or while travelling.

To date, the main way new technologies have been used to augment training is through virtual reality (VR). Combining VR with AI will offer boundless opportunities for extending the skills of trainees in a targeted fashion.

AI and robotics are redrawing the healthcare landscape. The wave of innovation being driven by these technologies is not only transforming clinical decision-making, patient monitoring and care, and surgical support, but fundamentally changing how we approach healthcare for our populations. We are already experiencing this shift as we focus on integrating prevention and wellness into our health systems and we are heading towards a time when people work more proactively with their healthcare professionals across illness and wellness.

This shift will inevitably alter many of the roles of healthcare professionals. As these new technologies and perspectives become more integrated within and across our healthcare systems and more ubiquitous among the population, the skills that are required by our new health landscape may well be markedly different than those that are needed today. We currently train our doctors and nurses in the context of health systems that may no longer exist once they graduate medical school. An understanding of technology will be imperative. Programming, data analytics and human behaviour may well be as much a part of the medical curricula as anatomy and neurology.

AI and robotics technology will free up clinicians for other types of work that enable them to spend more meaningful time with their patients. Rather than a profession of 'healthcare providers', AI and robotics will open opportunities for more holistic patient care, with a focus on keeping patients healthier longer, instead of primarily treating illness.

AI will likely challenge the traditional role of the doctor. But, rather than worrying if these technologies are going to replace doctors and other healthcare professionals, we should be considering more deeply their wider role in the entire healthcare continuum with a clear eye towards training our healthcare workforce for the future.

Investment

AI investment heats up

From predictive insights to robotic surgery, investment is booming

Investing in health is always a long-term prospect, whether it is a matter of training a doctor, developing a new drug, building a new facility or developing AI and robotics. The question is, given that long-term view, and the potential of AI and robotics, where should that investment go? Already AI is coming of age, and the AI healthcare market is poised for dramatic growth. Frost & Sullivan predicts that the AI market for healthcare will increase by 40% between 2014 and 2021. And they estimate growth from US$633.8m to US$6.662bn[9].

According to Frost & Sullivan analyst Harpreet Singh Buttar, 'By 2025, AI systems could be involved in everything from population health management, to digital avatars capable of answering specific patient queries.'[10]

Figure 1: Artificial Intelligence for Healthcare Applications, World, 2014, 2021 (in Millions)
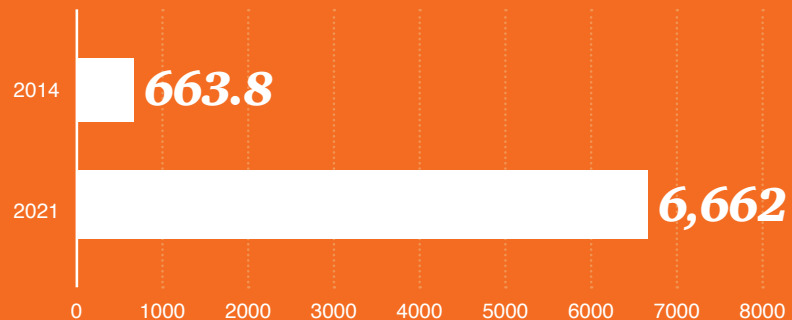
Source: Frost & Sullivan 2016 Transforming healthcare through artificial intelligence systems

In 2011 there were fewer than ten deals related to healthcare AI; this leapt to almost 70 deals in 2016. Some of the 2016 deals included a US$25m Series A round raised by London-based health services startup, Babylon Health, and a US$154m Series A round raised by China-based iCarbonX[11].

According to CB Insights, healthcare is the hottest area of investment within AI. They identified over 100 companies that have raised an equity funding round since January 2013[12]. From insights and analytics, imaging and diagnostics, drug discovery to remote patient monitoring and virtual assistants, AI is poised to impact every aspect of healthcare.

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[9] Frost & Sullivan (2016). Transforming healthcare through artificial intelligence systems. AI Health and Life Sciences.

[10] As quoted in Huffpost Tech UK, "Artificial Intelligence For Healthcare Is Booming", by Reuven Cohen (31 Jan 2017). http://www.huffingtonpost.co.uk/reuven-cohen/artificial-intelligence-f_b_14437718.html

[11] CB Insights (Feb. 3, 2017). https://www.cbinsights.com/blog/artificial-intelligence-startups-healthcare/

[12] Ibid.

[13] CB Insights (Feb. 3, 2017). https://www.cbinsights.com/blog/artificial-intelligence-startups-healthcare/

AI Investment Highlights[13]

Insights & risk analytics: Health insights and risk analytics has been the hottest category for investment since 2015. Companies in this category provide predictive insights about a patient's health using machine learning and natural language processing algorithms. The analytics are based on factors that include medical history and demography.

Imaging & diagnostics: This category has become more saturated with companies in recent years compared to other areas of healthcare AI, with more than 80% of deals raised after January 2015.

Remote patient monitoring: Deals to the category have picked up since 2015, though there are fewer companies here than in diagnostics or risk analytics. London-based Babylon Health, backed by investors including Kinnevik and Google-owned DeepMind Technologies, raised a US$25m Series A round in 2016 to develop an AI-based chat platform.

Core AI companies bring their algorithms to healthcare: Core AI start-up Ayasdi, which has developed a machine intelligence platform based on topological data analysis, is bringing its solutions to healthcare providers for applications including patient risk scoring and readmission reduction.

Drug discovery: This category is gaining attention, and venture capitalists have backed six out of the nine start-ups on the map, who are using machine learning algorithms to reduce drug discovery times.

Oncology: IBM Watson Group-backed Pathway Genomics has recently started a research study for its new blood test kit, CancerIntercept Detect.

The company will collect blood samples from high-risk individuals who have never been diagnosed with the disease to determine if early detection is possible.

Emergency room & hospital management: Start-ups here provide insights and real-time analytics, specifically in a hospital environment. Gauss Surgical, for instance, uses image recognition to monitor blood loss during surgery in real time using an iPad.

Virtual Assistants: This category has a relatively low deal count, less than ten since 2012, but has the potential for increased investment activity. One of the start-ups, Babylon Health in the United Kingdom, was backed last year by investors including Kinnevik and Google DeepMind in a US$25m Series A round.

Mental Health: This is another category with relatively low deal count, as well as fewer companies. Seed-stage start-up Avalon uses AI to predict brain degeneration, and focuses on neuro-degenerative disease like Alzheimer's and Parkinson's.

Research: This category includes China-based iCarbonX, which joined the unicorn club in Q2 2016. Another start-up, Desktop Genetics, helps scientist with genome editing and CRISPR research. It received funding last year from genetic research company Illumina.

Nutrition: Ireland-based Nuritas uses artificial intelligence to mine data and identify compounds in food that are beneficial to health. Marc Benioff invested over US$2m in the company in Q2 2016.

Rise of the robots

Alongside AI, robotics is becoming one of the hottest new markets in tech. According to IDC, the overall market has been growing at a compound rate of 17% a year and will be worth US$135bn by 2019, with a boom taking place in Asia, Japan and China.

Markets and Markets estimates that the market for healthcare robotics will grow to US$11.4bn by 2020[14]. Surgical robots comprise the largest component of the medical robotics market, according to IndustryArc, specifically the use of robots to facilitate minimally invasive surgery (see box-out).

Changes soon could cause something of a shift in power around the operating table. Surgical robots may cease to be dumb, programmable machines and transform into smart assistants.

Yet there is also growing opportunity in the home health and end of life care space for robots. The global personal robot market, including 'care-bots', could reach US$17.4bn by 2020, according to Frost & Sullivan, driven by rapidly ageing populations, a looming shortfall of care workers, and the need to enhance performance and assist rehabilitation of the elderly and physically handicapped.

Japan is leading the way with one-third of the government budget on robots devoted to the elderly. The Japanese 'care-bot' market alone is estimated to grow from US$155m in 2015 to US$3.728 billion by 2035 (source: Ministry of Economy, Trade & Industry)[15].

Bionics, exoskeletons and the next generation wearable robot are also becoming a reality and could revolutionise how we treat and care for those with diminished or lost functions due to ageing or physical challenges and injuries. The rehabilitation robot market was estimated at US$203m in 2014 and is expected grow to US$1.1bn by 2021[16].

New entrants, minimally invasive surgical robots[17]

Verb Surgical is working with Johnson & Johnson's Ethicon and Alphabet Inc's Verily to develop the generation of surgical robots, incorporating advanced visualisation, machine learning, data analytics and connectivity.

Mazor Robotics Renaissance surgical guidance system transforms spine surgery from freehand procedures to guided procedures. Mazor's ADSs trade on the NASDAQ under the symbol MZOR. The company reported a 54% year-over-year Q4 2015 revenue increase to US$8.8m.

TransEnterix is a medical device company that is pioneering the use of robotics to improve minimally invasive surgery. They are developing and commercialising its ALF-X System, a multi-port robotic surgery system that enables up to four arms to control robotic instruments and a camera, and its SurgiBot System, a single-incision, patient-side robotic-assisted surgery system.

Titan Medical is a development stage company that is developing its SPORT (Single Port Orifice Robotic Technology) Surgical System composed of a surgeon-controlled robotic platform with 3D vision and interactive instrument control for performing minimally invasive surgery. The company believes SPORT will enable surgeons to perform procedures within small- to medium-size surgical spaces for general abdominal, gynecologic, and urologic indications. The company is pre-revenue. The company recently raised CAD$15.1m through a public offering.

Hansen Medical develops, manufactures, and sells medical robotics designed for the positioning, manipulation, and control of catheters. The company's Magellan Robotic System controls the proprietary Magellan Robotic Catheter, a telescoping and robotically steerable catheter. In 2016 the FDA approved Hansen's Magellan Robotic Catheter eKit and a few days later, the company announced its first clinical procedure with the Magellan in the US.

Stereotaxis designs, manufactures, and markets robotic systems and instruments for the treatment of abnormal heart rhythms. Its products include the Niobe ES robotic system and Vdrive system. Stereotaxis has strategic alliances with Siemens and Philips Medical Systems. The company recently reported its first quarter of positive free cash flow – of US$1.6m – which management indicated helped drive a 71% reduction in 2015 annual cash burn, For FY 2015, Stereotaxis registered total revenue of US$37.7m, which represented an 8% year-over-year improvement.

The sheer scope of opportunity raises many questions for investors. There are risks – competitive, regulatory and market risk, among others. But with healthcare undergoing such massive change, and the rapid progress of AI and robotics, how safe are current, traditional healthcare investment strategies? We believe that healthcare is fundamentally about the most effective application of knowledge in order to keep people healthy. As knowledge progresses, it is the investor who has the power to bring that knowledge to life.

[14] Markets and Markets (Feb 2017). http://www.marketsandmarkets.com/PressReleases/medical-robotic-systems.asp

[15] Bank of America (2016). http://about.bankofamerica.com/assets/davos-2016/PDFs/robotic-revolution.pdf

[16] Bank of America (2016). http://about.bankofamerica.com/assets/davos-2016/PDFs/robotic-revolution.pdf

[17] MedDeviceOnline (February 12, 2016). New Entrants to Open Up Surgical Robotics Market. https://www.meddeviceonline.com/doc/new-entrants-to-open-up-surgical-robotics-market-0001

Findings

The public is ready

In November 2016, we asked YouGov Research to conduct a survey of the general public across Europe, the Middle East and Africa (EMEA) to understand 3 things:

- if there was the appetite to engage with AI and robots for healthcare;
- the circumstances under which there would be greater or lesser willingness to do so; and,
- the perceived advantages and disadvantages of using AI and robots in healthcare.

We surveyed over 11,000 people across 12 countries and the evidence strongly indicates that there is a growing enthusiasm among consumers to engage in new ways with new technology for their health and wellness needs.

The message is clear; the public is ready and willing to substitute AI and robotics for humans.

But behind that message is a lot of important information that has implications for how these new technologies will shape New Health. The findings of the survey suggest three key themes that are impacting how consumers are willing to engage with AI and robotics:

- People are increasingly willing to engage with AI and robots if it means **better access** to healthcare;
- **Speed and accuracy of diagnosis and treatment** is a critical factor for this willingness; and
- **Trust** in the technology is vital for wider use and adoption; the 'human touch' remains a key component of the healthcare experience.

Trends did emerge across regions – people in those countries with well-established, and therefore more rigid, healthcare systems were willing to engage with a non-human healthcare provider, but less so than those in countries where healthcare still has the ability to shape and form.

In fact, for all questions throughout the survey a pattern can be seen between developed and emerging economies:

- **Developed economies** with entrenched healthcare systems– characterised by a high per capita health spend and a long legacy of universal healthcare coverage delivering good overall value – occupy the bottom half of the scale where respondents were less willing to rely on AI.
- **Emerging economies** are significantly more willing to engage with the new technologies. These countries have mixed degrees of healthcare coverage (Turkey enacted universal healthcare in 2003, for example) but lower per capita health spend compared to developed economies. Some still have access constraints and quality disparities between public and private care.
- Countries in the **Middle East** sit in the middle of our survey results. These countries have a longer history with universal coverage and spend two to three times more per capita on healthcare than other emerging markets, but are affected by workforce issues and capacity constraints[18].

However, there is generally a surprisingly high willingness among all respondents to engage with AI and robots, regardless of country, gender or age. From fitness counsel, monitoring and advice on diabetes and heart conditions, to both minor and major surgery, we found that consumers across demographics are willing to consider non-traditional options for managing and treating their health.
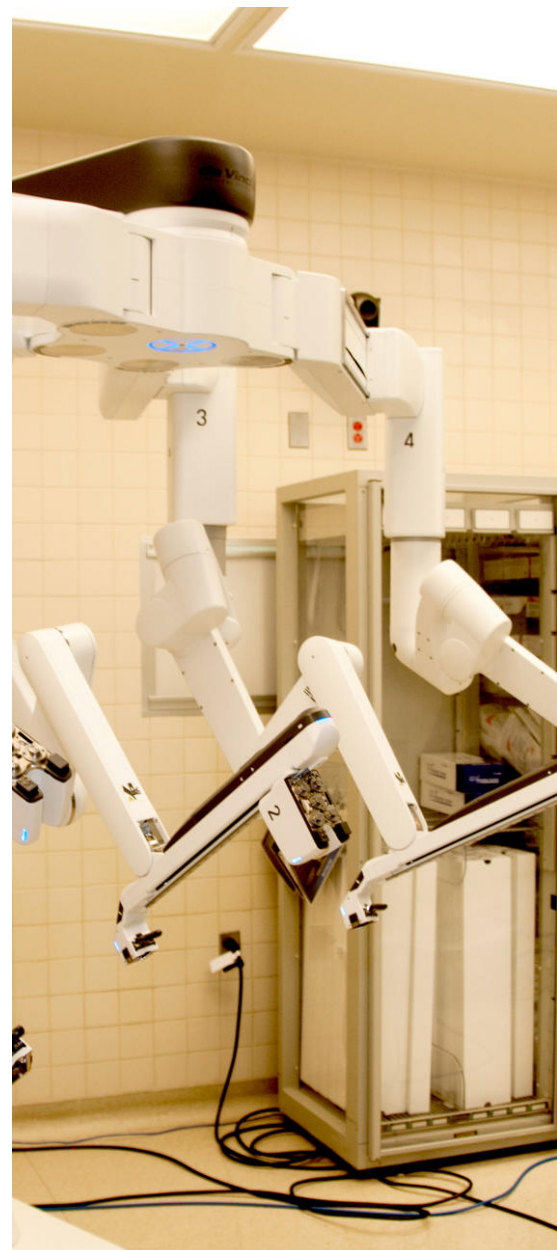
[18] Total health expenditure (THE) in the developed economies in our survey (e.g. UK, Northern and Central Europe) ranges between $3,377 and $6,347 per capita. Middle East countries range between $2,400-3,000 per capita. South Africa and Turkey's THE per capita is around $1,000, while Nigeria has the lowest in the sample at $217 per capita. All amounts are Int$ (PPP) for 2014. Source: WHO Global Health Expenditure Database

Will AI replace the consultation?

The human 'face-to-face' element of healthcare is traditionally cited as vital to healthcare. And yet most doctors probably spend more time going over medical records and interpreting data from tests and other medical interventions than actually spending time with their patients.

As we've noted, there is already existing technology that can perform these functions. This may well evolve into a human-like interface for patients and consumers of healthcare services – either remotely or in a clinical environment – where the experience will feel like an interaction with a 'real' doctor.

How willing are patients to interact with such technology?

We asked our survey participants to consider advanced computer technology or robots with AI that had the ability to answer health questions, perform tests, make a diagnosis based on those test and symptoms, and recommend and administer treatment. We wanted to understand how willing they would be to engage with this technology if it was more accessible and could process health information faster and more efficiently than their doctor or other health professional.

As a whole, across EMEA there is more willingness than unwillingness to engage with AI and robots, with more than half willing (55%), one-third unwilling (38%) and 7% neither willing nor unwilling.
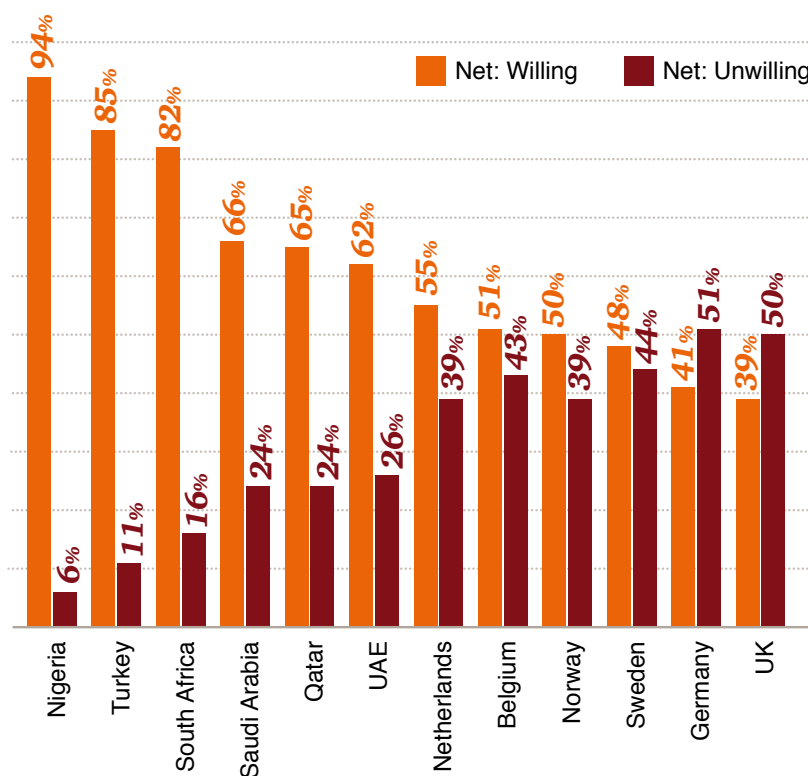
Yet when we looked at the individual country data, there were interesting findings. From almost four out of ten respondents in the UK (39%) to more than nine out of ten in Nigeria (95%), willingness to talk to and interact with a device, platform or robot with artificial intelligence varied widely.

Figure 2: Percentage of respondents willing/unwilling to engage with AI and robotics for their healthcare needs (total sample)

| 55% | 38% | 7% |
| Willing | Unwilling | Neither willing nor unwilling |
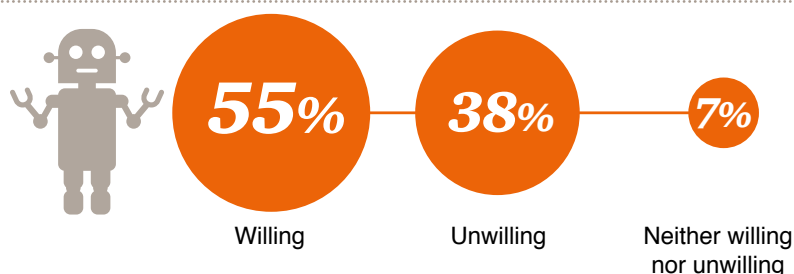
Source: PwC survey

Figure 3: Percentage of respondents willing/unwilling to engage with AI and robotics for their healthcare needs (by country)

Net: Willing   Net: Unwilling

	Net: Willing	Net: Unwilling
Nigeria	94%	6%
Turkey	85%	11%
South Africa	82%	16%
Saudi Arabia	66%	24%
Qatar	65%	24%
UAE	62%	26%
Netherlands	55%	39%
Belgium	51%	43%
Norway	50%	39%
Sweden	48%	44%
Germany	41%	51%
UK	39%	50%

Source: PwC survey

While there was generally high willingness to engage with AI and robots across all countries, a clear pattern emerged:

- Nigeria, Turkey and South Africa are significantly the most willing (94%, 85% and 82% respectively).
- Two-thirds of the Middle East are willing, with percentages statistically the same across the region.
- The Netherlands (55%), Belgium (51%), Norway (50%) and Sweden (48%) are less willingness yet still represent a significant percentage of the sample.
- Germany and the UK are the only countries where unwillingness (51% and 50% respectively) is greater than willingness (41% and 39% respectively).

But the variation across countries should not be taken to mean there are not opportunities in every country for AI and robotics to be adopted. In every country, a highly significant proportion of the population is willing to engage with AI and robotics for healthcare services. Yet the findings clearly suggest that implementation is key – the introduction of AI and robotics for these services will need a different approach in the different countries.

There were some distinctions with regards to gender – men were generally more willing than women (61% versus 55%), yet women were significantly more willing than men in Turkey (91% versus 80%), Norway (57% versus 42%) and Sweden (54% versus 41%).

This was the pattern across all countries with the exceptions of Nigeria, where the most willing were aged 18-24 (95%) and over the age of 45 (100%), and Turkey, where willingness increased with age (from 82% to 89%).

Figure 4: Percentage of respondents willing/unwilling to engage with AI and robotics for their healthcare needs (by age)
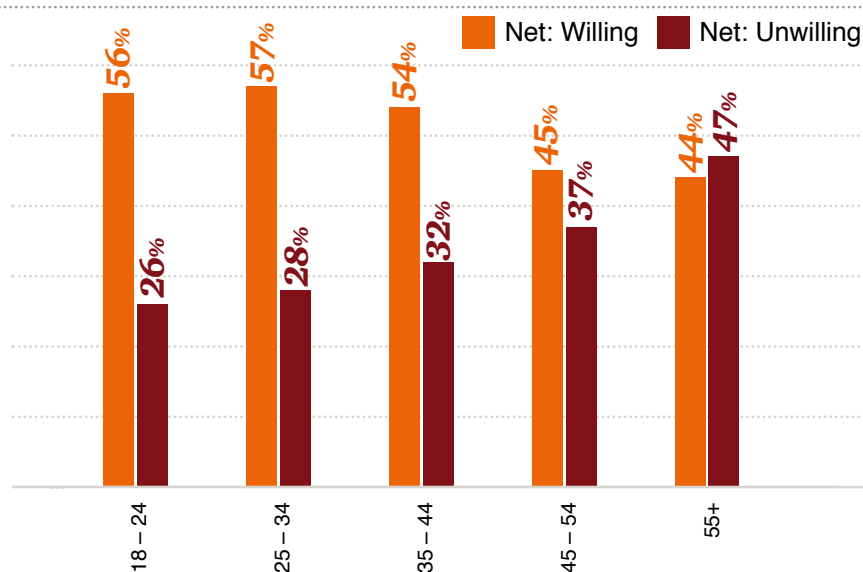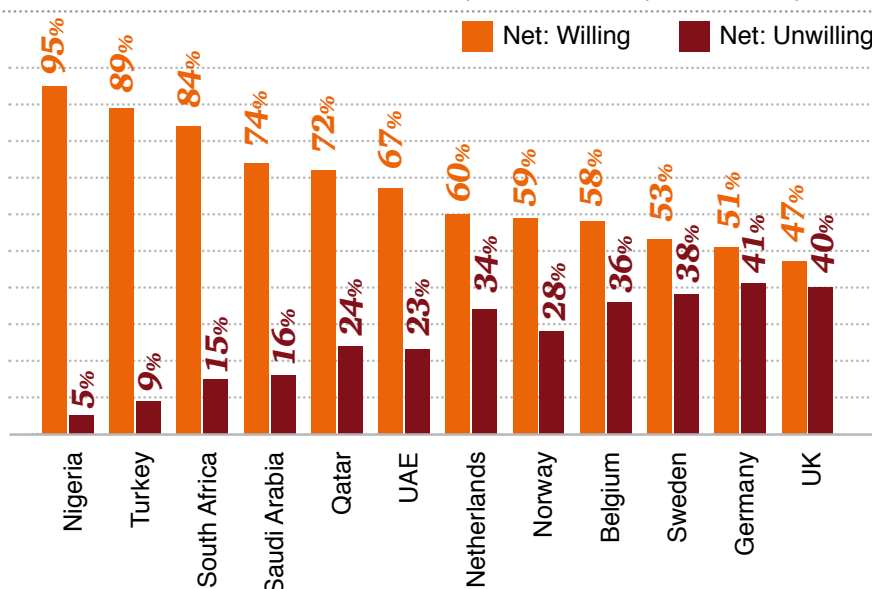

Source: PwC survey

We then wanted to understand how people felt about receiving health advice and information remotely, from an 'intelligent healthcare assistant', via a smartphone, tablet or personal computer – in a situation that involved their own health and also for a loved one (such as parent, spouse or child). We asked them to imagine a specific health situation in each case. For their own situation, we asked them about remote diabetes monitoring and recommendations for any treatment or lifestyle changes that were necessary – this would involve taking pulse and blood pressure, testing blood sugar levels, checking kidney function, and monitoring weight and level of exercise.

The patterns remained consistent with the willingness to engage face-to-face, with the exception of Germany and the UK, where respondents were more willing than unwilling in this specific situation, even though they remained the least willing and most unwilling of all the countries.

Figure 5: Percentage of respondents willing/unwilling to use an 'intelligent healthcare assisstant' via a smartphone, tablet or personal computer

Source: PwC survey

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When the situation involved a loved one, the respondents were less willing, though not substantially so. Specifically, we asked them to imagine that a loved one was feeling unwell and they needed advice about treatment. This would involve making a diagnosis based on their symptoms, medical history and vital signs (pulse, blood pressure and temperature).

While the patterns from country-to-country remained consistent, with significantly higher willingness for Nigeria, Turkey and South Africa, and high willingness across the Middle East, respondents across Northern and Western Europe expressed significantly less willingness. In Sweden, Germany and the UK those who were reluctant to use this technology for their loved ones outnumbered those who would be willing.

Again, percentages of willingness remained high, reinforcing the indication for different implementation strategies.
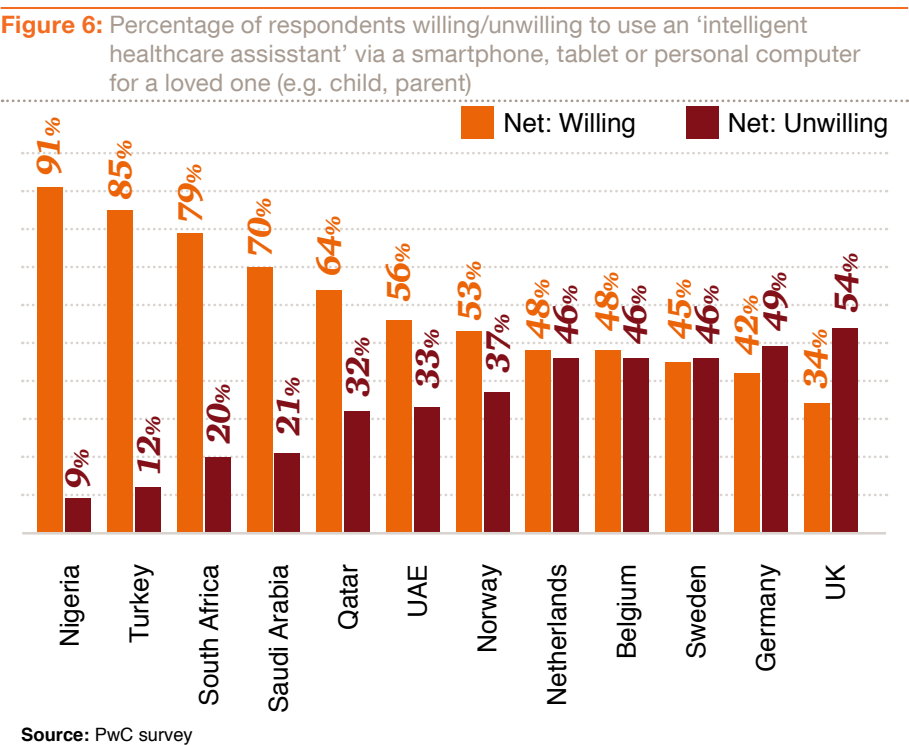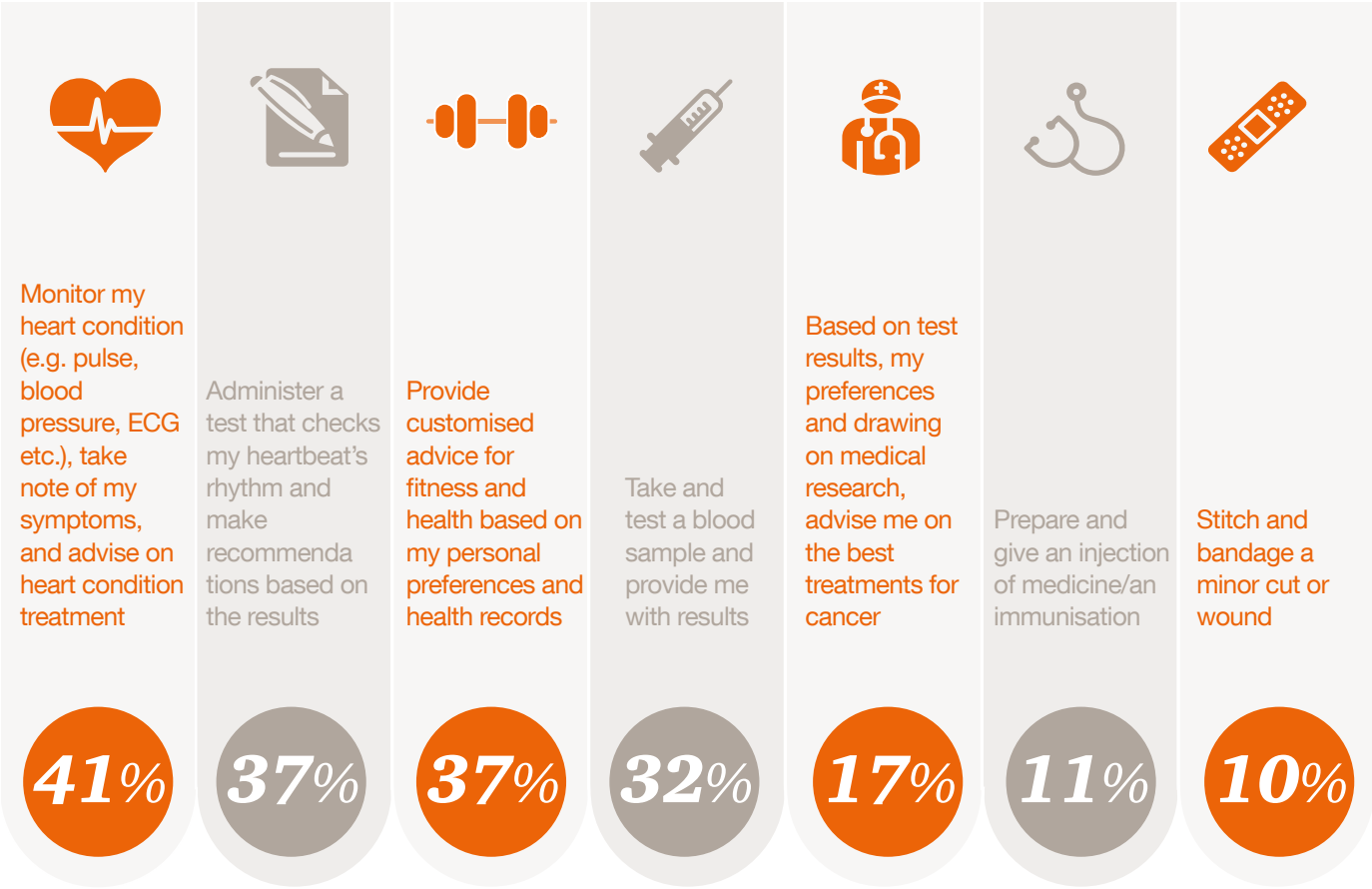
Figure 6: Percentage of respondents willing/unwilling to use an 'intelligent healthcare assisstant' via a smartphone, tablet or personal computer for a loved one (e.g. child, parent)

■ Net: Willing ■ Net: Unwilling

Country	Net: Willing	Net: Unwilling
Nigeria	91%	9%
Turkey	85%	12%
South Africa	79%	20%
Saudi Arabia	70%	21%
Qatar	64%	32%
UAE	56%	33%
Norway	53%	37%
Netherlands	48%	46%
Belgium	48%	46%
Sweden	45%	46%
Germany	42%	49%
UK	34%	54%

Source: PwC survey

Figure 7: Procedures respondents were most willing to recieve from an AI/robot, when asked to rank three

Monitor my heart condition (e.g. pulse, blood pressure, ECG etc.), take note of my symptoms, and advise on heart condition treatment — **41%**

Administer a test that checks my heartbeat's rhythm and make recommendations based on the results — **37%**
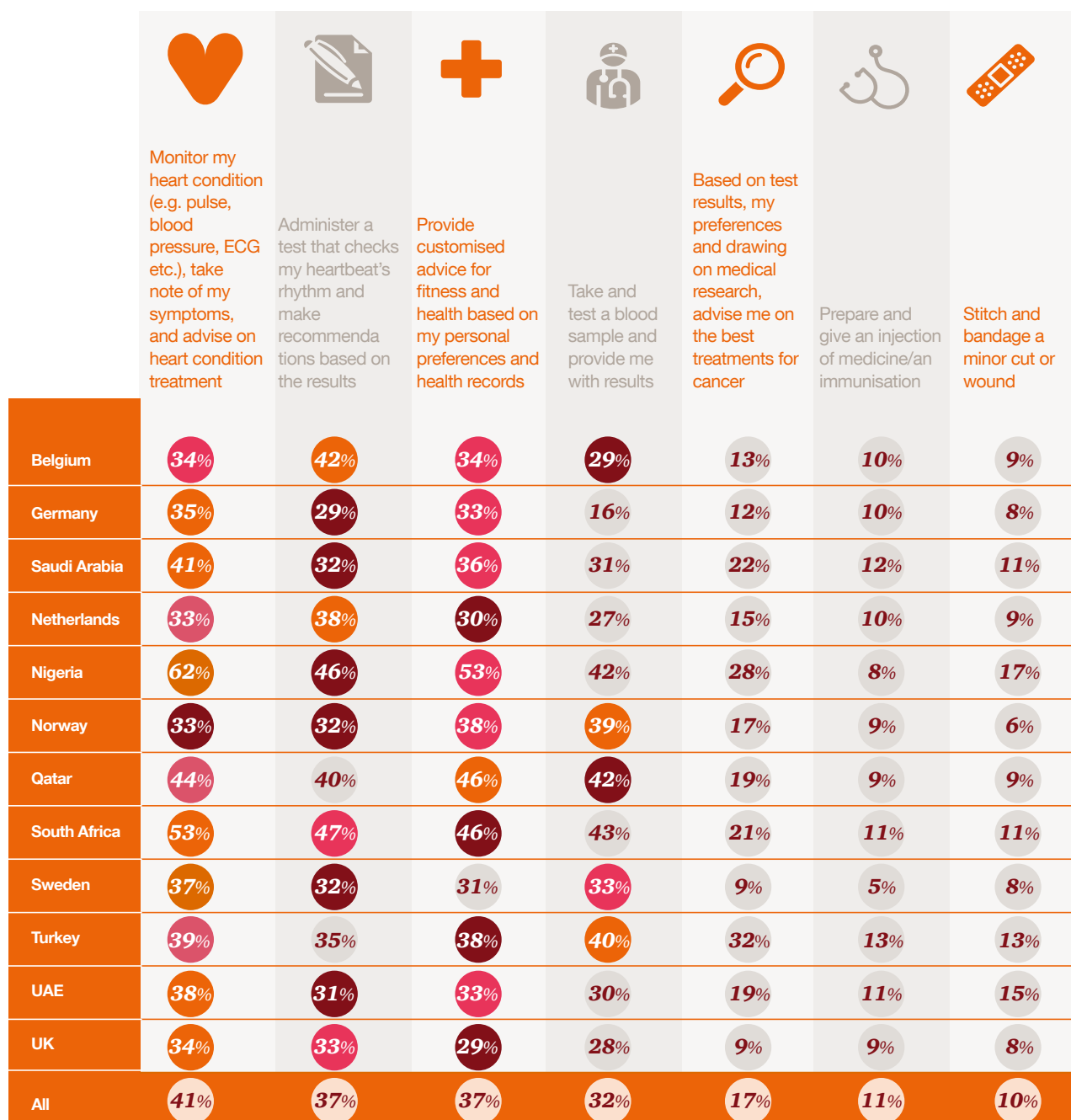
Provide customised advice for fitness and health based on my personal preferences and health records — **37%**

Take and test a blood sample and provide me with results — **32%**

Based on test results, my preferences and drawing on medical research, advise me on the best treatments for cancer — **17%**

Prepare and give an injection of medicine/an immunisation — **11%**

Stitch and bandage a minor cut or wound — **10%**

Service preferences

A significant percentage of respondents were highly willing to choose certain treatments, tests or services administered by an AI or robot and there was widespread agreement about these services across the countries surveyed.

Specifically, consumers across the region were most willing – by a significant margin – to receive four types of services:

- Monitor my heart condition (e.g. pulse, blood pressure, electrocardiography (ECG), etc.), take note of my symptoms, and advise on heart condition treatment (41%).
- Administer a test that checks my heartbeat's rhythm and make recommendations based on the results (37%).

- Provide customised advice for fitness and health based on my personal preferences and health records (37%).
- Take and test a blood sample and provide me with the results (32%). Consistent with our 2016 report Care Anywhere: Moving health and wellness out of the hospital and into the hands of the consumer, these findings suggest that the public is most willing to use AI and robotics for monitoring and providing advice. But this survey has also shown they are willing to replace a human for these same services. In a world increasingly dominated by chronic disease this has a major implication for ambulatory or clinic-based care.

However, while every country surveyed agreed that these four services were the ones they would be most willing to receive, the priorities were slightly different from country to country.

Furthermore, it's worth noting that a remarkably high percentage of respondents in a majority of countries would be willing to receive advice on treating cancer. And even though the UK and Germany had a significant number of people unwilling to use such technology for any type of health service or procedure compared to other countries, there is still greater willingness than unwillingness; again, important to note when it comes to implementation.

Set a broken bone and put it into a cast	Monitor me and provide general care/offer advice during pregnancy	Deliver my baby	Other	Don't know	Not applicable – I would not be willing to use an advanced computer/ robot with artificial intelligence for any type of procedure/ service
7%	**5%**	**1%**	**1%**	**10%**	**20%**

Figure 8: Healthcare service priorities, by country

	Monitor my heart condition (e.g. pulse, blood pressure, ECG etc.), take note of my symptoms, and advise on heart condition treatment	Administer a test that checks my heartbeat's rhythm and make recommendations based on the results	Provide customised advice for fitness and health based on my personal preferences and health records	Take and test a blood sample and provide me with results	Based on test results, my preferences and drawing on medical research, advise me on the best treatments for cancer	Prepare and give an injection of medicine/an immunisation	Stitch and bandage a minor cut or wound
Belgium	34%	42%	34%	29%	13%	10%	9%
Germany	35%	29%	33%	16%	12%	10%	8%
Saudi Arabia	41%	32%	36%	31%	22%	12%	11%
Netherlands	33%	38%	30%	27%	15%	10%	9%
Nigeria	62%	46%	53%	42%	28%	8%	17%
Norway	33%	32%	38%	39%	17%	9%	6%
Qatar	44%	40%	46%	42%	19%	9%	9%
South Africa	53%	47%	46%	43%	21%	11%	11%
Sweden	37%	32%	31%	33%	9%	5%	8%
Turkey	39%	35%	38%	40%	32%	13%	13%
UAE	38%	31%	33%	30%	19%	11%	15%
UK	34%	33%	29%	28%	9%	9%	8%
All	41%	37%	37%	32%	17%	11%	10%

● 1st choice ● 2nd choice ● 3rd choice

Source: PwC commissioned survey (2017)

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Set a broken bone and put it into a cast	Monitor me and provide general care/offer advice during pregnancy	Deliver my baby	Other	Don't know	Not applicable – I would not be willing to use an advanced computer/ robot with artificial intelligence for any type of procedure/ service
5%	8%	2%	1%	10%	19%
6%	3%	0%	0%	11%	25%
10%	0%	0%	1%	14%	6%
4%	4%	1%	1%	12%	20%
12%	9%	3%	1%	1%	2%
3%	4%	0%	1%	9%	19%
7%	1%	1%	0%	7%	12%
9%	11%	2%	2%	2%	7%
4%	1%	1%	1%	10%	22%
10%	11%	4%	1%	3%	8%
11%	5%	2%	0%	11%	8%
4%	3%	1%	0%	9%	31%
7%	5%	1%	1%	10%	20%

Will robots replace surgeons in the operating theatre?

In the three decades since robots first began performing surgery, the exponential advances in robotic technology are enhancing a surgeon's ability to see, feel and do. Autonomous surgery performed by robots, replacing the surgeon, is likely to further the effectiveness, safety, consistency, and accessibility of surgical techniques. For example, experimental studies have already shown autonomous robots to perform higher quality suturing than surgeons.

Are consumers ready?

We asked our survey participants if they would be willing for a robot to perform a minor or major surgical procedure instead of a doctor if studies showed that they could do it better than a doctor (e.g. more quickly, more accurately, with a faster recovery time).

- We defined a minor surgical procedure as a non-invasive or minimally-invasive surgery, such as cataract surgery or laser eye surgery, and found that, overall, close to half and up to 73% of all respondents would be willing to undergo minor surgery performed by a robot instead of a doctor. personal preferences and health records (37%).
- Take and test a blood sample and provide me with the results (32%).

Minor surgery

Nigeria, Turkey and South Africa were the **most willing** to undergo minor surgery performed by robots (73%, 66% and 62% respectively), with the UK the **least willing** (36%). In Belgium, the UK, Germany and Sweden the unwilling respondents outnumbered the willing, yet those countries still have over one-third of the public still willing to undergo such a procedure.

Perhaps unsurprisingly, the situation changed dramatically when it came to major surgery. We defined major surgery as **invasive** surgery – such as replacement of a knee or hip joint, removal of a tumour, or heart surgery – and found much higher unwillingness for a robot to perform a major procedure instead of a doctor.

Major surgery

Even so, Nigeria, Turkey and South Africa were far more **willing** (69%, 60% and 51% respectively) than **unwilling** to undergo major surgery performed by a robot. Again, the UK was the **least willing** of all the countries surveyed (27%) and Belgium (60%), Germany (59%), the UK (58%), Sweden (55%), the Netherlands (53%) and Norway (51%) were all much more **unwilling** than willing to undergo major surgery performed by a robot.

Figure 9: Percentage willing/unwilling to have minor surgery performed by a robot instead of a doctor
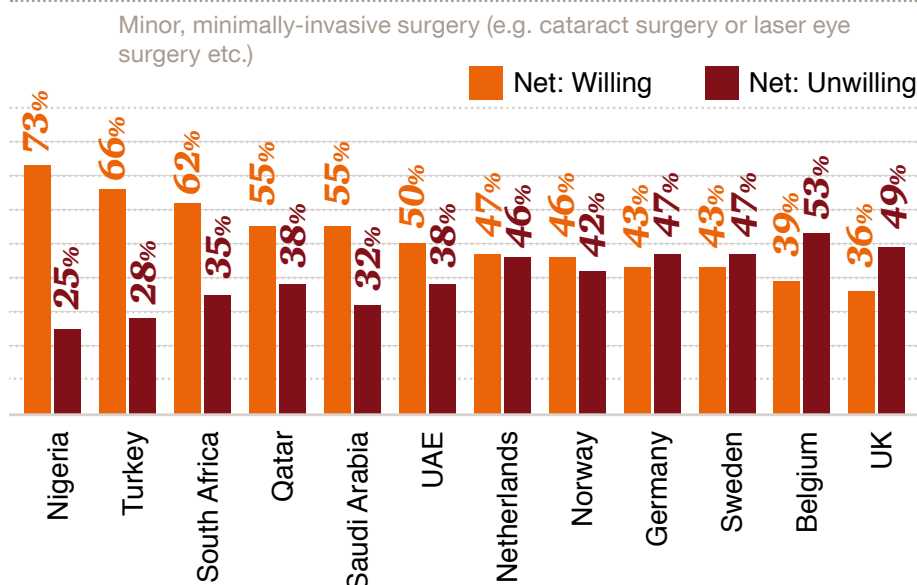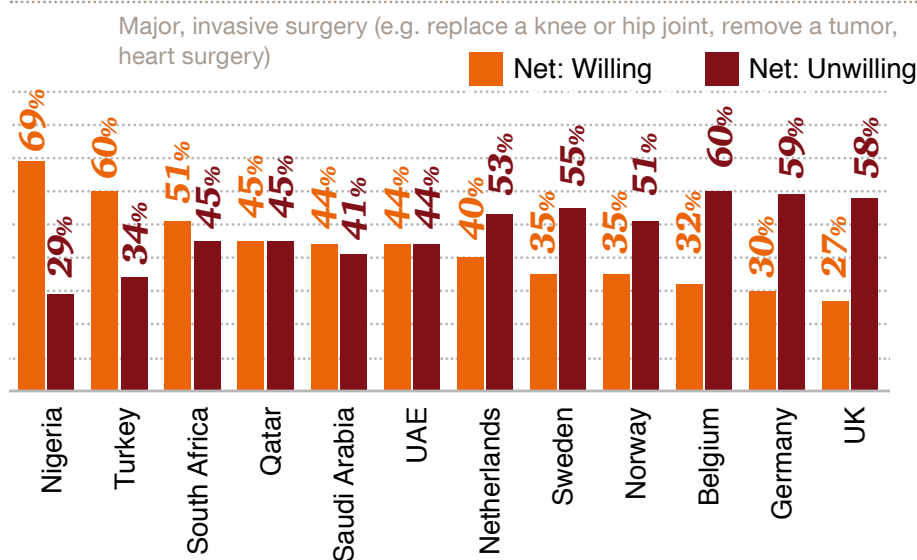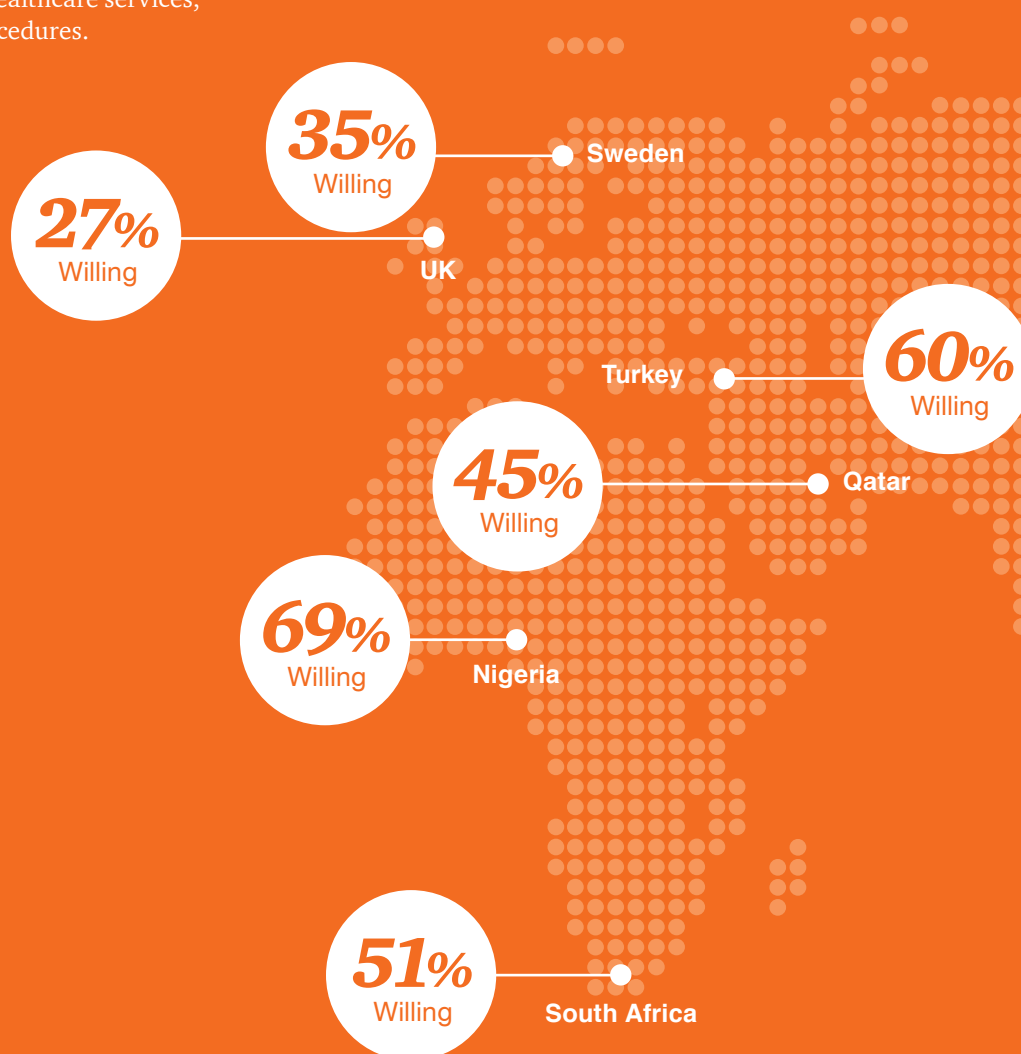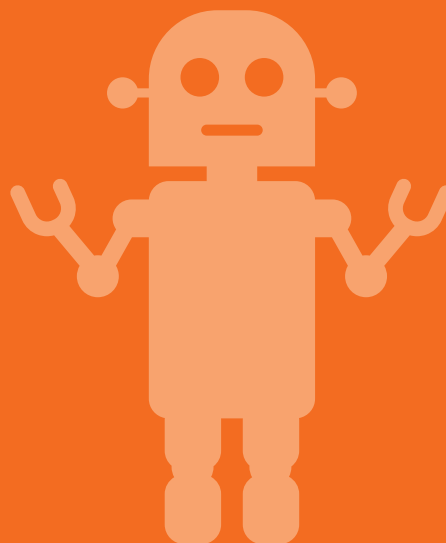
Minor, minimally-invasive surgery (e.g. cataract surgery or laser eye surgery etc.)

Figure 10: Percentage willing/unwilling to have minor surgery performed by a robot instead of a doctor

Major, invasive surgery (e.g. replace a knee or hip joint, remove a tumor, heart surgery)

Undergoing major surgery performed by a robot

Again, it is important not to focus too much on the lower percentages in countries with the more established health systems. It is still very interesting that fully one-quarter of people in the UK, and almost one-third in Germany would be willing to have major surgery conducted by a robot in place of a human. That represents millions of operations a year.
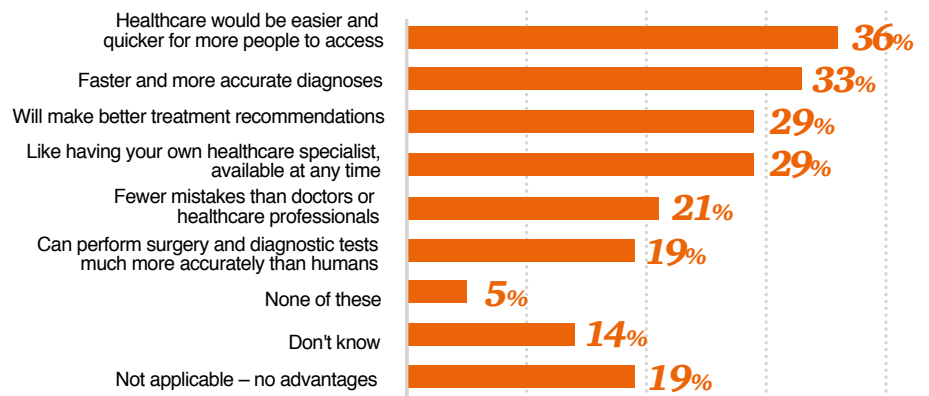
These findings are telling and point towards a greater – and in some countries almost complete – acceptance of AI and robots for delivering many different types of healthcare services, treatments and procedures.

35% Willing — Sweden

27% Willing — UK

60% Willing — Turkey

45% Willing — Qatar

69% Willing — Nigeria

51% Willing — South Africa

The new imperatives for health

Why are consumers willing or unwilling to engage with new technology for their healthcare? We asked our survey respondents to choose what they felt were the three biggest advantages and disadvantages of using AI and robots for healthcare.

Healthcare would be easier and quicker for more people to access — **36%**
Faster and more accurate diagnoses — **33%**
Will make better treatment recommendations — **29%**
Like having your own healthcare specialist, available at any time — **29%**
Fewer mistakes than doctors or healthcare professionals — **21%**
Can perform surgery and diagnostic tests much more accurately than humans — **19%**
None of these — **5%**
Don't know — **14%**
Not applicable – no advantages — **19%**

Market reactions to the survey

We went out to our clients in both the public and private sectors across EMEA with the results of the survey. There was some surprise that the general public is so willing to embrace these new technologies and the perception was that physicians may be more resistant than the general public. There is a very real fear that machines will take over many jobs, and that the physician role may well be the first

to go. Yet there was wide agreement that AI and robotics are the future of healthcare. One client commented, "Each new advance in technology has changed the patient/physician relationship and it's important to remember that it is the health of the nation which is of utmost importance." The patient is ready; AI and robotics are able to achieve much wider access for much less cost. The biggest question was how we 'bridge the gap between legislative and regulatory framework and innovation'.
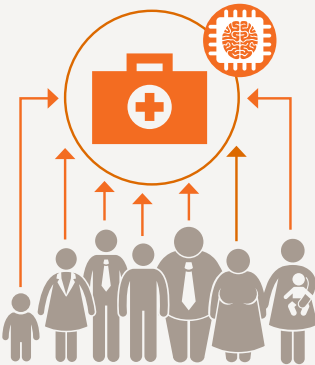
PwC staff survey

We also went out to our PwC staff across the region and they were even more willing than the general public to embrace AI and robotics for all questions. The key messages that came from our staff were that the ability to access and analyse the vast amounts of data meant there would be fewer mistakes and more accurate diagnoses, although the perceived loss of the 'human element' of healthcare was of greatest concern.

**Figure 12:** Perceived disadvantages of using advanced computers or robots with AI for healthcare

People need the "human touch" when it comes to their healthcare — **47%**
If something unexpected is found (during surgery or in a test), I don't trust robots to make decisions on what to do — **41%**
Only a human healthcare professional can make the right decisions (e.g. look beyond the data, use intuition, etc.) — **40%**
We don't understand this kind of technology enough to know if it can benefit or be dangerous in healthcare — **32%**
It's too complicated for people to access and use this kind of technology — **17%**
I don't see how this kind of technology can do a better job than a human — **17%**
None of these — **3%**
Don't know — **13%**
Not applicable - no disadvantages — **9%**

The top advantages in order were:
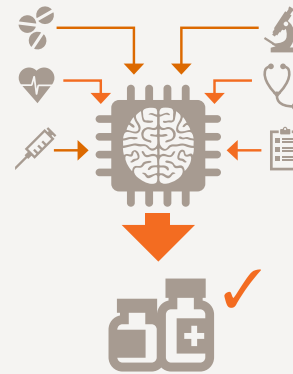
① 36%

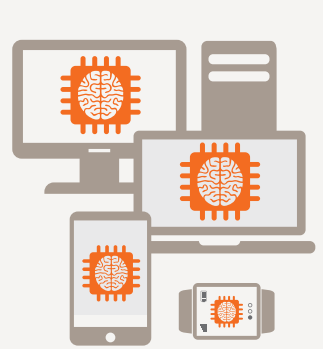**Healthcare would be easier and quicker for more people to access**

② 33%
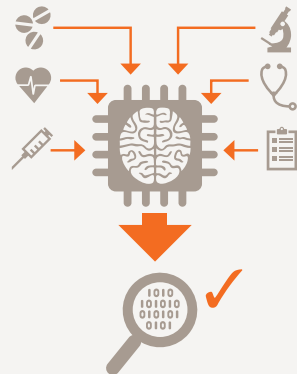
Advanced computers/ robots with AI can make a diagnosis faster and more accurately

③ 29%

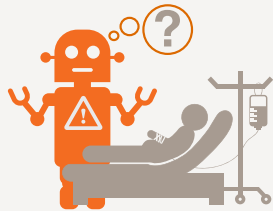**Advanced computers/ robots with AI will make better treatment recommendations**

④ 29%

Like having your own healthcare specialist, available at any time (e.g. via a smartphone, tablet, computer etc.)

It's also of note that many respondents felt that there would be **fewer mistakes** (21%) and **more accuracy** (19%) than with humans, although 19% overall felt that there would be no advantages, with respondents from the UK far more likely (at 27%) to find none.

Though the percentages varied from country to country, these advantages in this order were the same across all countries.

The top disadvantages in order were:

① 47%

If something unexpected is found (e.g. during surgery or in a test), I don't trust robots with artificial intelligence to make decisions on what to do

② 41%
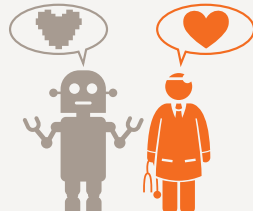
Advanced computers/ robots with artificial intelligence are impersonal and people need the "human touch" when it comes to their healthcare

③ 40%

Only a doctor or human healthcare professional can make the right decisions for health treatments/ procedures (e.g. they look beyond the data and take into account context and underlying, complexities, are able to use intuition, etc.)

④ 32%
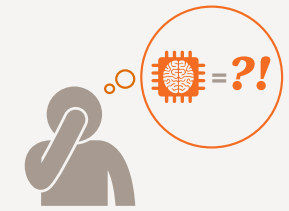
We don't understand this kind of technology enough to know if it can benefit or be dangerous in healthcare

It's worth noting that 17% overall chose both 'I don't see how this kind of technology can do a better job than a human' and 'It's too complicated for people to access and use this kind of technology' as disadvantages, yet only 9% didn't feel there would be any disadvantages.

As with the advantages, though the percentages varied from country to country, these disadvantages in this order were the same across all countries, with

the exception of Saudi Arabia and Qatar, where respondents felt the lack of 'human touch' was the biggest disadvantage.

Thus, for our survey participants, **better access to** and **accuracy of healthcare** services were the primary motivators for willingness to use an AI-enabled or robotic service, with lack of trust and the **human element** as the primary reasons for their reluctance.

Conclusion

Good health for everyone

Access, Accuracy, Trust, Accountability

Artificial intelligence and robotic technologies have long been seen as promising areas for healthcare. The explosion of healthcare data combined with the rise in demand from ageing populations around the world, rising costs, and a shortage of supply – both in the number of healthcare professionals needed to treat and care for an increasing number of sick people and the availability and access to a broader range of necessary services than ever before – has left a monumental gap that only technology can fill.

Over the past few years the rapid progress of technology has started to fulfil this promise and it's just the beginning. As these technologies develop, faster and better diagnoses, and more effective treatments, will save more lives and cure more diseases, and we will have more opportunities enabled by this technology to live healthier lives.

Whether we like it or not, AI and robotics are the future of healthcare.

Access to quality, affordable healthcare, and good health for everyone is the ultimate goal. The economic and social advantages to be gained from integrating AI and robotics seamlessly into our existing healthcare systems, and then create new models of healthcare based on these technologies, are enormous. Yet healthcare remains personal, and we mustn't lose sight of the human element. This will mean redefining the various roles of healthcare professionals, and ensuring that the necessary new skills are understood and taught in or medical schools.

The public is ready to embrace this new world of healthcare, but a few things need to happen:

1. **For governments:** create quality standards and a regulatory framework which are applicable to and obligatory for the entire healthcare sector, as well as the appropriate incentives for adopting new approaches. Linking regulations to facilities or humans, will naturally inhibit adoption. Also, AI and robotics should be seen as making healthcare more accessible and affordable. There is a risk that these technologies may become the provenance of the well off.

2. **For healthcare professionals:** understand how AI and robotics have the potential to work for and with them in a medical setting as well as throughout the healthcare eco-system, and be open to change. If clinicians will not be as good at monitoring, diagnosis, decision making or surgery, then what is the unique role for the human, and how can they prepare for it?

3. **For patients and the general public:** become more accustomed to artificial intelligence and robots and discover its benefits for themselves. Although, we suspect just as they have already adopted AI in their everyday lives, health technologies will similarly be taken up with alacrity.

4. **For the private sector developing AI and robotics solutions:** and those solutions need to solve the big issues of demand and resource that every health system faces. In essence, by providing AI and robotic driven solutions, the private sector has the opportunity to disrupt healthcare for the good.

5. **For decision-makers at healthcare institutions:** develop an evidence base, measure the success and the effectiveness of the new technology; phased implementation, prioritise and focus on what consumers want and need.

Innovation from AI and robotics lies at the core of our ability to redefine how we deliver healthcare to our citizens. Digitally enabled care is no longer a nice-to-have, but a fundamental imperative for governments and business to reinvent how healthcare is accessed and delivered. This is creating unprecedented opportunities to transform what has been provision of healthcare that is traditionally focused on the clinician, the hospital, their legacy infrastructure, and incentives to maintain the status quo. AI and robotics are the next wave in this transformation.

Our survey also suggests that we will need to be aware of how we approach these wide-scale changes, remaining sensitive to the existing country-specific systems:

- Beyond the disinvestment required for countries with **entrenched healthcare systems** the biggest challenge may well be the fundamental shift in ingrained practices and behaviours by both clinicians and the public. But there is also the opportunity for real disruption, especially if access to AI and robotics becomes broadly accessible at lower costs, leaving the public health system as a safety net.

- There is potentially the greatest opportunity for countries with **established but still developing** healthcare systems, because there is not the same level of legacy infrastructure and process as with entrenched systems. In addition, their populations are younger and highly tech-savvy across demographics. But they risk copying the best of the very established systems, and their population may begin to look elsewhere for their healthcare needs.

- Those countries that are still on the path of establishing widespread healthcare systems or universal access have shown a high willingness to engage with advanced technologies to fill the gaps in care delivery. But there is risk: AI and robotics as the foundation for healthcare access, capacity and capability will either be transformational or doomed, depending upon the implementation. Currently we see the potential but don't yet have the evidence that AI and robotics will fulfill their promise. Building flexibility into developing new systems will require constant evaluation and assessment.

But the world has changed. The public is ready and willing to adopt these technologies. We in healthcare must change with it. The transformative power of technology has the potential for those of us in healthcare to help industry leaders make the fundamental, necessary shift from reactive acute episodic care delivery towards proactive continuing and enduring care for everyone. We have the potential to harness data, turn it into applied knowledge and do it more cheaply and with greater access, thus enabling a New Health era.

In other words, good health for everyone.

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About the survey

This research was conducted in November 2016 by YouGov, the world's premier qualitative and quantitative research suppliers. 11,086 people participated in an online survey.

Who we surveyed:

- Nationally representative samples for Belgium, Germany, the Netherlands, Norway, Sweden, Turkey and the UK;
- Urban representative samples for Nigeria, Qatar, Saudi Arabia, South Africa, and the United Arab Emirates.

Gender

48% Female

52% Male

Age groups

18% 35 – 44

17% 45 – 54

21% 25 – 34

16% 18 – 24

28% 55+
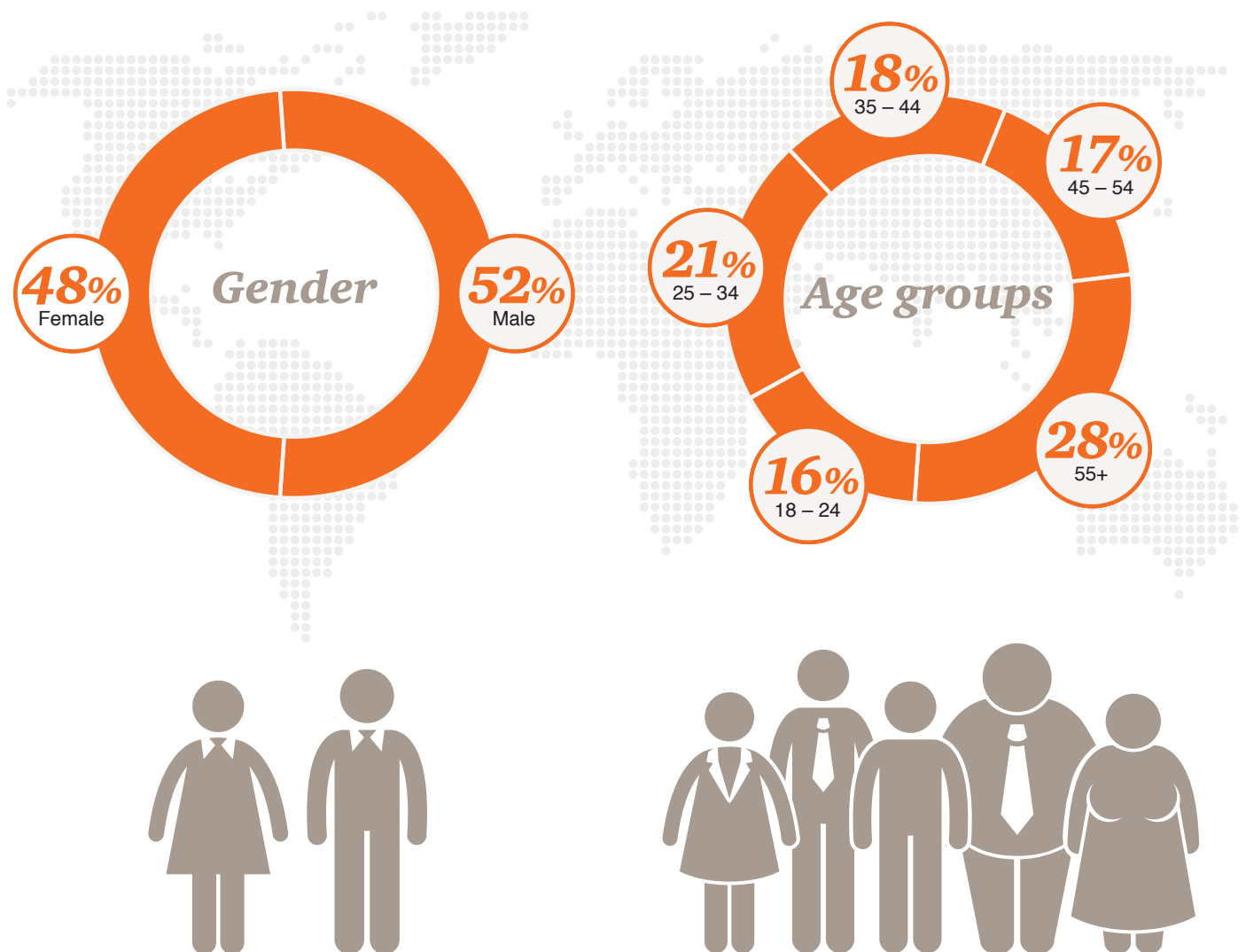
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