The UAE health care ecosystem

Future trends and insights

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Contents

Foreword

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In an era marked by transformative change, it is essential to navigate the complexities of the global health care landscape with an innovative mindset.

Smart health systems that improve the health and wellbeing of citizens are a key pillar in the shift toward a digitized and innovative national health care ecosystem.

The UAE has an ambitious vision to become one of the top 10 countries in the world in the quality of health care over the next decade. Global megatrends and their local impact in the health care landscape will bring opportunities for the UAE for future societal and economic value.

It has been a great pleasure to collaborate with Dubai Science Park and the health system leaders, policy makers and experts in the UAE and globally in the preparation of this report. This report provides a long-term perspective on the major trends and forces reshaping health care, with a special focus on the UAE.

The health care systems of tomorrow will be quite different. Technologies are moving fast as they build a digital future. Health systems around the world are moving away from legacy models that struggle to keep pace with the changing environment of today.

The five trends in the paper point the way. These trends lay the ground for the necessary shift in the health conversation toward reimagining health care with fresh eyes and setting course for a radically different future.

Foreword

Marwan Abdulaziz Janahi
Senior Vice President, Dubai Science Park

Further government efforts are needed to encourage educational opportunities and employment pathways in the health and life sciences industries. Private sector partnerships and innovation will also be pivotal as the UAE takes on a bigger role as a medical tourism destination.

In the next decade, health care service delivery in the UAE will be vastly different than today. Technology advancements, coupled with the changes arising from the global COVID-19 pandemic, have permanently altered the way health care will be delivered, financed and regulated in the coming years.

Innovation from both the public and private sectors will be essential to drive advancements. The Dubai Economic Agenda (D33) and the Dubai Research and Development (R&D) Program launched by HH Sheikh Mohammed bin Rashid Al Maktoum and HH Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum are prime examples of government efforts to promote new opportunities for economic growth through innovation and R&D at the highest level.

Health care is a critical component of these socio-economic programmes as global governments look to build smarter cities that can better serve customers as well as attract more innovators and investors to deliver future advancements.

This study is part of our vision to pave the way for the industry to thrive in this new landscape.

We have found that smart city investments must make room for increasingly smart and intelligent health care ecosystems. We must address the knowledge and resource gaps in the global and regional health care sector and drive greater integration between supply chain partners in the wellness, medical devices and R&D segments.

Further government efforts are needed to encourage educational opportunities and employment pathways in the health and life sciences industries. Private sector partnerships and innovation will also be pivotal as the UAE takes on a bigger role as a medical tourism destination.

Equally impactful are our focused investments to promote research.

Globally, health care demands have grown exponentially in recent years and that pace of growth is only set to increase. Dubai is no different. Tomorrow's health care will need to be more proactive, preventative and personalized than ever before.

For health care service providers and pharmaceutical companies that can leverage the burgeoning med-tech sector, this evolution presents the opportunity to target an ever-expanding base of educated and self-aware customers. Together, we can pave the way for a patient-centric, smarter health care industry for people in the UAE, the region and the world.

Executive summary

The world is fast becoming smart – smart cities, cars, utilities and homes leverage the Internet of Things (IoT), data and intelligent connected systems to support economic, social and environmental sustainability.

The UAE is actively pursuing smart city futures by incorporating networked solutions across multiple areas of urban living including mobility, smart infrastructures, waste and the environment.

Smart health systems that improve the health and well-being of citizens are foundational to smart cities. Highly interconnected and technologically advanced, smart health systems are a key pillar in the shift toward a digitized, innovative, and comprehensive national ecosystem.

Over the next decade, the "We The UAE 2031" vision for the UAE is to raise the country's rank to one of the top 10 countries in the world in the quality of health care, to secure social well-being and act as an attractive and influential economic hub. The building blocks for a technologically enabled smart future are being put in place. The UAE has a clear vision of becoming the best country in the world by the centennial year 2071.

The UAE health care ecosystem future trends and insights

This study sought to understand global megatrends and their local impact across the health care landscape. The goal was to showcase innovative opportunities for the UAE health care sector with potential for future societal and economic value.

In 2023, Dubai Science Park in collaboration with the EY organization engaged with 18 health system leaders, policymakers and experts in the UAE and globally to provide an analysis and long-term perspective on the major trends and forces reshaping health care.

The context for this research includes the structural forces that impact on health care such as growing and aging populations, increasing chronic and lifestyle diseases, new and re-emergent infectious diseases and a global health workforce shortage. Industry dynamics include a shift in perspective toward wellness and prevention, disruptive new technologies and changing care models, emerging novel therapeutics and the global challenges of the environment, climate, resources and energy.

Three questions were considered

1. What global megatrends are influencing the future of health care?
2. What key insights arise from the megatrends and the likely impact on the UAE?
3. What are the critical enablers of the health care megatrends in the UAE?

This was accomplished through a series of interviews, an EY Wavespace™ immersive design thinking experience and desk research. Interviewee's were industry luminaries, drawn from key areas of health care including regulators and government agencies and those with expertise in R&D, bio-and pharmaceutical sciences, clinical service delivery, health information technology and strategy, among others. Conversations explored global trends in health care and perspectives on the likely impact and opportunities for the UAE.

Five megatrends

Five megatrends shaping the future of health care were identified as being of interest to the UAE.

1. **Moving from digital to smart**, where smarter health care arises through interconnecting people, the environment and infrastructure as a unified system of care. The most futuristic of the five trends, this touches on the building blocks of smart and intelligent health systems. Highly technologically enabled, smart health ecosystems take advantage of the full capabilities of technologies that are changing health care, including artificial intelligence (AI), robotics and automation.

2. **Radically different models of care**, where digital transformation supports care anywhere, anytime models that are predictive, preventive, personalized and participatory. The traditional model of health is changing toward the pursuit of wellness, prevention and highly personalized care. Digital-health technologies are transforming the very foundations of health care including virtual delivery, remote monitoring and interactive person-centered tools. Care is becoming decentralized and better patient experiences arise as care is integrated across all aspects of a person's health and care needs.

3. **Data as a core asset,** where as an information-intensive industry, data in health care supports better care and improved outcomes, but also has scientific and commercial value. Unlocking the power of data brings promise of better health and well-being as well as opportunities for innovation and improving the quality and efficiency of services. AI, powered by massive health data sets, is significantly changing health care, bringing the promise of predictive and personalized care in the future.

4. **Advancing medical science,** where ongoing innovation and advancements in medical research and digital-health technology drive breakthrough products for personalized, efficient and effective care. Exponential scientific advances in health care significantly advance personalized medicine and the treatment of complex and rare conditions. Innovations in research and digital health have given rise to software-based clinical-grade therapeutics. Other technology-driven advances, including robotics and 3D printing, open up new horizons.

5 **Sustainability and transformative technologies,** where health services are delivered in more resilient and sustainable ways and build capacity to achieve sustainability goals and future-proofing through health system self-sufficiency. Climate-smart health systems are responsive to environment, social and governance (ESG) imperatives and Sustainable Development Goals (SDGs). As the momentum around sustainability increases it touches on not only environmental sustainability but also the workforce and health systems resilience and self-sufficiency.

Different trends have different time horizons – some short, others extend into the next decade.

The trends are highly intertwined – each interconnects with the other and data is the core that underpins them all. This reflects the complexity and heterogeneity of health care.

Smart health systems won't be smart without data, interconnectivity and innovative models of care. New care models depend upon data, disruptive digital technology and advances in medical science. Innovation in medical sciences is built on data and discovery of new ways of solving intractable problems through personalized-smart solutions. As a whole, health systems need to be intelligent, efficient, effective and sustainable.

This paper introduces each trend in an outlook, giving a snapshot of the trend. This is followed by a deeper dive into sub-trends and spotlights, of real-world examples. Each trend concludes with discussion of the current and future status for the UAE.

The future of health care in the UAE

The UAE is leading the way with smart city initiatives and smart solutions. Highly visionary building blocks for a technologically-enabled smart future are being put in place. A vibrant health care system plays a major role in achieving the future vision of being a prosperous society and an economic powerhouse. Creation of a world-class infrastructure in health care and life sciences sectors is a priority area for government investment. This is not only to further socio-economic development but also to increase the competitive advantage as a leading regional and global health care provider and increase global standing as an investment and innovation hub.

The vision for the UAE of a highly technologically advanced health care ecosystem that improves citizens health and happiness was uniformly shared by the people with whom we spoke. This extends to industrial strategy and manufacturing for self-sufficiency in pharmaceuticals, medical tourism as a key economic lever and a technologically advanced high-quality health care system.

Strategic frameworks like We the UAE 2031, Dubai Economic Agenda 'D33', and Dubai Research and Development Programme are encouraging knowledge-led innovation in the country.

The UAE is positioned and future-ready, being well advanced with foundational digital technologies including cloud computing, the IoT, AI and automation.

In combination, these are expected to have a powerful effect in the UAE on the production and distribution of health care, scientific R&D and advances in medical sciences.

The focus is on transformation for value creation to enhance the UAE health system's operating and environmental performance and contribution to the broader economy. Value will arise through the harnessing of technology as a game-changer for productivity, particularly in the context of the diminishing health care workforce. Technology provides the tools to deliver future UAE health strategy of moderating demand and embracing personalized, participatory and preventive health care for better health outcomes for all. Technology also brings opportunity to extend beyond the borders and become a breakthrough regional player in health care services and research.

An enabling regulatory environment facilitates investment in developing an innovative health care service system and infrastructure built as a smart health care ecosystem. Such an environment positions the UAE for competitiveness at a global level, as does the sponsoring of medical and scientific R&D and innovation capabilities.

Strong interest in and expectations for the long-term are held for key areas of well-being and care delivery, data and platforms and care enablement. Opportunity exists to further build in the biotechnology, nanotechnology and new materials spaces as global discovery continues at pace. These exert a gravitational pull for innovators and investors who are shaping the future of digital health care, R&D and the broader health care landscape.

Finally, the UAE has unique environmental conditions and energy needs, and faces finding the right balance between ambitious environmental policy goals and an ESG agenda with a financial sustainability agenda.

The UAE health care system

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Overview of UAE health care

The Ministry of Health and Prevention (MOHAP) is the federal regulatory authority in the UAE and is responsible for the implementation of health care policy in all areas of technical, material and coordination with the Ministries of State, and cooperation with the private sector in health locally and internationally.

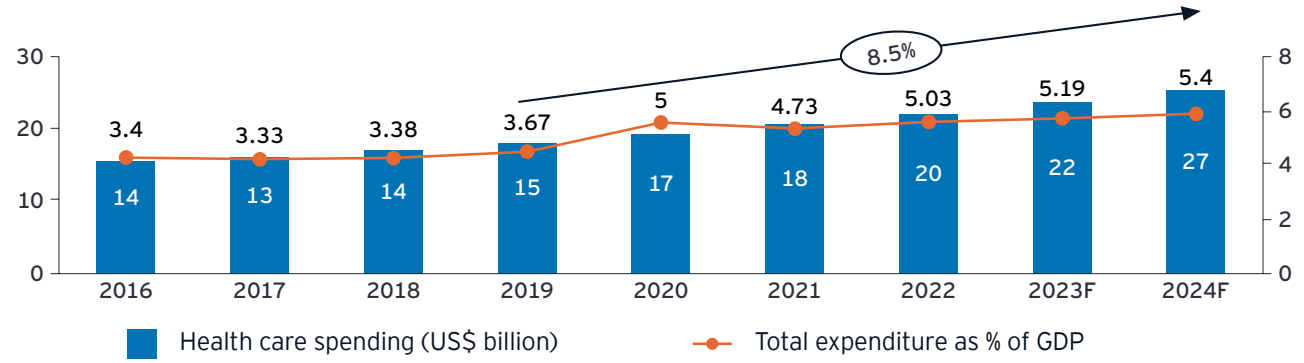
With an estimated population of 9.2 million residents, the UAE health care sector caters to a rapidly growing population.

The rural population only accounts for 13% of the total with 57% of total population residing in two cities: Dubai and Abu Dhabi. The UAE has a young population with 74% being of working age, between 20 to 55.

The population is aging with only 1% of the population being aged over 60 years in 2016. By 2050, this will reach 2 million people, or 16% of the population.

Private sector health care spending is forecast to increase at a CAGR of 9.5% compared to a government sector growth of 4.4%. This growth offers future opportunities

UAE health care sector spending outlook



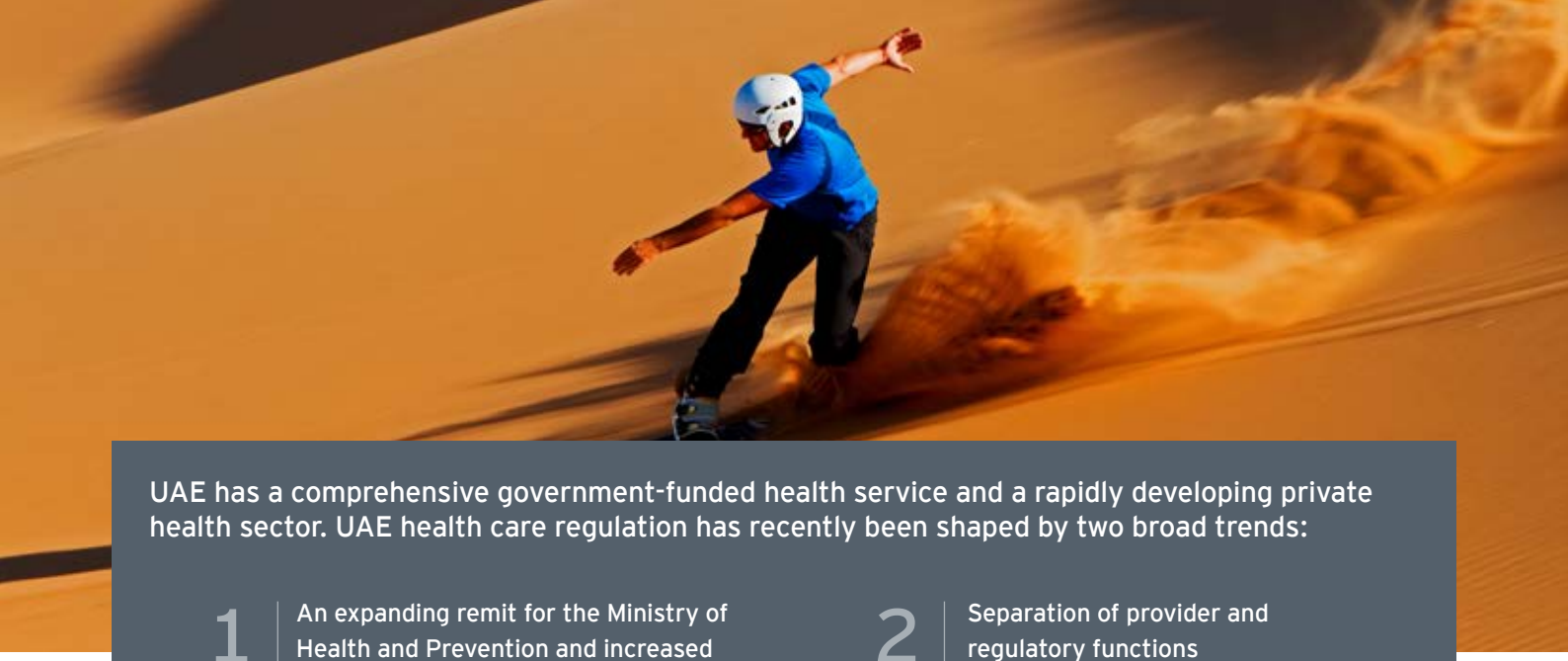
EY analysis

At 5% of GDP, the UAE's health care spending is one of the highest in the GCC . Health care spending as a percentage of GDP is projected to increase to 5.4% by 2024 at a compound annual growth rate (CAGR) of 8.5%.

Overweight and obesity are major health problems with prevalence in adults being 68% overweight or 28% obese. Nearly one in five adults have diabetes and 2.2 million people will be living with diabetes by 2040.

for international companies and health care institutions to partner with the UAE government and private entities and build toward achieving the UAE's health care strategic goals.

A key driver of the health care sector in the UAE has been the increasing penetration of health insurance. However, the market remains fragmented.



UAE has a comprehensive government-funded health service and a rapidly developing private health sector. UAE health care regulation has recently been shaped by two broad trends:

1 An expanding remit for the Ministry of Health and Prevention and increased coordination among regulatory authorities

2 Separation of provider and regulatory functions

Public health care system

The health care sector in the UAE is managed by the government through different regulatory authorities including the Ministry of Health and Prevention (MOHAP), Department of Health (DoH), the Dubai Health Authority (DHA).

The strategic priorities for the health care regulators are to be a leader in digital ecosystems, research and care excellence with an overall goal of improving the well-being of the population.

The UAE life sciences industry is primarily regulated at the federal level by MOHAP, with MOHAP having authority over pharmaceuticals, vaccines, and biological products, other medical products and medical devices.

In November 2022, the UAE launched its latest federal government strategy, "We the UAE 2031", which aims to rank the UAE in the top-10 countries globally for quality health care.

Private health care system

Private health care system As the UAE redoubles the commitment to developing the health care sector, both at the federal and emirate level, the private sector has an important role to play.

The private sector in the UAE is becoming a medical destination with an increased share in-patient encounters in recent years and controlling almost two-thirds of health care facilities.

Dubai and Abu Dhabi are hubs for medical tourism, and the private sector has state-of-the-art facilities with clinics established in collaboration with renowned-global providers including the Mayo and Cleveland Clinics.

The roll out of private health insurance in all emirates is expected to increase demand and patient volumes for providers.

Mental health, rehabilitation, urgent care, long-term care, MedTech (medical technology) start-ups, population health management are among the priorities for investment to 2025.

The UAE has a multi-dimensional approach to addressing the future of health care sector.

Become a medical tourism hub

Medical tourism is a significant driver of the UAE health care growth. In 2021, Abu Dhabi and Dubai were nominated as being two of the top-10 medical tourism destinations in the world.

Abu Dhabi and Dubai offer unique approaches to medical tourism, outlined by the DOH Abu Dhabi as well as Dubai's Medical Tourism Strategy for 2017-21.

2030 Industrial Strategy

Dubai expects to attract US$2.5b in investments in the pharmaceutical industry over the next five year as it accelerates efforts to attract international corporations to establish manufacturing bases in the emirate as part of the 2030 Industrial Strategy.

A key focus for UAE authorities at the federal and emirate level has been increasing domestic manufacturing capacity for pharmaceuticals and medical devices. The "Make it in the Emirates" initiative, a broad vision to increase local manufacturing across various sectors, places focus on pharmaceutical and biomedical manufacturing, as does Dubai's 2030 Industrial Strategy.

Leading role in 3D printing

In 2016, HH Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai, launched the "Dubai 3D Printing Strategy" in order to exploit this technology for the "service of humanity" and promote the status of the UAE as a leading hub of 3D printing technology by the year 2030.

A key focus area is to the medical products sector, with potential for developing 3D-printed teeth, bones, artificial organs, medical and surgical devices and hearing aids.

Encourage public-private collaborations for smart health care

Public-private collaboration and coordination are key to the UAE achieving its strategic smart health care goals. Key players in this strategy are health technology companies seeking to leverage the latest technologies including artificial intelligence and machine learning in integrated health care delivery.

The UAE is in the early stages of realizing value from telemedicine, blockchain, AI, cloud technology and mobile technology to underpin integrated health care delivery.

Initiatives focused on preventive health, innovative digital services and sustainable concepts, to enhance health and the quality of life across the UAE.

1 Integration of Riayati, Malaffi and Nabidh

MOHAP during Arab Health 2023 announced the successful and seamless integration of the National Unified Medical Record (Riayati), DoH's "Malaffi" and DHA's "Nabidh" platforms.

2 Hayat Organ Donation Program

Launched in 2016, Hayat aims to promote and enhance national efforts to save the lives of patients with organ failure. The program is set to support the country's efforts to lead by example at the regional and global level in the area of human organ and tissue transplantation.

3 Tatmeen platform: national pharmaceuticals track and trace

The first of its kind in the region, the platform will enhance the security of the UAE's medical supply chains by providing real-time tracking and tracing of pharmaceutical products.

4 3D-digital metaverse assessment service

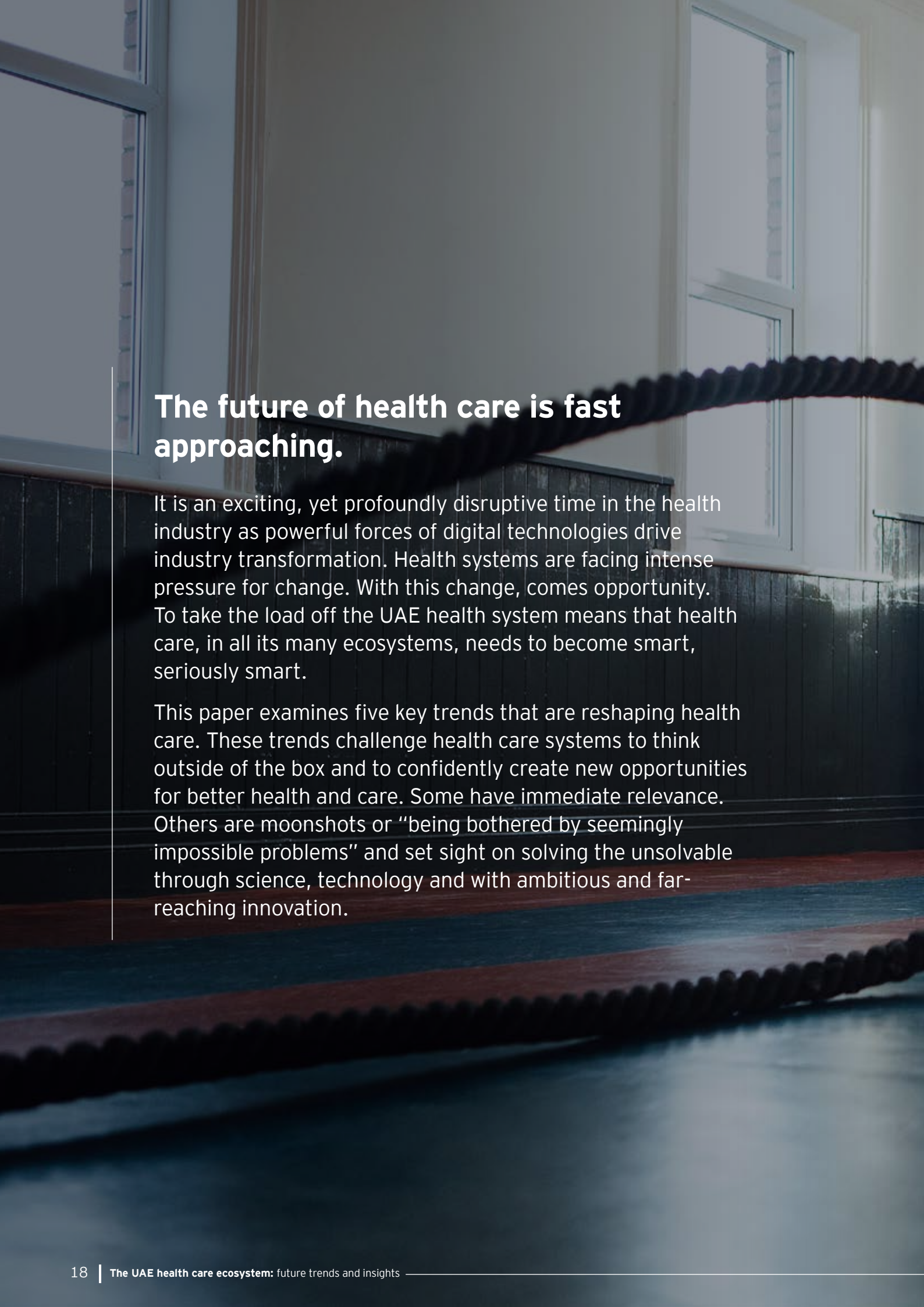
MOHAP launched an innovative service to evaluate health care professionals, including doctors and allied health practitioners, using cutting-edge metaverse technology.

5

Life sciences system for health care in the metaverse

DoH: Abu Dhabi has unveiled the "Life Sciences System for Health care in Metaverse" to enhance Abu Dhabi's position as a leading destination for innovation in life sciences. This virtual platform aims to bring together entrepreneurs, investors, and health care providers to exchange knowledge and experiences and create a virtual version of the emirate's health care system.

The UAE hosted the 28th session of the Conference of the Parties — more commonly known as COP28, the premier climate change conference of the United Nations (UN) — in Dubai in November 2023. Sustainability was a key theme across all sectors leading to the conference, which focused on efforts to advance sustainability across multiple industries.



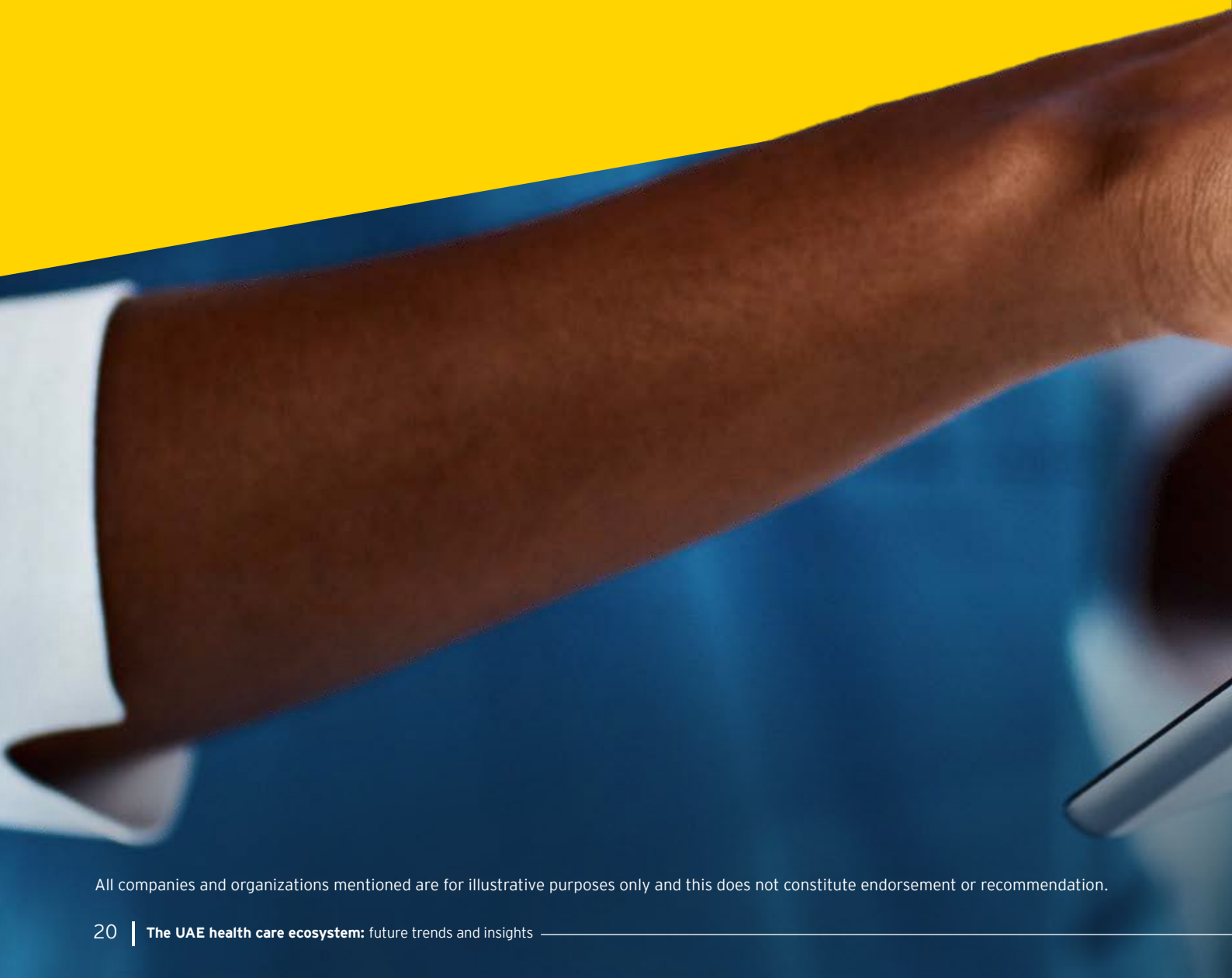
The future of health care is fast approaching.

It is an exciting, yet profoundly disruptive time in the health industry as powerful forces of digital technologies drive industry transformation. Health systems are facing intense pressure for change. With this change, comes opportunity. To take the load off the UAE health system means that health care, in all its many ecosystems, needs to become smart, seriously smart.

This paper examines five key trends that are reshaping health care. These trends challenge health care systems to think outside of the box and to confidently create new opportunities for better health and care. Some have immediate relevance. Others are moonshots or "being bothered by seemingly impossible problems" and set sight on solving the unsolvable through science, technology and with ambitious and far-reaching innovation.

Trend
01

Moving from digital to smart for future value



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Moving from digital to smart for future value

Smart health is a unified system of care that interconnects people, the environment and infrastructure. Future value arises as smart health systems fully leverage the power of an intelligent, data optimized system.

Smart cities and digital intelligence will sustain resilient, future-ready environments. Smarter health care will improve the lives and health of citizens through advanced disease monitoring and surveillance, health risk mitigation, and connected health ecosystems that will deliver the right care to the right person at the right time.

Smart health systems are foundational to smart cities. Smart health systems are highly interconnected and operate as digital-first, integrating technology across the care continuum.

The outlook in this trend highlights the key building blocks of a smart health system: the connections between people, the environment and infrastructure. As health care is delivered in a combination of physical and virtual spaces, everyone and everything is connected.

Importantly, all elements must work together in order to realize the full potential of the technologies that define the health industry of the future. Namely, AI, robotics, intelligent automation, next-generation telecommunications and edge computing.

Upcoming trends include the metaverse of immersive virtual spaces that will remotely address clinical and behavioral health. Closely related to the metaverse is the concept of digital twins or a mirror world that replicates individuals, physical assets and processes.

As AI continues to break new ground and mature, new forms including generative AI and large language models (LLMs) will bring new insights to health and care.

This trend concludes with spotlights on emerging fields of digital humans and immersive reality.

Key trends

- Highly technologically advanced and interconnected, smart health ecosystems have the building blocks in place to take advantage of the full capabilities of new technologies that will become foundational to health care of the future.
- Immersive and experience-led technologies, including the metaverse and digital twins, bring entirely new ideas and spaces to health care.
- Health care ecosystems will become a predominant feature of the health sector and as they grow in sophistication will become increasingly specialized and defined by the care needs and health journeys of specific populations.

Outlook

Smart, sustainable and future-ready

Citizens hold rising expectations of digital government services, access to advanced medical care and public health and seek a high quality of life and living standards. Pressure is mounting to improve the liveability and quality of life of cities as urbanization continues to grow. The UAE is rapidly urbanizing with 87% of the population living in highly-dense cities in 2021 and predicted to reach 92% by 2030.[1]

Smart cities and digital intelligence sustain resilient, future-ready environments. These use intelligent integrated technology that interconnect the workings of urban life – transportation, utilities, environmental management and human health.

Smarter health care will improve the lives and health of citizens through advanced disease monitoring and surveillance, health risk mitigation and connected health ecosystems that will deliver the right care to the right person at the right time.

A future-ready health system

To move into the future, health systems will need to become smart: highly technologically advanced and interconnected. The key building blocks of a smart health system are the connections between people, the environment and infrastructure within a unified intelligent, data optimized system of care. All elements must work in together to realize the full potential of the foundational technologies that define the health industry of the future. Namely, AI, robotics, intelligent automation, next-generation telecommunications, and edge computing. This is the point where health becomes smart.

However, just changing information into a digital form falls far short of achieving the end goal of a smart system built upon seamless and connected care. Smart health creates hyper-connected care networks of hubs and spokes, home monitoring, virtual pharmacies, drone deliveries, hospital-at-home, rehabilitation and wellness centers, and more.

To move into the future, health systems and hospitals will need to take advantage of forthcoming communications technology, such as 6G, which will enable wireless health care to become a reality.[2] They will also need to embed AI and other enabling technologies, including digitization and automation in services, systems and operations.

Central to smart health are advanced technologies that optimize and automate processes and support new and alternative care models.[3,4]

As hybrid models of health care emerge that combine in-person and virtual care, everyone and everything is connected. Embedded sensors in objects connect buildings and spaces and allow control of the physical environments. Connected systems collect, process and distribute data. This allows for real-time informed decision-making about people, the physical environment and systems. User experience is enhanced by a seamless integration of many streams of information and this being available across many devices.

Quality experiences will be achieved by augmented reality (AR), virtual reality (VR), holographic communications, haptic touch and intelligent devices, including drones.

The role of the hospital is expected to incorporate mobile hospital-to-home services and virtual wards that support remote monitoring. Data will be analyzed close to the source through edge computing which has low latency, is scalable and able to handle the massive volume of data generated by medical devices and consumer wearables.[5]

> Dubai and Abu Dhabi are actively pursuing smart city futures. This includes networked solutions across multiple areas of urban living including mobility, smart infrastructures, waste and environmental damage. Both are ranked in the Top 30 Smart Cities globally with Abu Dhabi at 28 and Dubai at 29, in 2021.[6,7]

Smart ecosystems

An ecosystem is a complex web of interdependent enterprises and relationships that creates and allocates value.[8] In health care, for example, ecosystems offer the promise of making health care experiences more personalized and complete, mixing and matching service offerings from a variety of providers into a comprehensive integrated whole.

This requires bringing together the right partners, defining relative value from the perspective of all partners and introducing the guardrails or principles that define cooperation and coordination to support seamless integration, data flow, and to achieve scale.

The vision is for better continuity of care, better care outcomes, and reduced overall system cost through minimizing duplication and waste. Prevention and chronic condition management become possible through technologies that support self-assessment and monitoring and make data exchange, communication and coordination easier in an integrated care approach.

Health care ecosystems are expected to further evolve and in the future are likely to be defined by the needs of different populations and care journeys.

This may range from ecosystems catering to the needs of healthy individuals with personal wellness goals through to more complex ecosystems that address the needs of people with multiple chronic conditions.

The distant horizon

Much lies on the horizon for health care. As AI continues to evolve and mature, new forms of AI, including generative AI (a category of AI algorithms that generate new content in the form of images, text and audio) and LLMs that learn and can readily be applied in multiple situations will be applied to problems in health care.

The metaverse is an emerging concept with applications being seen in clinical services and in operational matters but the full extent to which the metaverse will reshape the health sector has yet to be imagined. Closely related to the metaverse is the digital twin. This concept already has considerable applications in health care and is the focus of most of the research and development activity globally.

Other emerging trends include highly personalized care to the "N of 1" using a patient's own data, which has implications for optimal clinical outcomes from oncology to transplantation and beyond.

Future Readiness Index 2022[9]

The UAE was ranked 27 out of 124 economies in a measure of the pace and breadth of digital transformation, integral components of future readiness. The UAE was highly ranked in all four pillars of the Index of:

- Physical capital (rank 6)
- Human capital (rank 59)
- Technology (rank 33)
- Competitiveness (rank 34)

High rankings were scored in digital usage (2), transport network (2) and digital infrastructure (8) reflecting the widespread internet access and large infrastructure investments, favorable digital policies and a conducive market environment.

A deeper dive

Metaverse

The metaverse is a futuristic perspective of what could be created, beyond what is already known. It has been defined as a "digital environment generated by computer technology that mimics the real world using concepts like AR, VR, blockchain and social media."[10] In the metaverse, individuals (often as avatars of themselves) occasionally inhabit an immersive reality 3D virtual world for social, leisure, health and economic purposes.

It is early days with key technologies under development.[11] However, the market is growing quickly. Estimates of the global market size of the metaverse in health care in 2022 were around US$6.5b. This is projected to reach around US$72b by 2030.[12,13]

MetaIncubator – the first metaverse incubator in the Middle East, was launched in Dubai in 2022 and intended to attract investment in the new digital economic sector and to help build out Dubai's metaverse and Web3 ecosystems.[14]

Metaverse and health care

Some expect that the metaverse will be widely used in health care in the future; [15,16] others consider it to be a technological fantasy. [17] Opportunities envisaged for health care include improving clinical outcomes, clinical trials, improving the efficiency of service delivery and resource utilization, and in various communication channels.[18] Non-clinical applications include research, drug and device development, education and training.[19]

Thus far, the use of virtual reality (VR) and AR in medicine has been in diagnostic and surgical procedures and rehabilitation for pain, stroke, anxiety and depression, cancer and neurodegenerative disorders.[20]

Health care applications include:

- Avatars who interact with humans, act as coaches or offer personalized simulations of a person's possible future. For example, **Soul Machines** digital people (NZ); **Medical Avatar** (US); and **Didimo** digital humans (Portugal).
- Medical education including holographics of anatomical structures, perioperative planning and use of AR platforms for complex surgical procedures. For example, **8chili** (US) **HintVR** platform; **Augmedics** (US) surgery guidance system; and **Goggleminds** (UK) for medical education.
- Therapeutic applications include **XRHealth** (US) at home physical and occupational therapy; **OptiVu** Mixed Reality (US) for team collaboration, visualization and monitoring; and **DEHealth** Decentralized Metaverse (UK) digital platform where users (clinicians and patients) can interact and use 3D models from physically different locations.
- In the UAE, **ShopDoc** metaverse platform plans to introduce a metaverse digital eye test and surgeons in Abu Dhabi are testing new surgical techniques using HoloLens AR headsets. Indian fitness platform **GOQii** is building a metaverse ecosystem with a virtual token program and has partnered with Harley International Medical Clinic to pilot Digital Therapeutics and Health Metaverse in the UAE.
- MOHAP launched the world's first metaverse customer service center, the Customer Happiness Service Centre, in 2022. A digital interactive sensory experience, the customer can complete transactions with the Ministry in the 3D patient-provider portal.
- The DoH, Abu Dhabi unveiled the **life sciences system for health care in the Metaverse** to enhance Abu Dhabi's position as a leading destination for innovation in life sciences. This virtual platform will bring together entrepreneurs, investors and health care providers to exchange knowledge and experiences and create a virtual version of the emirate's health care system.

> "We're still waiting to see how humans will consume the metaverse and to understand the areas where it will work.
>
> **Professor Rachel Dunscombe**
> UK Government AI Council and Visiting Professor, Imperial College, London, March 2023

Digital twins

Closely aligned with the metaverse, the digital twin is an emerging technology that is beginning to play a key role in health care. A mirror world is created when virtual places are linked to the real world via digital twins. Digital twins are a digital replica of a physical asset or process, that provides nearly real-time monitoring without being in close proximity.[21]

Emerging from the fields of building design, engineering and manufacturing, a digital twin collects data in real time from an asset's sensors which is used for simulations and analysis for performance optimization over a lifecycle.

Digital twins are a core component of smart cities and are deployed in urban management for such things as scenario analyses and simulations of natural disasters and emergency responses, optimizing energy savings and generating design options for city spaces and infrastructure planning. More than 500 urban digital twins are expected to be deployed by 2025.[22] (See Singapore digital twin)

Health care applications include digital replication of the physical assets, people and systems of hospitals to monitor, adjust and optimize the functions of physical settings, such as pre-emptive maintenance or demand management prediction.[23]

A digital twin was created and ran different scenarios to identify the use of optimal equipment and physical layouts. Results achieved included shortened MRI wait times for patients, faster turnaround times and increased equipment utilization and productivity.[24]

Health care use cases under development include the application of digital twin for trauma management.[25] Other applications are emerging around personalized medicine and well-being, where continuously collected data is drawn together and triangulated between preventive care, medical care and the digital twin.[26] For example, physiological models and AI can aggregate a full spectrum of information about an individual to create a lifelong personalized model to support diagnosis, treatment planning, better targeting of therapy or behavioral interventions for the individual.[27]

Digital twins are expected to have an impact in personalized medicine, e.g., customizing virtual organs, understanding disease progressions and responses to new drugs and treatments. Particular applications of personal digital twins include cancer patients, those with rheumatoid arthritis, multiple sclerosis and long-haul COVID-19, among others.[28]

Singapore digital twin[29]

The entire nation of Singapore has been replicated as a digital twin. Digital mapping and geospatial analytical tools were used to create a high-quality 3D model of the city.

Developed in 2022, a 1:1 scale model of 3D Singapore covers the entire city from aerial to city blocks and streets. Information is collected in real time about the built environment through drones and sensors.

The digital twin will inform architectural, engineering and urban planning design and provide information for analysis of environmental impacts and enable visualization of the built environment. A metaverse version of Singapore is planned.

> "There is growing excitement around artificial intelligenceand machine learning. Think of the journey in three stages - you digitize it, you do the proof of concept to validate it, then you scale.

Dr Aaron Han

Chief Medical Officer, Alliance Care Technologies, March 2023

Generative AI

Generative AI and LLMs are attracting attention. LLMs are a new development in the maturity of AI and considered as foundation models – large pre-trained AI systems that can be repurposed across different domains with minimal effort.[30]

In the past decade, deep learning AI models which learn and recognize patterns in data, have been applied in image analysis, billing operations and managing supply chain and cybersecurity. However, LLMs are a new type of AI algorithm. They look for patterns and relationships in large amounts of language data and generate new text based on this training.[31] They find patterns in the text but don't connect words to meaning, thus outputs can be off-track, fabricated and misunderstandings.[32]

A prominent example of generative AI is ChatGPT, a general LLM recently developed by OpenAI. ChatGPT has generated significant attention performing at or near passing the threshold of 60% accuracy in the US medical licensing exam (USMLE).[33] The latest version ChatGPT-4, is a multimodal model that accepts images and text inputs and performs against certain professional and academic benchmarks and also includes filters against answering malicious or hurtful questions.[34]

It is at a very early stage for LLMs/generative AI. The impact is as yet unknown, as are associated risks. Concern is expressed regarding the quality of source information, the high potential for inherent bias, the misunderstanding and misinterpretation of content, and the huge volume of data and computational power required for effective training of the models.[35]

Globally, government attention is focusing on the need for responsible AI, or the ethics and governance required to ensure AI is created and used ethically and safely with standards, principles, governance and leadership and the elimination of bias in algorithmic programing.[36]

Applications suggested for health care include potential for integrating diverse medical information and data including medical records, images, biological information such as genome and microbiome and social determinants of health.[37] Other opportunities include drug design and development, clinical trial research, creation of synthetic data and completing paperwork such as writing discharge letters.[38,39]

Generative AI in health care

- **Atropos Health** (US), an on-demand consultation service providing evidence from electronic health records to answer questions arising during clinical care.
- Synthetic health data company **Syntegra** (US), uses machine learning models to generate synthetic data that cannot be linked to any real persons.
- This will open up opportunities in AI transformational research in drug discovery, explore aging research and sustainable chemistry, and the digital transformation of health care.

Spotlights

Digital humans

Digital humans are AI-powered lifelike simulations of human beings. They act as intelligent virtual agents and are often photorealistic and interactive. 3D interactive modeling and animation simulate human movements and emotion recognition and sentiment analysis are used to interpret the emotions, behavior and responses of the client or patient.

Digital humans make extensive use of AI including natural language processing, speech recognition and generation to function in a human-like manner. Conversational capabilities include asking and responding to questions from humans in real time and being able to interpret a human's facial expressions, the tone of voice and emotions during a conversation.

Advantages include ready availability 24/7, growing consumer engagement and companionship, and a safe alternative to discuss difficult issues, e.g., mental health.

Virtual therapists have been found to be impactful in helping veterans discuss their mental health and PTSD problems.[40] Other use cases in health care include training and education, coaching, information gathering on symptoms, clinical decision support and remote patient monitoring.

- **UneeQ** digital humans (NZ) creates immersive interactive digital humans for meaningful patient interactions. Applications include patient health literacy, medication adherence, mental health support, dietary coaching and companionship.
- **MayaMD** (US) personal health assistant. Advanced clinical algorithms process any number or combination of symptoms, physical signs and past medical history in less than a half a second. Detailed clinical notes are shared with clinicians prior to a visit.

Immersive reality

VR, AR, mixed reality (MR) and extended reality (ER) are immersive technologies with the potential to improve health care. Technological advances in graphics, display, 3D software and processing power make immersive reality programs immensely scalable.

Blurring the space between the real and virtual worlds, immersive reality allows users to feel fully immersed in the experience, or "presence" in the virtual environment.

Health care applications include targeting emotional responses, immersing patients in a specific exposure or environment, or function as a distraction from reality. Other uses include medical education and practice teaching content, evaluation methods and evaluating performance in surgical training, stroke and rehabilitation therapy.

- **AppliedVR** (US) applies immersive therapeutics to prevent, manage or treat medical disorders including chronic pain, anxiety and post-traumatic stress disorder (PTSD). Other applications include stroke, behavioral health and neurodegeneration.
- **FundamentalVR** (UK) virtual reality-based medical education platform. At the human-computer interface, it combines immersive technology with haptics (enabling perception of force, mass, vibrations and movement) and machine learning for surgical simulation and training.
- **Impressivo** (South Korea) ambient intelligence next-generation input solutions for wearables and IoT devices. Fabric-based 5D multi-touch interfaces with sensors that can recognize pressure and type of touch. Health care applications include wearables and smart home connectivity through sensors embedded in furniture or the floor.

The UAE perspective

The UAE is leading the way with key smart city initiatives and smart solutions including the National Strategy for Artificial Intelligence 2031, the National Happiness Agenda and data initiatives in both Dubai and Abu Dhabi, among others.

Highly visionary building blocks for a technologically enabled smart future are being put in place. The UAE has a clear vision of becoming a world leader in AI by 2031, to increase the contribution of the metaverse sector to the emirate's economy by 2030, and to be the best country in the world by the centennial year 2071. A vibrant health care system plays a major role in reaching these goals. As Dr. Omar Najim, Director of Executive Affairs and Special Projects Office, DoH Abu Dhabi, observed "Health care is not only health care. Health care is an economy, politics, a security and it is education. Everything that you look at as an industry, will have a health care impact on it or be impacted by it."

Among regional countries, the UAE is considered to have very good infrastructure that enables the transition from digital health care to smart health care ecosystems. There is a comprehensive health care infrastructure of hospitals, clinics, home health services, diagnostic laboratories, and a substantial life sciences and technology sector. A dual delivery system of public and private health care is thriving. Clinical expertise is growing in specialty areas that are important to the health of citizens including diabetes, cancer treatment and cardiology services.

The sector is at the forefront of introducing new technology-driven care models including telemedicine, the metaverse and virtual hospitals. Moreover, the sector maintains collaborations with influential global health brands including the Mayo Clinic, Cleveland Clinic, Imperial College London and King's College London, among others.

Inbound medical tourism is a major economic pillar for Dubai and Abu Dhabi leveraging highly developed transportation and tourism infrastructure and high-quality and trusted health care. Digital-health technologies bring the tools to further expand medical tourism beyond the geographic borders of the UAE and deliver services to the consumer, wherever they may reside. Dr. Omar Najim also observed, "If regulators and policymakers focus on improving quality, the medical tourists will follow". Lessons can be learned from the way the UAE started to regulate the crypto market to understand how to regulate cross-border health care.

An enabling regulatory environment facilitates investment in developing an innovative health care service system and infrastructure built as a smart health care ecosystem.

How can an intelligent smart health ecosystem make the UAE a global health care destination?

The people we spoke with identified that to move from digital to smart for future value, the UAE should consider:

1. Creating a regulatory environment and digital infrastructure that will attract manufacturers, investors and innovators to the UAE.
2. Creating educational opportunities and employment pathways that will encourage and inspire UAE citizens for careers in the health and life sciences industries.
3. Through innovative disruptive technology and the articulation of value proposition of quality health care, grow the UAE's role as a regional medical hub and further develop its appeal as a global health tourism destination.

Trend
02

Radically different approaches to care

All companies and organizations mentioned are for illustrative purposes only and this does not constitute endorsement or recommendation.

Radically different approaches to care

Digital transformation supports care anywhere, anytime models that are predictive, preventive, personalized and participatory.

Digital-health technologies are transforming the very foundations of health and care with digitally enabled care models including virtual delivery, remote monitoring and interactive person-centered tools.

The outlook in this trend highlights the shifts in the system as new tech-enabled care models make anywhere anytime health care possible, in places closer to the patient – at home or in the community. Tech-enabled care models also open possibilities for innovative cross-border services, subject to legal and regulatory factors.

As people become more health conscious, how we understand and think about health is changing. The notion of health care is transitioning from sick care systems to wellness, chronic care and population health. It is extending to include mental health, social determinants and environmental factors in a system of care that is diverse, integrated and seamless.

This outlook describes six shifts that are shaping the future of health care, which include changes in care location from hospitals to the home, the clinician's role evolving to that of a guide as patients embark on their health journey, increasing personalization and the important role of data in driving better outcomes.

This outlook concludes with spotlights on two emerging trends of wearables and digital-first.

Key trends

- Widespread adoption of virtual and digitally enhanced care models and non-traditional care locations.
- Digital-first, where digital is the default setting.
- Shift to proactive and wellness-oriented models.
- The patient journey is reimagined – technology and automation create integrated health care ecosystems designed to streamline the patient experience through the health care cycle.

Outlook

Transforming health care

Digital-health technologies are transforming the very foundations of health and care with digitally enabled models including virtual delivery, remote monitoring and interactive person-centered tools.

The COVID-19 pandemic accelerated the uptake of virtual and technology-enhanced care models and demonstrated that health care can be delivered in new ways. In the long run, the impact of the disruption has been a permanent change in the way health systems organize and deliver health care.

In response to the COVID-19 pandemic, six telemedicine solutions were approved for use in the UAE by the Telecommunications and Digital Government Regulatory Authority (TDRA) in April 2020 — Mind Mina Telemedicine, NextGen Healthcare, vSee, OKADOC, DOXY and GetBEE.[1]

Digital technology has now been developed and applied to almost every aspect of health and care. The scope is extensive, ranging from self-care at home to outpatient care, emergency department management, virtual ICU, assisted image reporting and robotic-assisted procedures, through to public and population health.

The way we think about health and care is changing

The concept of health is moving from reactive to proactive care where the focus is on wellness, chronic care and population health management. The vision of the future of medicine is predictive, personalized, preventive and participatory. Individuals are actively engaged, through digital-health technologies, in managing their health and wellness.

Health systems of the future will be:

- Proactive rather than reactive
- Preventive with early intervention to prevent disease progression to crisis points
- Oriented to individuals who play a key role in optimizing their health

Future health care will be built around highly personalized products and services and optimizing patient and workforce experiences. Key to this is consumer participation including self-managing health and wellness through personalized app-based services and consumer- and clinical-grade wearables.

The UAE telehealth market (including virtual visits, mHealth and remote patient monitoring) is estimated to reach:[2]

US$536.5m by 2025 from

US$121m in 2019, a CAGR of

28.2%

> “People expect to receive care at their home and not be bothered with a long patient journey. So, we are looking at digitalization in medical field including every single point of touch for patients, expanding virtual care and even bringing Artificial Intelligence into diagnostic processes with patients.
>
> **Dr. Nahed AbdulKhaleq Monsef.**
> Director of Strategy & Governance, Dubai Health Authority, March 2023

Care anywhere anytime

Virtual care is a profound change in the health care value proposition.

Virtual care anywhere and at any time brings a host of new delivery choices and channels in addition to the more traditional episodic and facility-based care. This ranges from simple tele-visits to robust hospital-at-home models.

Hybrid models that integrate virtual and in-person care are emerging and these targets freeing up staff and hospital beds, improving outcomes and keeping patients healthier at home for longer.

Integrative virtual care supports earlier intervention, timely access to critical specialist expertise, admission avoidance through care in place, earlier discharge and productivity improvements.[3] (See Decentralization of health care, Singapore)

Highly flexible, these models are relevant at any point in the patient's health care journey and can support many different types of patient populations.

Benefit includes:

- New clinical journeys that simplify workflow and reduce clinician burnout
- Better patient experiences that build engagement and high-trust relationships

Investing in technology for new care models

This new future of tech-enabled health care requires health information architectures and infrastructures that support hybrid care models. Venture capital investment in the MENA region 2016-22 has been in digital care (US$153m), clinical decision support (US$29m) and digital-health insurance (US$27m).[4]

Internationally, the health sector continues to pursue the interoperability of information systems and infrastructures, data liquidity and the supply-chain of products and devices. The US is firming policies on trusted exchange frameworks;[5] Australia has a Multi-Agency Data Integration Project (MADIP) linking data from various domains [6] and the EU is working on cross-border exchange of electronic health data.[7]

Decentralization of health care Singapore[8]

- Singapore is pursuing a national decentralization strategy based upon continuity of care, prevention and remote care closer to home.
- Since 2019, the MOH Office of Healthcare Transformation (MOHT) has provided alternative care models to in-patient care, including outpatient monitoring, multidisciplinary care and telehealth solutions.
- Key to this is the home hospitalization program — Mobile Inpatient Care at Home (MIC@Home), a partnership between public hospital partners and private providers including Speedoc, a mobile medicine provider, Doctor Anywhere, that specializes in remote care delivery and technology providers including Biofourmis, ISANSYS and Connected Life.
- Future plans include advanced automation using AI for frictionless patient experiences, patient ID verification and extracting text from images.

In the UAE, the national health information exchange, launched in 2023, is transforming information exchange between public and private sectors as a seamless interconnected system.[9]

Health information exchange UAE

Riayati is a digital-health care platform for the National Unified Medical Record (NUMR) program. Patient records from 3,000 medical facilities across seven emirates are linked enabling seamless access to health information, which can be accessed by over 90,000 health service providers.[10]

A deeper dive

Six shifts shaping the future of health care

Care delivery is changing, moving closer to where consumers are; health services will increasingly happen outside traditional health settings. Globally, the home health care market was estimated to be worth US$345.6b in 2022 and likely to reach US$666.9b by 2030, a CAGR of 7.93% from 2022 to 2030. This growth is driven by population aging, rising incidence of chronic conditions and increased patient preference for value-based care.[11]

As care delivery changes, so will the role of the physician. Physicians will manage health with a host of new tools, products and services to manage chronic diseases and eventually, proactively manage lifestyle and wellness.

Mobile connectivity, cloud storage, wearable sensors, durable environmental sensors and portable medical devices make new sources of data available. This data, combined with clinical information, offers the promise of a more holistic view of health and disease.

SEHA virtual hospital, Saudi Arabia[12]

The first virtual hospital in the Middle East providing the latest in virtual health care. The Virtual Hospital supports 130 hospitals around the Kingdom, with over 30 specialized services and capability to reach over 400,000 beneficiaries.

Specialty services include emergency and critical consultations, specialized clinics, support services (including pathology and pharmacy) and multidisciplinary committees covering such things as heart, diabetes and psychology, and home care services.

The hospital uses AI to triage examinations in need of urgent medical intervention through the use of medical imaging algorithms.

AR and direct transmission of surgeries advises the surgeon during surgery and transfers knowledge of complex procedures among the medical community. IoT technology supports remote patient monitoring and capture and transmission of vital signs with alerts to prompt any necessary interventions.

1 Point-of-care

Hospitals → Home

Care delivery moves closer to where consumers are and health services happen outside of traditional health settings.

2 Data ownership

Institutions → Patients

Health data is owned by the patient and shared with other parties. Platforms feed analyses to the patient and support self-management.

3 Reference point

Population → Individual

Treatment is personalized with precision medicine, empowering better engagement and adherence to health plans.

4 Clinician's role

Authority → Guide

From authority to a guide for patients, who are empowered to actively participate in shaping decisions about their care and drive their own outcomes.

5 Data analysis

Buckets → Big data

Harness the power of big data and multifactorial predictive analysis to give insights to participants, patients and clinicians for improved outcomes.

6 Interactions

In-person → Virtual

Digitally enabled health ecosystem that seamlessly combines virtual and in-person care and integrates services across the care continuum.

The model of health is changing profoundly

The health care model is shifting to preventive, personalized and participatory care. The health system of the future will be consumer-centric, wellness-oriented, able to deliver care outside the traditional structures of health systems and digitally connected. There will be a shift from the traditional reactive illness model to a customer-centric and needs-based proactive model.

Complex and high-risk cases and trauma care mean that hospitals will always play a vital role in health care systems, however across the board, digital technology brings opportunities for introducing higher-value models of delivery. Value arises in terms of clinical effectiveness in many clinical topics and care pathways, more efficient use of valuable clinical resources and greater convenience and time and cost savings for patients.[13]

The IoT, smart wearables and sensors make possible a suite of new health care offerings around well-being, remote care, smart homes and communities, that ultimately move care from the hospital to closer to the consumer — at home or in the community.

Cross-border practice

Medical tourism is one area that may benefit from cross-border telemedicine. Key focus for the UAE is encouraging individuals to seek care at home (preventing outbound medical tourism) but also to encourage inbound tourism from around the world.

Technology can support follow-up care through remote monitoring and minor procedures as necessary with a UAE-based surgeon or specialist operating through partner hospitals in the home country.

> “Telehealth will change the focus of health care from being an interaction with a provider to an interaction with wearables.
>
> **Dr. Omar Najim**
>
> Director of Executive Affairs and Special Projects Office, DoH, Abu Dhabi,
> March 2023

However, medical regulations and licensing, physician codes of conduct, insurance and liability cover and the definition of telemedicine and regulation vary between countries. Other issues arise concerning patient consent, data collection, processing and transfer, and patient privacy laws. At this point in time, cross-border remote second opinions and professional peer-to-peer consultations are considered to offer the most promise, subject to the local regulatory environment.[14,15]

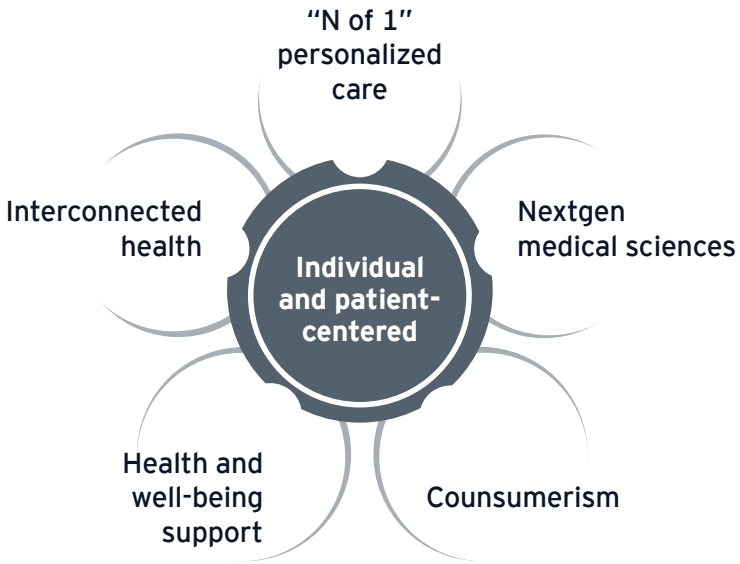
Participation and highly engaging patient experiences

Smart health technology along with the human touch is transforming how care is organized and experienced. Optimizing experience will be a key differentiator in terms of long-term value for the health industry.

Participatory health is reflective of a deep and profound shift in perspective toward well-being and wellness, convenience, flexibility, self-direction and personalized experiences. It is grounded In-patient engagement, shared decision-making, patient activation, patient-centered and consumer-directed care. It goes beyond “sick care” to “healthfulness” inspiring, encouraging and teaching individuals to make positive care and lifestyle choices and be engaged in lifelong health.

The Society for Participatory Medicine has been instrumental in articulating patient empowerment and engagement through participation. The Society describes participatory medicine as a cooperative and active relationship between “patients, professionals, caregivers and others along the continuum of care on all issues related to an individual’s health.”[16]

A participatory health paradigm



Technologies advancing health care

Internationally, virtual and digitally enhanced care models are extensively deployed and cover a diversity of settings, clinical topics and outcomes. These include self-monitoring, virtual visits, remote monitoring, virtual triage, hospital-at-home and virtual ICU, among other applications.

In addition, health care organizations are also introducing administrative, operational and user-experience capabilities such as digital front doors, predictive analytics, AI and machine learning, robotics, 3D printing and digital twins.

Virtual care

Scheduled or on-demand, telehealth platforms remotely connect patients and clinicians either by telephone or video. Augmented with online pharmacy/e-prescriptions.

Relevant for a range of specialties, including neurology, psychiatry, ICU, nephrology, infectious disease management, radiology and allied health.

Telehealth services give access to video appointments through a smart phone or tablet abound. Examples include at Hand, Livi, Pushdoctor in the UK/Europe, Ro and Teladoc in the US and Health at Hand, Okadoc, and Nabta Health in the UAE.

Remote patient monitoring

Collection, storage and evaluation of health information (vital signs, etc.) through live monitoring via devices that transmit information from the home or care facility to a provider. Devices (e.g., wearable sensors) are used at home for diagnostics, medication adherence, biometrics capture, monitoring and condition status tracking.

BioIntelliSense (US),an on-body sensor that captures a broad range of bio-signals (temperature, respiratory, gait, etc.) for medical grade monitoring at home.

ProvenMed is a UAE-based medical devices innovation start-up that has developed smart wearable devices for urinary incontinence.

Wellness, prevention and lifestyle

Wearables, apps, virtual coaches and digital assistants for virtual programs, on-demand coaching, behavioral support tools, motivational nudges and gamification.

Takalam (UAE) is a start-up online counseling and mental health well-being portal. Users select professional counsellors to have a private personalized digital experience using video, audio and instant messaging on a secure platform.

Dubai start-up, **Valeo Well-being's** personalized tracking and guided well-being app supports scheduling at-home well-being tests and advice, certified well-being coaches who focus on behavioral health and nutrition.

Hospital-at-home

Acute care is provided at home for patients with medium acuity who need hospital-level care but are sufficiently stable to be safely monitored from their homes. This is through a combination of clinical-grade home technologies, remote monitoring and coordinated at-home visits.

Suited to conditions with well-defined treatment protocols including COPD, pneumonia, congestive heart failure and diabetes. Certain diagnostics can be performed at home including electrocardiograms, echocardiograms and X-rays.

Huma, a British digital-health start-up offers episodic and chronic digital health care. It is partnering with the governments of the UK, Germany and the UAE to grow a digital-health ecosystem based on its remote care platform. The platform is used to provide hospital-at-home telehealth services to patients with complex conditions.

It covers over 180 diagnostic groups and is built upon an integrated technology platform of biometrics monitoring, medical record integration, AI-powered analytics, workflow automation and management and clinical and operational rules. Services are run in real time through a command center.

Virtual & augmented reality

Immersive technologies combine visual, auditory and other sensory data with the physical world, typically through a head-mounted display. Virtual Reality (VR) is an entirely immersive, 3D synthetic experience with no sense of the real world. Augmented reality (AR) overlays digital information onto the real world, while mixed reality (MR) combines both the real and the virtual realms.

Applications include health professional training, surgical training, training on invasive and complex procedures, pain management, mental health (anxiety, phobic disorders, post-traumatic stress).

Roomi (US) is an immersive AR and VR world teaching children about medical illnesses and procedures intended to reduce stress and fear associated with attending a health service.

VROOM (Australia) is an immersive experience model that allows clinicians to understand complex genomic data to identify the biological basis of a patient's cancer and guide precision medicine.

Vera Concierge (Israel) is a navigation app that displays the most direct route to any destination, superimposed over the view of the surroundings, seen through a phone camera. Delivers efficient patient wayfinding and backend analytics that give insights into patient flows and bottlenecks.

Robotics

Assistive robots are transforming surgeries, streamlining supply and disinfection, and engage with and care for patients. Use cases include surgical assistance, modular robots (including exoskeletons and prosthetic limbs), autonomous mobile robots (including disinfection, telepresence, medication delivery), service robots transport linen and supplies, and social robots that interact directly with people.

Robosculptor (UAE) is a robotics platform for non-invasive body treatments, that require positioning of the body in real time. Applications include medical massage, lymphatic drainage, and skin rejuvenation.

Peppermint robotics (UAE), autonomous intelligent housekeeping, material handling and service robots for industrial and commercial uses.

Spotlights

"In" and "on" the body: sensors and wearables

Advancements in sensors are rapidly creating a new Internet of Medical Things (IoMT) …"inside" us and "on" us. Wearables offer personalized solutions for prevention, diagnosis and treatment.

Digital wearables combine smart sensors, AI, IoT, big data and medical bots. They can identify risk factors, predict deterioration, measure and transmit biometrics or vital signs, track sleep and stress levels. Key applications include managing chronic illness and maintaining health and wellness.

Small in size, wearables give people the tools to monitor their own health and can have a significant impact on health and quality of life. The field is broad, ranging from consumer-grade devices such as smart watches to highly technologically advanced solutions such as exoskeleton technology, stretchable artificial skin and the emerging field of nanobots, which is expected to have applications in cancer diagnosis and drug delivery.

"In" and "on" the body

Digital-first

New care models include digital-first access models in which patients are expected to have an initial contact by video, telephone or asynchronous web-based message before being offered a face-to-face consultation. Recent policy in the UK has strongly promoted digital-first primary care under the National Health Service (NHS).

Under this digital-first approach, primary care is being transformed. An AI-powered platform drives virtual clinical operations connecting patients with providers through the web and mobile applications. Patients use online tools to access all primary care services including booking appointments, receiving advice, having an online consultation, receiving a referral and obtaining a prescription.

Examples include virtual primary care services **Pushdoctor** (UK), **Livi** (UK), **Ping An Good Doctor** (China).

Other digital-first applications include AI-enabled ambient listening and medical documentation systems that use natural language processing and automated speech recognition to record point-of-care content in real time but also asynchronous medical record documentation.

- **Nuance** (US) captures multi-party conversation ambiently and automatically creates clinical documentation.

The UAE perspective

The UAE has been an early mover in telemedicine with the first telemedicine framework being adopted in 2013 and covering the regulatory guidelines for six major elements of telehealth: telediagnosis, telecounseling, telemedical interventions, teleconsultation, teleprescribing and telemonitoring.

Adoption was accelerated as early in the COVID-19 pandemic the UAE responded quickly with innovative solutions including the remote care platform for digital care and extending the "doctor for every citizen" service to all UAE residents.

The pillars of a technology-enabled health system are being put in place and are supported by a readiness of the sector to adopt technology. Technology provides the tools for future UAE health strategy of moderating demand and shifting to personalized, participatory and preventive health models. As Dr Aaron Han Chief Medical Officer, Alliance Care Technologies noted, "Health care resources must transition from our current focus on curing and managing illness to promoting wellness and preventing disease."

Telemedicine or virtual care forms the baseline upon which smarter and value-based health care systems in the future will be built. Placing digital technology at the core of the health care system also allows the UAE to plug into the global network of experts with strong ties in other countries as a pipeline of referrals and source of future business.

There is an increased sense of wellness in the region with a rapid growth of wellness oriented services, such as yoga studios and gyms. Corporate wellness challenges are also emerging, including the Dubai Corporate Games to promote competition in sports and a growing awareness of health, fitness and wellness. Behavioral nudges are encouraging the population to increase their physical activity levels through programs such as the 30 x 30 annual fitness challenge program, to commit to do 30 minutes of activity each day for 30 days.

Regarding the long-term horizon, Dr. Omar Najim, Director of Executive Affairs and Special Projects Office, Department of Health Abu Dhabi, observed "The priority for the UAE is how do you build a system to be fit for the future population you are serving, so in 10-years time, in 20-years time or 30-years time? What this means is that we need to digitize health care and use AI and machine learning."

Input from the wavespace session indicated that the UAE is seen as a window into the future of health care across the globe because of the way the system is being set up for the future. This future is built on fast information sharing, mature digital systems and driven by a high ambition to drive research and innovation and to shape what the future of health care will look like.

How can the UAE use the power of AI to ask better questions and unlock new answers for a healthier future?

The people we spoke with identified to move to radically different approaches to care, the UAE should consider

1. Creating innovation opportunities through enabling environments that co-locate entrepreneurs from multiple sectors to foster development in the medical, wellness, biopharma and devices sectors.
2. Educating and further growing the awareness of the citizens of the UAE about health, wellness and preventing the onset of chronic health conditions.
3. Creating the conditions that will support the successful scale-up of digital health innovations.

Trend

03

Data as a core asset

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ERYTHROCYTES
NEUTROPHILIS
MONOCYTE

Data as a core asset

An information-intensive industry, data in health care supports better care and improved outcomes, but also has scientific and commercial value.

Data and analytics are transforming every aspect of people's lives. Data has always played a major role in the delivery of health care through evidence-based practices. However, what has changed, is the scale, scope and velocity of data creation in health care.

New care models and locations give rise to vast streams of data that must be integrated with clinical data for holistic and personalized care. Unlocking the power of data brings promise of better health and well-being as well as opportunities for innovation and improving the quality and efficiency of services. Value arises through advanced technologies such as generative AI and powerful analytic tools that support extraordinary advances in health care.

The outlook in this trend covers how understanding and utilizing data is one of the keys to modernizing health care. Increasing costs, shortages of clinicians and continued health disparities are prompting health care systems to refocus their strategies to work smarter, not harder.

This includes using digital technologies and data solutions to drive productivity, preserve scarce clinical resources for patient-facing care and to optimize patient and clinician experiences.

Data is central to health care and an invaluable asset for research, clinical applications and commercial interest. However, for data to be reliable and drive decision-making, it must be well governed and built upon shared standards as a single source of truth.

Data science in health care is moving past simply reporting data to providers to natural language processing and machine learning algorithms in a dynamic environment of predictive analytical models. AI, in all its many forms, is significantly reshaping health care and brings the promise of a future built upon portable diagnostics, AR in surgery and mental health care and precision medicine.

Finally, this outlook spotlights two emerging trends of synthetic data and secure health care information.

Key trends

- Data is becoming a central asset in health care; patient data is a highly valued asset and monetization is of interest.
- Emerging connected and integrated health care ecosystems realize the value of health data in accelerating novel approaches to care.
- Better health outcomes as AI and analytics enable predictive insights, real-time information and shape service delivery and population health.

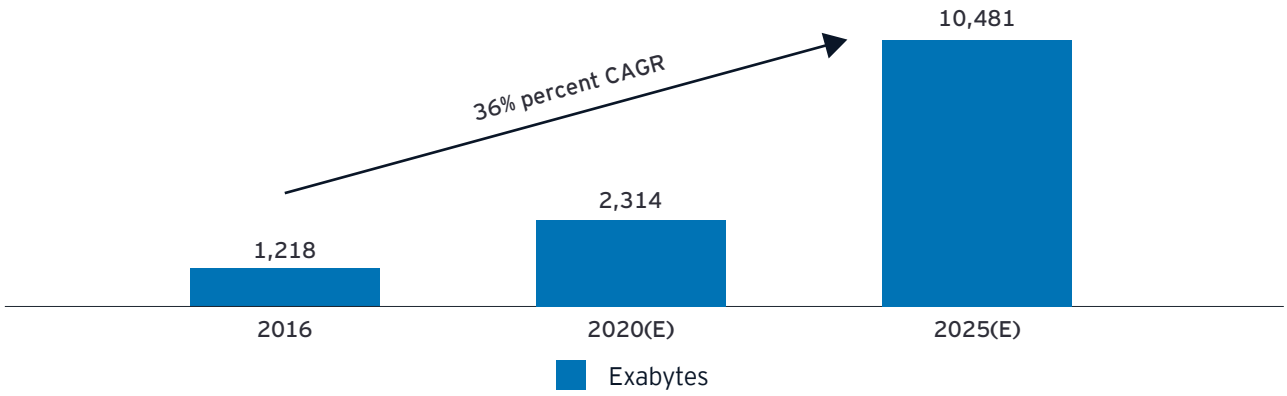
Outlook

Data-driven health care

Vast amounts of data are being created both within health systems and externally. Approximately 30% of all the world's data volume is now being generated by the health care industry.[1]

Next-generation platforms will ingest and make sense of the streams of data arising from wearables, biosensors, genetic, omic, imaging, text, clinical and environmental information for prevention and early diagnosis and will delay or avoid the onset of disease.[4]

Growth in health data[7]



The volume and velocity of health data generation is creating interest in the commercial value of such data. A health data economy is emerging with rising demand for massive data sets for scientific and research purposes and for training algorithmic technologies.[2]

Within the next decade

It is expected that integrating vast streams of data arising from many different and varied sources will lead to a comprehensive and highly personalized picture of an individual's health and well-being.

This will take into account individual variability in environment, lifestyle and genes for each person.[3] Anywhere, anytime care will be built upon consumer-oriented technologies such as apps, wearables and environmental sensors that capture and share permissioned information across the care continuum.

> "The world's most valuable resource is no longer oil but data.
>
> **The Economist, 2017[8]**

At the population level, machine learning will bring predictive accuracy to big data to understand and predict demand and population health outcomes including epidemic and syndromic surveillance.[5]

To efficiently advance population health research, countries including the UK, China, Japan and the US have established population-level biobanks, which form a research infrastructure that combines biospecimens with health and lifestyle information and linked administrative data to efficiently identify emerging health trends and problems.[6]

The Emirati Genome Programme[9]

The Emirati Genome Programme aims to use genomic data to improve the health of the Emirati population. The project goal is to profile and determine gene sequencing among UAE Nationals for the prevention and treatment of chronic and rare diseases. Advanced sequencing technology and AI generate and analyze the genomic data and create a reference genome specific to UAE citizens. The information will support advanced diagnosis and treatment options and personalized preventive programs.

The program is a public-private partnership between the DoH, Abu Dhabi and G42, a health care technology company.

Data science and AI

Data science models, including intelligent process analysis and medical data mining, are increasingly used to inform real-time clinical decision-making.[10]

Applications include identifying and managing high-risk and high-cost patients, risk stratification, prediction of adverse events (such as renal failure and sepsis) and clinical risk prediction for certain diseases.[11,12]

Command centers, often compared with air traffic control, use real-time data and predictive analytics from multiple data sources to manage logistics, improve hospital-level flow and efficiency, reduce turnaround times, and coordinate transfers across multiple sites.[13]
(See care control systems)

At the enterprise and health system levels, intelligence functions convert data into actionable insights around population health, clinical decision support and streamlining operations for greater efficiencies.

The global analytics market is expected to reach **US$329.8b** by 2030.[14]

Massive health datasets generated by clinical activity (in electronic health records and imaging systems) and by digital technologies such as biosensors, wearables and ambient sensors need powerful tools to organize, interpret and draw insights from them.

AI and natural language processing are critical in turning complex information into usable insights, including individualized care plans and efficient service provision across the health system. Value arises through processing the wealth of data for biomedical discovery, diagnosis, prognosis, treatment and prevention.[15]

Multimodal AI models, that integrate distinct types of data, are emerging. In the future, it is anticipated that the capability to include many layers of omics data will result in deep phenotyping of an individual, for an exact understanding of each person's biological uniqueness and how it affects health.[16]

> “If data is used correctly it will help in providing lots of insight and innovative approaches. Real-world data will be used more and more in research, drug discovery and drug repositioning.

Dr. Osama AbouElkhir
CEO and Co-Founder of TachyHealth, March, 2023

Care control systems

Care control systems such as operational command centers drive hospital efficiencies and lower operating costs through patient flow improvements, more timely patient transfers and reduced wait times for beds. Patient outcomes are improved through early detection and prevention of harm for patients at risk of clinical deterioration through real-time data analytics.

Johns Hopkins Command Center

(Baltimore, MD)

- Improved bed utilization from 85% to 94% in 2021 and opened the equivalent of 16 more beds (virtually) on a daily basis without building new facility or adding new staff.
- Increased capacity to handle complex transfers from other hospitals by 65% with ambulance teams dispatched 43 minutes earlier to pick up patients. Emergency Department (ED) patients are assigned a bed 38% (3.5 hours) faster and transfer delays from Operating Room (OR) after a procedure have been reduced by 83%.
- Efficiencies contribute an estimated. US$16m to annual revenue. Investment had a 24-month payback period.

Humber River Hospital Command Center

(Toronto, ON)

- Efficiencies reflect the equivalent improvement in patient flow of opening 35 new virtual beds, saving approximately CAD11.5m in annual operating costs.
- Wait time for having an in-patient bed cleaned has been reduced by 45% and the time a patient in the Emergency Department waits for an in-patient bed has been reduced by 33%.
- Payback period of 18 months.

Source: GE HealthCare Command Center. Outcomes.

Governance and risk

While data sharing brings immense value, connecting and sharing data also brings risk. Robust governance structures, policies and practices are required and cover the ethical, legal and moral aspects of collecting, storing and sharing of sensitive health data.

Internationally, policy attention is being directed toward establishing interoperable systems for data sharing and usage as a foundation for the future health industry. The future vision is that of permissioned sharing of data that moves seamlessly and securely between systems.

Momentum is gathering around the need for shared data and terminology standards. The end goal is to achieve a reliable standards-based foundation of data, known as a "single source of truth" or health reference data, to deliver actionable information from the consolidation of various data sources. Several international standards are backed by the World Health Organization (WHO) in terms of increasing efficiency, quality and safety, as well as scalability of health systems. Those supported include HL7/FHIR, Integrating Health care Enterprise (IHE), openEHR and SNOMED CT.

Furthermore, emerging trends in software development such as low-code platforms are expected to become the default in enterprise applications and can be used by non-programmers and will simplify the work of health and care teams.[17]

"

People need to know that the data they have been given is standardized. What we're seeing in the UK and in Europe is a move toward SNOMED coding so that we get codified data that can be used for machine readable purposes.

Professor Rachel Dunscombe

UK Government AI Council and Visiting Professor, Imperial College, London. March 2023

Cybersecurity

Cybersecurity demands attention, not only due to rising cyber threats and attacks but also risks from cloud computing, AI, big data and the increasingly connected and networked medical and IoT devices. Key trends in the changing cybersecurity landscape include digital identity management, third-party risk management, asset security such as managing building and systems risk (e.g., refrigeration systems and elevators), and zero trust security policies and frameworks that assume constant exposure to external and internal risk.[18]

Spending on cybersecurity in the medical device sector will grow from US$869m to US$1.2b between 2020-25, a CAGR of 7.3%.[19]

A deeper dive

Patient data: a valuable new asset

Governments and health care organizations are increasingly recognizing that health data is a strategic asset. In the future, data sharing, interoperability and innovation will allow common challenges to be tackled, new business models, operational and research opportunities.

A multi-billion dollar industry operates in collecting, merging, analyzing and packaging patient data. Buyers range from health policy researchers to pharma companies and marketing corporations.

Sharing organized and complete data to generate insights for better health outcomes is the point at which patient data becomes a highly valued intangible asset.

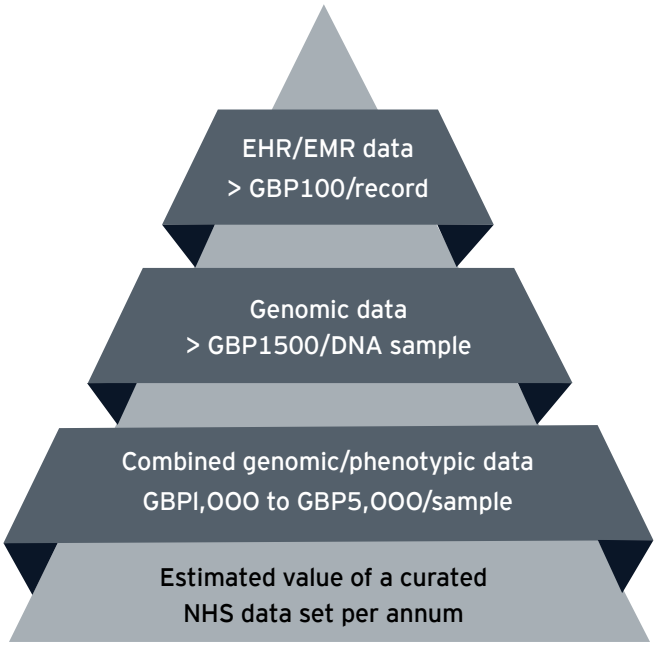
The benefit arises through enhanced patient outcomes, potential operational savings for health systems and creation of wider economic benefits through R&D program. For example, it has been estimated that the value of a curated NHS data set could be as much as GBP5b per annum, delivering around GBP4.6b worth of benefit to patients per annum. Furthermore, estimates of productivity savings could be equivalent to 2% of the annual NHS budget and equate to GBP2.7b per annum.[20]

Ethical concerns arise in collecting and using health data including the threat of re-identification, malicious actors and concerns about the concentration of data in a small number of companies. The collection and use of such data must adhere to medical ethics, privacy and research regulations. However, public benefit arises through consolidating patient records into the highest quality longitudinal patient-level data set.

Value arises in terms of economic uplift – benefits to patients and the economy – and commercial opportunity, such as incremental profit or licensing income from successful business deployment of insights gained from the data.

Key issues in a booming health care data economy include:

- Defining and protecting patient privacy
- Consumer protections in the event of potential discrimination or data misuse
- Disclosure obligations on the collection and use of data
- Hacking and data breaches with patient records being sold on the dark web. Malicious third parties value health care data at US$250 per record on the black market.[22]



Source: EY Realising the value of health care data: a framework for the future. 2019

The government of the UK introduced a strategy in 2021 to unlock the hidden value of public sector knowledge assets. Intangible assets across the public sector were estimated to be GBP150b in 2021 with an estimated value of knowledge stock in the NHS of GBP56b.[21]

Analytics, AI and precision medicine

Advances in data analysis, AI and the IoMT promise a future that may include artificial patients, synthetic analysis, portable diagnostic devices and AR in surgery.

Deep learning

Deep learning has been transformative for health care bringing speed and precision to the analysis of data. This is a form of machine learning that filters data through multiple layers, learning from previous results for greater accuracy in correlations and connections. Deep learning is the basis of medical image analysis such as MRI results or X-rays; the clustering of patients into risk-based cohorts; and for highlighting relationships between symptoms and outcomes, e.g., diagnosing crucial neurological conditions such as stroke or brain hemorrhage.[23]

Emerging types of machine learning such as generative AI (a category of AI algorithms that generate new content in the form of images, text and audio), have applications in artificially generating patient data for clinical research purposes, especially in conditions with limited data or are high-cost to acquire authentic data, while protecting patient privacy.[24]

Analyzing big data can shed light on individual behavior patterns and predict future behaviors, barriers to change and solutions to overcome behavioral traits. Insights gained regarding the well-being of communities suggest new ways to improve public health and medicine, including disease surveillance and risk factor identification, epidemic monitoring, and targeting of public health campaigns.

Building and analyzing a wealth of health and health-related data such as health outcomes, prescribing, insurance, consumer-generated, population health, patient-reported outcomes and genetics forms the foundation of predictive, preventive and personalized health care.

Value arises through the collection, curation and harmonization of datasets.

Connected medical technologies and novel applications of technology such as real-time wearables and always-on biosensors create new data streams but also raise regulatory and policy issues. Big data in health care brings big challenges of privacy and security, complexity, infrastructure, data management, commercialization and ownership.

Training algorithmic technologies requires access to huge data sets and gives rise to increased demand for health data. Algorithmic bias is a noted issue and pervasive bias, often on racial and economic details, can influence clinical care, workflow and health policy.

A systematic review of **82 studies** comparing the diagnostic performance of deep learning models in image analysis found it to be equivalent to that of health care professionals.[25]

The growing presence of AI within health care is reflected in the FDA approval of more than 520 marker-cleared AI medical algorithms as of January 2023. The vast majority relate to medical imaging.[26]

396
Radiology

58
Cardiology

14
Hematology

10
Neurology

7
Clinical Chemistry

7
Ophthalmic

5
Gastroenterology & Urology

5
General & Plastic Surgery

4
Pathology

4
Microbiology

3
General Hospital

1
Dental

1
Orthopedic

Connected health care systems

Health data and the way it is stored, shared and managed commands current attention and will significantly impact the future of the health industry.

Sharing organized and complete data to generate insights for better health outcomes underlies improving health.

Using better data in better ways will result in integrated and prevention-focused care rather than merely treating disease. Key to this is modernized information systems and infrastructures that can connect and share data, at scale. This should encompass the health and social dimensions of an individual's life journey and the value of health and other data in accelerating novel approaches for better and more efficient health and care.

The future vision of a connected health care ecosystem is that of a new type of digital care delivery platform that incorporates IoMT, advanced analytics, AI, consumer engagement and the ability to connect through aggregator platforms including health information exchanges.[27]

To this end, from a whole of health system perspective, regulatory, policy and implementation effort is being directed toward laying the foundations to build confidence and trust in the integrity and provenance of health information.

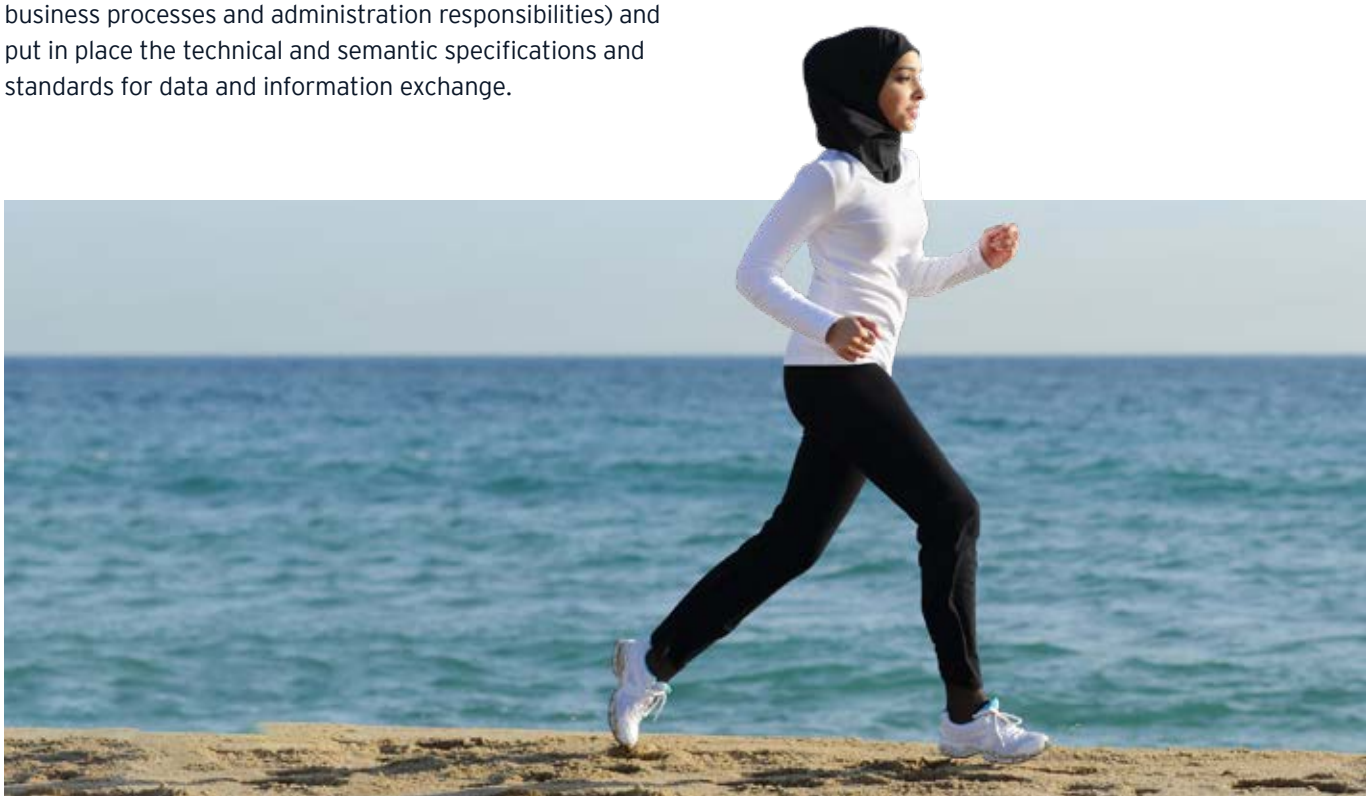
These building blocks seek to ensure that organizations can work together (e.g., privacy, legal frameworks, business processes and administration responsibilities) and put in place the technical and semantic specifications and standards for data and information exchange.

This includes maximizing the utilization, access and value of data through specifying such things as minimum datasets, shared common language (standards, semantics and structure), and interoperability standards, clinical data models and clinical terminology standards.

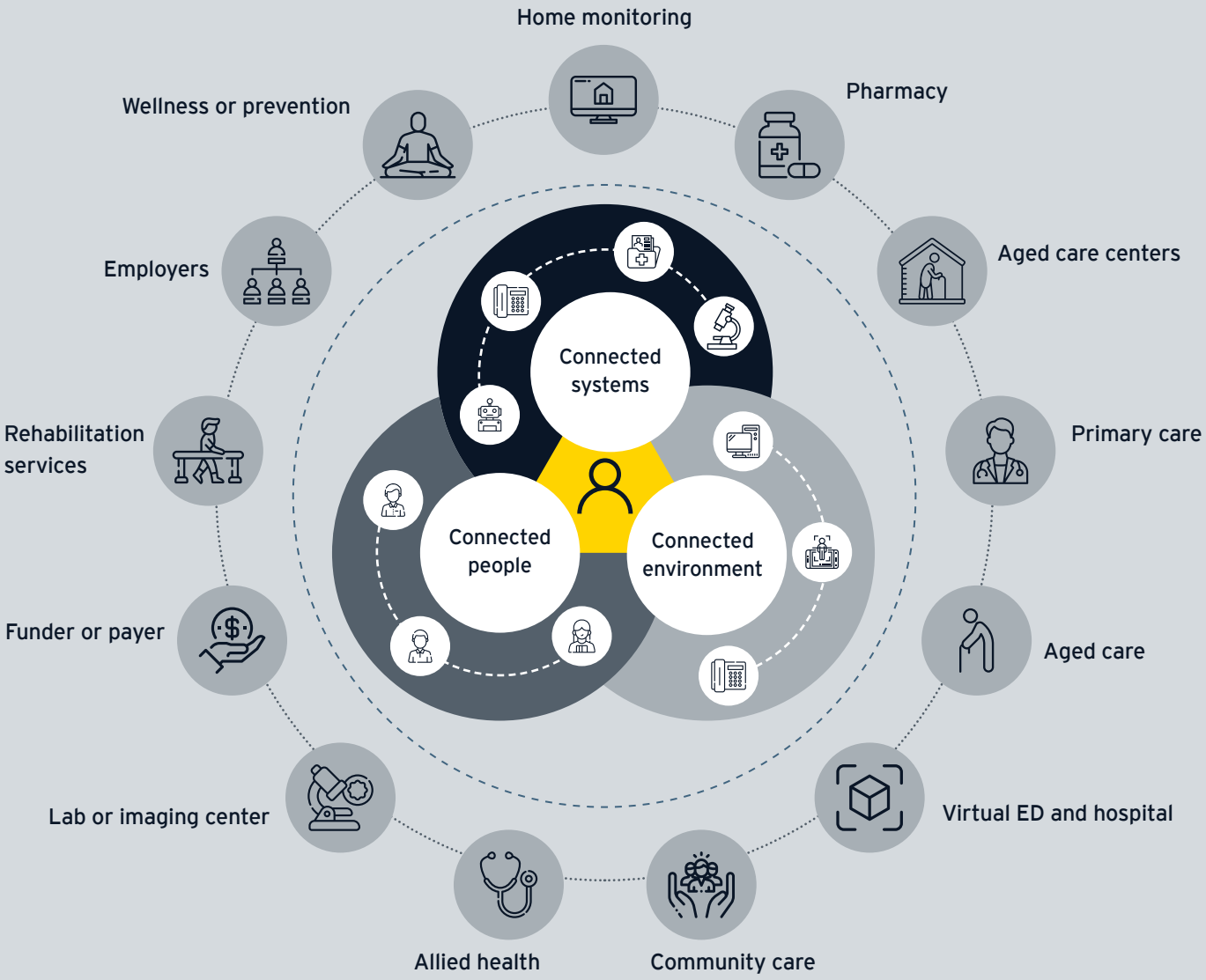
Electronic health records (EHRs) are a key pillar of digitally enhanced health systems. Internationally, the landscape is divided between large-scale investments in monolithic proprietary products and open systems that focus on end-user needs, vendor-neutrality, data persistence and fluidity.[28]

Notwithstanding, key shifts in the landscape include:

- Current and new EHR technology should be sufficiently interoperable to support the inclusion of health, social, economic, behavioral and environmental data for precision medicine and a learning health system.[29]
- A recognition that patients own their own data but that health systems can seek to maximize the use of, and value from anonymized health data.[30]
- Recognition of consent-based data portability where data movability should be seamless, requiring no effort from the consumer, like telephone number portability.[31]
- Governance of health data and interoperability standards to meet internationally recognized standards.[32]



A connected health ecosystem



Source: EY. Supercharging digital transformation in health care with confidence to commit. 2023, ©EY

Spotlights

Synthetic data

Privacy regulations governing the collection and secondary use of personal data make it difficult to gather sufficient real-world data to train algorithms.

Clinical data gathered through EHRs and smartphone apps are important sources of information on the treatment of health conditions and patient outcomes in everyday settings. However, this data is often locked in siloed systems and can be expensive and slow to collect. The data itself can be messy, patchy and insufficiently robust.

Synthetic data has been held out as having great promise for replicating and augmenting observational data with generated data that mimics and simulates real-world data. Synthetic data is non-reversible, artificially created data that replicates real-world and raw data.

Synthetic data can be used to model clinical conditions and user phenotypes without revealing patient data, and this can have significant applications in areas of data paucity, including rare diseases and chronic condition trajectories over a lifetime.

- **Diveplane (US)** Generative AI creates a verifiable synthetic "twin" dataset with the same statistical properties as the original data, without real-world confidential or personal information. Applications in health care include research, rare diseases modeling and insurance fraud detection.

Secure health care information

- **SOLID** (Social Linked Data) allows people to store their data (of any type) securely in decentralized data stores or PODS. Access to data in the PODS is through apps that use standard, open and interoperable data formats and protocols. Data in the PODS are linked, meaning that different applications can work with the same data. E.g., Belgium has provided all six million residents with free PODS from the government for storing digital assets. Emerging ideas include a complex of PODS holding disparate parts of electronic medical records and as components of a metaverse AR/VR environment.
- **DEHealth,** a UK company with research centers in Ukraine, Israel, the US and New Zealand views health data as an intangible asset and a key to longevity and quality of life. Their app supports secure autonomous storage of personal medical data that users can share, manage and monetize. Transactions are executed using tokens. Providers are rewarded for sharing data and contributing to research. Meanwhile, data consumers access verified data for treatment and research.
- Emerging from a project that developed the world's first blockchain-powered genomics marketplace, **HLTH.network** (UK) are in the process of developing a tokenized ecosystem intended to enhance data integrity, security and privacy built upon a blockchain-based backbone. The vision is a unified and token-based health care system of open, collaborative and data- driven science. The network is developing multiple health care oriented marketplaces ranging from data analytics, e-commerce, AI methods and precision medicine to genome non-fungible tokens (NFTs).

The UAE perspective

The UAE has an open government data policy to bring transparency and accountability in government transactions supported by a legal framework. With respect to the health care sector, the UAE Health ICT Law (2019) introduced guidelines around the collection, processing and transfer of health data within the UAE, consistent with international best practices. This is in line with the UAE government's ICT Strategy 2021 and National Innovation Strategy that focuses on developing into a fully digitally enabled nation.

Wavespace participants discussed data as an enabler rather than a burden. To do this, the systems that collect, integrate and produce insights from it need to be, "built at the highest level and with the highest of investment to make it happen." Analytics is becoming a very important aspect of the health care system, not only for health care providers but also for payers, researchers and individual patients or consumers. Professor Rachel Dunscombe noted that, "It's very important that we have standards around how data is collected and that we have the right tools to do the correct analysis to come up with the right policies". Wavespace discussions suggested that, "the biggest challenge in the UAE is the amount of data that is being generated. The management, governance and ownership of that data is not clear. Sharing has to be set up in such a way that all feel safe about the data".

Key industry players in both the public and private sectors are experimenting with different approaches to use the data collected from patients for research, to optimize care, for workforce planning, and to attract investments.

Much activity is happening behind the scenes and holds promise for the future built upon research, smart pharmacies and precision medicine, among others. Wavespace participants commented that, "There are many emerging opportunities and it is still early days."

There is a strong data body in pharmaceutical medicine, which is now being added to claims data. Opportunities that benefit from this data include exploring the scope of precision medicine and algorithm training. This is especially the case with precision medicine for populations. The cost of genomic testing has fallen and population-wide data collections such as the Emirati Genome Programme bring opportunities to pioneer and set benchmarks for the industry. Suggestions arising in the wavespace session included views that industry leadership and commercial possibilities may arise through convening international communities of practice and in positioning to act as a global data hub.

The successful integration between three health information platforms Riayati, Malaffi and Nabidh into a National Unified Medical Record (NUMR) is a major step toward digital transformation strategy and achieving the goal of an integrated health system.

How can the UAE jumpstart innovation to unlock the power of health care data?

The people we spoke with identified that for data to become a core asset, the UAE should consider

1. Educating the health workforce (both existing and the pipeline) with the skills and readiness to work in a data-driven health care system.
2. Ensuring that robust governance structures, policies and practices are in place that address the provenance, integrity and usability of health data. This should also cover the ethical, legal and ownership issues relating to personal health data.
3. Leveraging the opportunity presented by big datasets along with breakthrough medical technologies (in genomics, nanotechnology, IoT and sensors) for developing innovative products and treatments.

Trend
04

Advancing medical science

All companies and organizations mentioned are for illustrative purposes only and this does not constitute endorsement or recommendation.

Advancing medical science

Ongoing innovation and advancements in medical research and digital health technology drive breakthrough products and treatments that change patients' lives and make health care personalized, more efficient and effective.

Advances in technology are accelerating evidence-based medicine. This gives a glimpse of the future where highly personalized treatments will better address complex human health issues and treat or prevent the emergence of disease.

The outlook in this trend highlights the shift toward innovative treatments based on an individual's lifestyle, genomic, epigenomic and other molecular measures. This will go a long way toward achieving the end goal of highly tailored health care that takes into account an individual's specific genetic makeup. This will also contribute to the emerging field of precision population health, where social, environmental and behavioral determinants of health are integrated with 'omics measures for the treatment and prevention of specific diseases.

Experiences arising from COVID-19 have set the scene for the future, for example with the fast-track development of vaccines, including the pioneering mRNA vaccines. This experience triggered a rethinking of traditional approaches to clinical trials, especially in terms of logistics, subject recruitment and data collection. Emerging trends in clinical trials include the use of hybrid and decentralized trials that incorporate digital health technologies and remote monitoring.

This outlook also covers emerging technologies with the potential to significantly reshape the health industry. For example, advances in medical research and digital health have given rise to digital therapeutics (DTx), which are evidence-based, clinically validated tools that use software and advanced technologies for health condition diagnosis, treatment and prevention.

Other technologies that are changing how health care is delivered include automation technologies such as physical robots, machine learning and robotic process automation bots, and medical 3D printing.

Finally, this outlook spotlights two key trends in regenerative medicine and cell and gene therapies.

Key trends

- Health system sustainability is sought by addressing the cost drivers of health care through game-changing technologies in 'omics, precision medicine, and regenerative medicine including cell and gene therapies.
- Breakthroughs in digital therapeutics, nanomedicine, genomics, metabolomics, among others are occurring exponentially.
- Innovation through automation and AI, robotics and 3D printing.

Outlook

Exponential scientific advances in health care

Exponential medical and scientific discoveries have significantly advanced personalized medicine. These have been accelerated by gains in the various 'omics technologies (for example, genomics, proteomics, metabolomics and microbiomes, among others)[1] along with genetics, molecular and cell biology. The application of big data science and AI, machine learning and neural networks (a method in AI that teaches computers to process data in a way similar to that of the human brain) further drives innovation.

Value arises as biological data from the 'omics can be analyzed at a collective level as well as at the single-cell level, allowing potential therapeutic targets to be identified, many of which may be cell or tissuespecific.[2] And thus, highly personalized precision medicine, such as precision oncology, becomes possible.

Greater availability and sharing of genetic data have enabled genome-wide association studies and characterization of the genetic features of human conditions.[3] This has been important for the growth in understanding of biological pathways and for the development of tools such as polygenic risk scores or assessments of heritable risk of developing certain diseases, that can inform individualized treatment and clinical trial participant recruitment.[4]

Deep population-specific data sets are being created. At present, most genetic samples used globally for pharmacogenomic research are from the US and Europe. The Emirati Genome Program has been established to generate a comprehensive genome database and produce a reference genome specific to UAE citizens. This will lead to personalized and preventive health care for UAE citizens and a comprehensive understanding of rare genetic disorders and new treatments. [5] Similarly, in the UK, the Our Future Health Program seeks to help people live healthier lives for longer through the discovery and testing of more effective approaches to prevention, earlier detection, and the treatment of diseases.[6]

The movement toward personalized medicine will continue as outcome data becomes more readily available, translational biomarker research progresses and a broader understanding of the human genome is gained. When further augmented with data held in electronic health records, wearables and sensors and gathered from behavioral and environmental sources, a full digital profile of the state of health of an individual becomes possible. The end goal is to better integrate therapies across a patient's care journey and to support precision population health at scale.

COVID-19 exposed the weaknesses in the health system, but it also set the scene for the future with the fast-track development and mass deployment of COVID-19 vaccines, including the pioneering mRNA vaccines.

The growth of hybrid and decentralized trials (alternative trial models that include digital health technologies, in-home clinical visits and remote monitoring) has been expedited by COVID-19.

These are expected to become a much larger proportion of studies over the next three years, with an estimated 50% of clinical trials being hybrid or decentralized by 2024.[7] This will likely increase as changes in regulatory guidance, data integration, and in-home trial execution further drive decentralized clinical trial adoption. These alternative models can reduce the costs of conducting clinical trials while increasing patient convenience and accessibility, improving equity in clinical trial recruitment, and enabling better data monitoring.

Abu Dhabi-based G42 Healthcare and Amazon Web Services in August 2022 announced a partnership to develop a genomics, proteomics and biobanking service.[8]

In October 2022, G42 Healthcare announced a partnership with Saphetor SA, a Swiss precision medicine company, for advanced capabilities in next-generation sequencing data for earlier diagnosis and treatment of cancer, rare and metabolic diseases and other genetic conditions in the UAE region.[9]

AI in drug discovery

Utilizing AI in drug discovery can speed up clinical trials through advanced data analysis and pattern recognition. It has also been utilized to enhance the overall value chain of drug manufacturing through the automation of key processes. Thanks to capabilities in processing and interpreting massive data sets, AI and machine learning can be deployed to design the right structure for drugs and make predictions around bioactivity, toxicity, and physicochemical properties.

Developments in digital biology, the computation of biological processes, and biosimulation are bringing new insights into gene regulatory systems and neural networks.

- **Isomorphic Labs** (UK) applies computational methods to simulate biological systems and for drug discovery and testing starting from an AI-first perspective.
- **Genedata AG** (Switzerland) provides enterprise solutions that digitalize biotherapeutic discovery and track, test and assess novel biotherapeutic drugs.

Globally, health systems seek to achieve the quintuple aim of improving population health, enhancing the care experience, reducing costs, improving the workforce experience and advancing health equity.[10] Key goals include greater system sustainability through addressing the cost drivers of health care including high-cost therapeutic areas of chronic health conditions and oncology, inefficient care such as avoidable hospitalizations, prescription drug nonadherence and low-value care. To this end, clinical R&D is advancing the targeting of such things as rare or orphan diseases.

This includes the rapidly growing field of study of metabolism at the global or 'omics level and steady progress toward precision medicine with advanced techniques that allow the sequencing of a single cell and individual genomes, creating better opportunities for new insights and discoveries.[11]

> "Genomics is another megatrend affecting the model, shape and sustainability of health care as we see it today.
>
> **Dr. Omar Najim**
> Director of Executive Affairs and Special Projects Office, Department of Health Abu Dhabi, March 2023

The 2019 Global Innovation Index (GII), health care identified cutting-edge emerging technologies most likely to revolutionize health care over the next decade.[12] These include:

1. **Single-cell analysis:** Single-cell analysis will allow scientists to study individual cells in their normal environment for the first time.
2. **Mapping the brain:** The Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative is accelerating the understanding of this most complex and critical organ.
3. **Regenerative medicine:** Replacement and regeneration of damaged human tissues and organs.
4. **Cancer immunotherapy:** The collection of immune cells and engineering them to produce chimeric antigen receptors to fight cancer.
5. **Gene editing to cure disease:** Gene-editing tools like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR-Cas) allow the correction of gene mutations.

A deeper dive

Digital therapeutics (DTx)

DTx offers a window into the future — of ever-present and always-on technology built upon learning systems to support behavior change.

The Digital Therapeutics Alliance distinguishes between digital health, digital medicine and digital therapeutics. Digital therapeutics combine clinical evidence and real-world outcomes and are seen as a subset of digital health. They are products that "employ high-quality software to deliver evidence-based therapeutic interventions that prevent, manage, or treat a broad spectrum of physical, mental, and behavioral conditions." [13]

There is a clear distinction between consumer health and well-being products and clinical-grade technology-based solutions. Key defining features are measurable evidence-based outcomes and the use of software programs and advanced technology that track and monitor a patient and provide support based upon behavioral science, cognitive behavioral therapy and motivational strategies.

Reaching patients directly through their smart devices, DTx has been proven effective in targeting some conditions where current management has failed to make inroads or where resources are scarce, such as neurological, substance abuse and mental health conditions.[14]

A key feature of DTx is the use of software programs and advanced technology in the diagnosis and treatment of complex and chronic health conditions. As software that functions as a medical device in its own right (SaMD), DTx are clinical-grade therapeutics that hold great promise for cutting through and motivating people to achieve their health care goals.

As a new industry, software that functions as a medical device in its own right raises a number of challenges to legacy regulatory and monitoring systems. As is often the case, the technology has moved faster than regulation. However, jurisdictions around the world are exploring regulatory frameworks that seek to find the right balance between regulation and evidentiary standards in products that, by their very nature, are dynamic.

A case in point is how regulation can deal with performance improvements, for example, driven by machine learning, in the software solutions that lie at the core of DTx.

At this point in time, diverse approaches to the regulatory problems are evident. For example, the US Food and Drug Administration (FDA) has trialed precertification that focuses on the quality of the company's development processes rather than regulating the specific product. Several jurisdictions, including in Europe, England and Australia, have modernized medical device regulations to more specifically define medical software, including software that functions as a medical device in its own right.[15-17]

Examples include:

- **GluCare** (UAE) operates a specialist clinic, the GluCare Integrated Diabetes Center in Dubai, and the company also employs a DTx model that utilizes software for clinical-grade therapeutic interventions. Patients are continuously and remotely monitored via a digital platform, and AI and ML provide real-time insights into disease risk factors, extending beyond diabetes.
- **Migrevention** (Estonia) is a tech solution to empower and educate people suffering from migraines to better control and prevent headaches.
  Users can log headaches, track details and then speak with a specialist. The next-generation device aims to transform the patient-specialist relationship and revolutionize personalized medicine by including diagnostic and treatment support through DTx, which would enable more accurate diagnoses and more personalized treatment plans.
- **BehaVR** (UK and US) offers clinically validated digital therapeutic treatments for wellness and mental and behavioral conditions, including serious mental illness. An immersive DTx company, the treatments are delivered on an integrated platform that simplifies the patient experience, enables clinician oversight and generates personalized care plans and measurable outcomes.
- **Una** (Germany) focuses on reversing metabolic dysfunction with precision nutrition and lifestyle management. App-based tech, biosensors, metabolic tests, AI and behavioral science are used to provide unique insights into metabolism, diet tips and coaching for personalized goals.

Automation technology

Automation technologies such as physical robots, machine learning and robotic process automation bots have the potential to significantly reshape the health industry. This is particularly important at a time of significant workforce burnout and high turnover to free up the workforce for higher-value, patient-facing tasks.

Repetitive activities such as back-office data collection and processing and customer-facing patient registration and inquiry functions have been successfully automated, at scale across health care organizations. Smart AI-powered chatbots support digitally accessible services and act as a digital front door to health care organizations. Some conversational bots field inquiries and navigation questions while others are highly specialized and may include triage protocols, a medical database, understanding clinical terminology and integration with electronic health records.[18] Opportunities for health care payers exist in claims processing and pre-authorizations, customer relations through patient portals and simplification of enrolment and billing processes.

Technological advances in robotics, AI and ML have brought new capabilities into robotics, including sensing emotions, perception ability to understand the surrounding environment and cognitive ability, including reasoning and problem-solving.[19]

Next-generation IoT-aided robotic systems are designed to perform complex operations in an integrated ecosystem of connected multiple robots in a smart environment.[20] Such robots function as intelligent devices and use advanced information and communication technologies, including cloud computing and big data analytics, to process and understand vast volumes of incoming data from sensors on people and in the environment.

Applications include at-home remote monitoring and rehabilitation (in smart homes), elderly care service robots that act as companions and caregivers, augmenting surgery, and the safe management of disease outbreaks.

Rashid Hospital in Dubai introduced the first robot dispensing service in 2017, as did Al Fujairah Hospital. These technologies reduce wait times, ensure safe storage and tracking of medications and tailored packaging for individuals' needs.

Emirates Health Service (EHS) launched four robotic pharmacies in 2022 to expand the automation of pharmaceutical service delivery. Smart electronic apps support the ordering and dispensing of medicines directly in smart self-exchange outlets. AI is used to locate and identify medicines and the preparation and dispensing of a prescription occur in less than a minute.[21]

Examples include:

- **Intuitive Surgical** (US) is now operating its fourth-generation Da Vinci Surgical Systems to advance minimally invasive surgery across a broad spectrum of surgical procedures. There are now approximately 6,335 Da Vinci surgical robot systems installed around the world.
- **Xenex** (US) LightStrike Robot and Disinfection Pod uses UV disinfection for health care facilities and deactivates a variety of pathogens that can cause hospital-acquired infections.
- **ZoraBot** (Belgium) has a range of robotic companions used in health care as companions, interaction with people to prevent cognitive decline and memory loss, as well as in pediatrics and physiotherapy.
- **Boston Dynamics** (US) is developing a range of next-generation robots with human-like characteristics and is advancing R&D to remotely measure body temperature, respiratory rate, pulse rate, and oxygen saturation.

The global medical robotic systems market size was estimated at[22]

US$16.1b in 2021.
It was expected to reach
US$21.2b in 2022 and
US$76.4b by 2030.

3D printing

3D printing has the potential to improve the efficiency of health care by producing customized and cost-efficient devices. These for example, can be used for building reference models for pre-operative planning, prototyping of medical devices and instruments, and molds, prostheses and customized implants.

Use cases include medical training and the tailoring of medical devices for anesthesia, for example, in complex procedures with little margin of error such as endotracheal intubation. Increased access to training through the use of such models can lead to improvements in clinical practice, reduced medical error and better health outcomes.

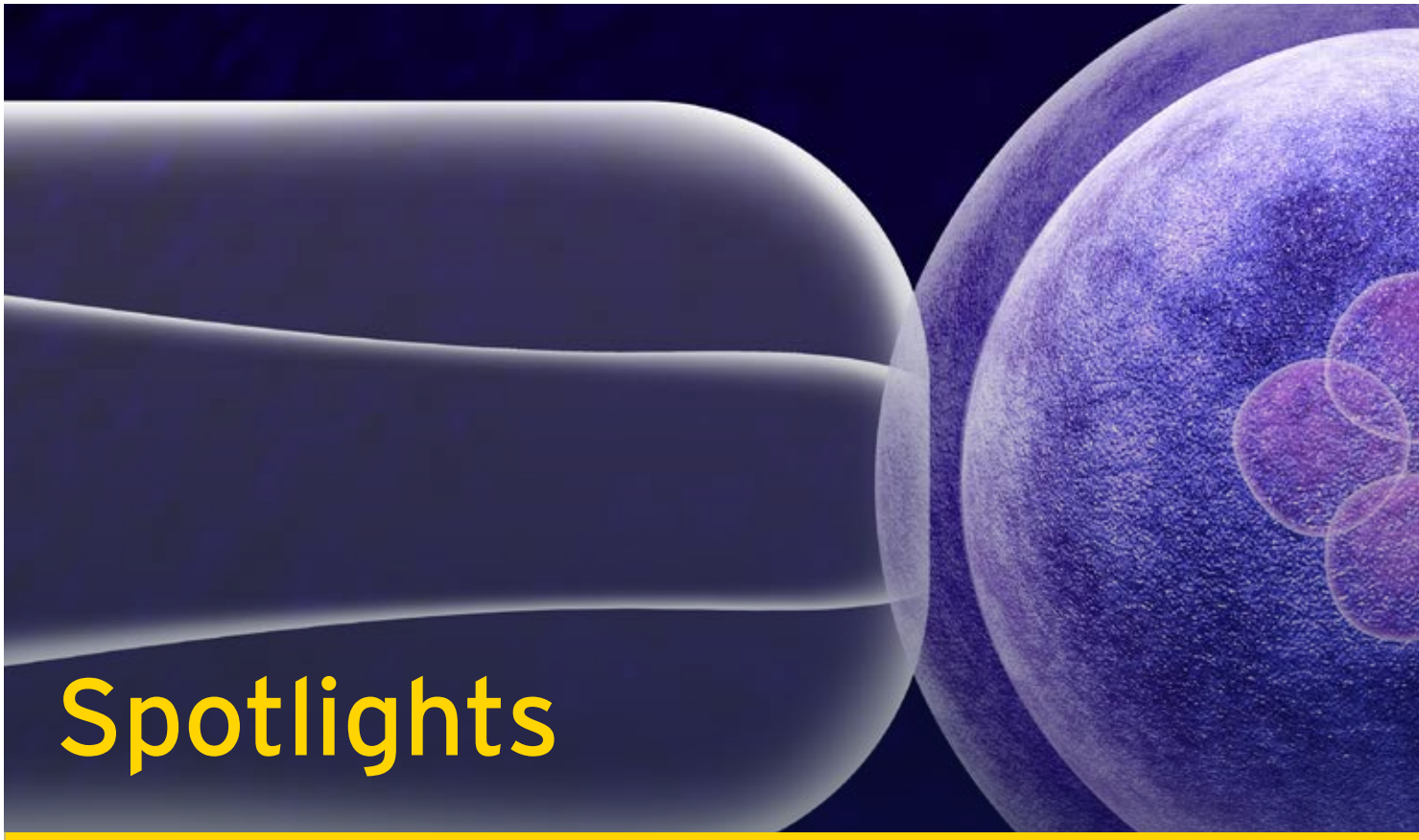
Medical 3D printing has applications in drug creation, models of organs in preparation for complex surgeries and biomedical implants, such as tissue scaffolds for bone and tissue regrowth, bioprinted blood vessels, synthetic skin and organs. In Dubai, a 3D printed model of a patient's arteries was used by doctors to design how to successfully operate on a cerebral aneurysm.[23]

New processes such as desktop stereo-lithography (for creating models and prototypes) are expected to increase access to 3D printing and to empower health care professionals to develop new clinical solutions and quickly manufacture custom devices.[24]

3D printing is also democratizing health care through initiatives such as e-NABLE, where communities around the world share information and open-source designs, so patients get a custom-designed and highly personalized prosthesis.[25]

Examples include:

- **Organovo** (US) is an early-stage medical laboratory and research company that designs and develops functional, three-dimensional human tissue for medical research and therapeutic applications. The company is developing its technology with the intention of eventually being able to replicate entire human organs for transplant.
- **Sinterex** (UAE) built a 3D Printing Lab with the Dubai Health Authority (DHA) to understand the impact of anatomical models on surgical outcomes. The company produces highly accurate anatomical models that closely replicate a real patient's anatomy. These models are used by surgeons for pre-operative planning and preparation and intra-operative review.
- **3D Middle East** (UAE) is a digital manufacturing solution provider that offers advanced solutions across various industries, including 3D model creation for surgery, virtual surgical planning, digital dentistry and the fabrication of medical devices and implants.
- **FabRx** (UK) is a specialist biotech company that is revolutionizing medicine manufacturing using innovative 3D printing technologies. Their novel and flexible platform enables the production of personalized medicines. They manufacture their own filaments, composed of pharmaceutical-grade materials, which can be drug-loaded to create sustained or delayed-release tablets, as well as multi-drug combinations (polypills).



Spotlights

Regenerative medicine

Regenerative medicine is a relatively new field of research that treats injuries and diseases by harnessing the body's own regenerative capabilities. It replaces or regenerates human cells, tissues or organs damaged by disease, trauma or congenital issues to restore or establish function.

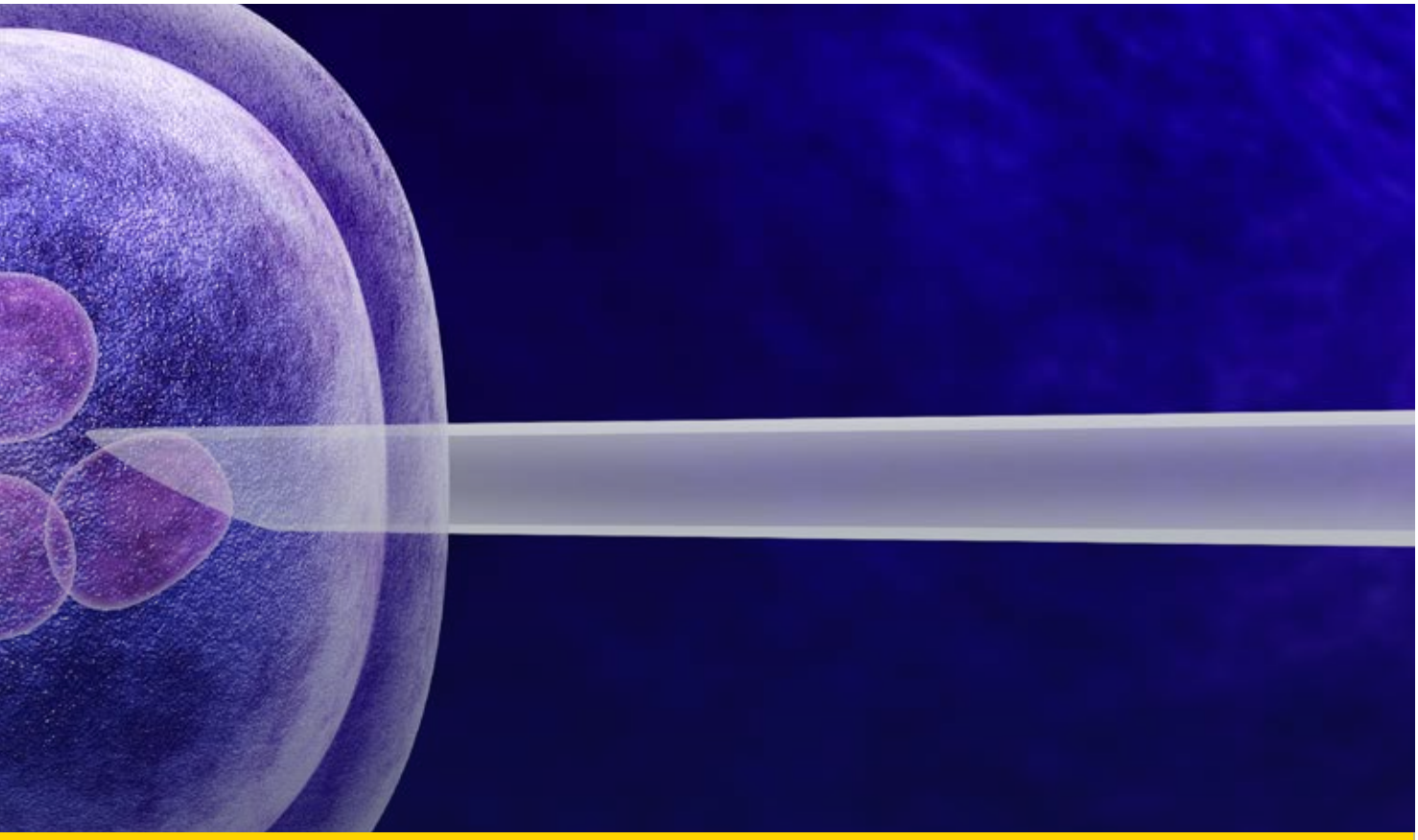
Regenerative medicine combines multiple fields, including biology, chemistry, engineering, genetics, medicine and robotics. Key areas of concentration include tissue engineering and biomaterials, cellular therapies including stem cells, and medical devices and artificial organs. Oncology is a prime target area with 52% of ongoing clinical trials, followed by central nervous system disorders and infectious diseases (both 8%), then hematology and genetic disorders.

Stem cell-based regenerative medicine is the focus of investigation for the treatment of intractable diseases such as cystic fibrosis, brain neurotrauma and spinal disc injury.

Regenerative medicine with stem cell therapy has grown in popularity in the UAE and is expected to grow significantly in the coming years.

For example

- **Abu Dhabi Stem Cell Center**, part of the PureHealth Group, has performed the region's first successful bone marrow transplant on a patient with Multiple Sclerosis (MS).



Cell and gene therapy (CGT)

Cell and gene therapies are a new class of therapies that in many cases, hold the potential for a cure with just a single dose, or a very short course of treatment. This brings considerable promise to patients. However, these therapies often have high upfront costs. List prices can range from tens of thousands to more than US$3m for a course of treatment, depending upon "value", development and manufacturing costs, and the size of the patient population involved.

As of December 2022, there were 23 FDA-approved CGTs and globally, 3,633 therapies (including RNA) in development. By 2027, the projected global market growth will be an estimated US$50b annually.[26]

FDA-approved CGT developments that will lay the foundation for the next generation of CGT technologies include:

- Spinal muscular atrophy (SMA). In 2019, the FDA approved Zolgensma, the first gene therapy approved to treat children under the age of two with SMA, a leading genetic cause of infant mortality when left untreated.
- Lymphoma. In early 2021, the FDA approved Breyanzi, a cell-based gene therapy to treat patients with certain types of large B-cell lymphoma cancer.

In the UAE, there has been a significant increase in government investment in biomedical research and development, including in advanced biotherapies.

- Researchers at the United Arab Emirates University (UAEU) have successfully used the gene-editing technology CRISPR-Cas9 to understand disease mechanisms which might provide an opportunity to develop novel therapies.

The UAE perspective

Advancing medical science and becoming the regional and global hub for research and innovation are key areas of focus for the UAE.

Government spending is being directed toward emerging medical technologies with a focus on biomedical research and development such as cell therapy, immunomodulation therapy, gene therapies and tissue engineering.

Targeted strategies include moving away from dependence upon imported drugs (80% of local pharmaceutical drug demand is imported) and therapeutic products to invest in increasing the domestic manufacturing capacity. Initiatives such as the "Make it in the Emirates", the Abu Dhabi Vision 2030 and the Dubai 2030 Industrial Strategy target attracting investment to increase local manufacturing. Priorities include pharmaceuticals, biomedical products and medical equipment. This includes strengthening local R&D and manufacturing capabilities as well as attracting international firms to establish manufacturing bases in the UAE.

The people we spoke with saw several streams of opportunity for the UAE. Dr. Omar Najim observed that the market extended beyond the UAE population to those living in the Middle East and Africa, bringing a growing demand for access to high-quality medical care. Dr. Aaron Han noted the favorable conditions in the UAE that are attractive to manufacturers, investors, innovators and entrepreneurs, including the ease of doing business, direct foreign investment policies and robust intellectual property protections. Discussion in the Wavespace session saw an opportunity for the UAE to create an ecosystem or research triangle type of cluster with other global partners, e.g., in Toronto, Berlin, London, Singapore, Shanghai or Boston to bolster strength by association and to "start thinking outside of the box."

Deep foundations for the future are being put into place through innovative partnerships that advance medical sciences. Existing partnerships exist with international health care providers including Johns Hopkins, Cleveland Clinic and the Mayo Clinic.

International partnerships have been formed with firms that are working on advances in medical technology, pharmaceuticals, clinical research and digital-health solutions. This includes Declarations of Collaboration between the Abu Dhabi Department of Health and several major US pharmaceutical and biotech companies to advance health care innovation, research and education in the emirate and in the MENA region.

If the biggest source of data is people, how can the UAE health care system capture value?

The people we spoke with identified that to advance medical science, the UAE should consider:

1. Creating innovation opportunities through enabling environments that co-locate entrepreneurs from multiple sectors to foster development in the medical, wellness, biopharma and devices sectors.
2. Educating and further growing the awareness of the citizens of the UAE about health, wellness and preventing the onset of chronic health conditions.
3. Creating the conditions that will support the successful scale-up of digital health innovations.

Trend
05

Sustainability and transformative technologies

All companies and organizations mentioned are for illustrative purposes only and this does not constitute endorsement or recommendation.

Sustainability and transformative technologies

Health services will be delivered in more resilient and sustainable ways. Capacity will be built to achieve sustainability goals and to future-proof health systems through self-sufficiency.

In recent years, awareness of setting policies and targets to reach Sustainable Development Goals (SDGs) and ESG has increased significantly, and the health care system has not been immune.

The outlook in this trend is primarily concerned with environmental sustainability, the health care workforce and the resilience and self-sufficiency of health care systems. This includes equitable access to health care, the economic sustainability of providers, and other players in the sector. It also includes expanding the concept of sustainability to include not just supply chain effects, but workforce well-being and the notion of creating shared value as a corporate responsibility for all players within an organization's ecosystem.

In the future, health care systems will need to be prepared for and respond to the changing natural environment. The experience of the COVID-19 pandemic raised awareness of the need to invest in sustainable and resilient health systems, especially in public health, to improve readiness for the next crisis.

The scale of the health sector means that health systems have a significant environmental impact. Globally, health care contributes around 5% of worldwide greenhouse gas emissions. Thus, sustainability is an important target in a rapidly changing health care environment.

There is a strong connection between achieving a sustainable workforce and strengthening health care systems. Achieving a sustainable health care workforce requires increasing labor participation rates, focusing on resource utilization and developing strong future pipelines of workers equipped to work in the digital age.

COVID-19 exposed the many vulnerabilities in global supply chains and prompted the sourcing of more stable options to better address supply constraints and variable demand. The supply chain is a prime area for AI because of the sheer volume of products, invoices and contracts. Intelligent supply chains will streamline getting the products to consumers to help achieve just-in-time delivery and minimize waste.

Finally, this outlook spotlights two key areas of environment-friendly hospitals and digitizing clinical trials through AI.

Key trends

- Climate-smart health responding to SDGs and ESG imperatives and retaining trust.
- Building workforce sustainability.
- Increasingly agile and resilient supply chains through transformative technologies.

Outlook

Increasing momentum for sustainable health care

Increasing awareness has shifted public attention toward sustainability and related environmental, social and economic matters. As the momentum around sustainability has increased, its meaning has evolved to include practices that support ecological, human and economic health for thriving, healthy and diverse communities.[1] In health care, this extends to such things as the well-being of patients, health care employees and the community.[2]

The health effects of climate change are becoming increasingly important, with more frequent direct effects such as heat stress and fires, flooding, and storms, and indirect effects, including food insecurity and altered patterns of infectious diseases. Pollution and poor air quality can trigger respiratory, allergic and cardiovascular conditions, all of which can place great demand on health systems.[3]

The WHO (2021) attributes

13·7 million (24·3%) deaths in 2016 to environmental factors. The direct damage costs to the health of this heightened public health risk are estimated to be between

US$2b to US$4b

annually by 2030.[4]

In the future, health care systems will need to be prepared for, and respond to the changing natural environment. This calls for resilient services that are capable of dealing with the health impacts and operational consequences of environmental changes.

Differences exist between high- and low-income countries. Interventions that improve the efficiency of infrastructure (including buildings, energy and transport) in developing economies may allow better health care provision while reducing environmental impact. In developed

economies, the task is to reduce waste (such as unnecessary plastics and single-use items), lower pollution (medical gasses, transport-related emissions) and invest in green building design and energy efficiency.[5]

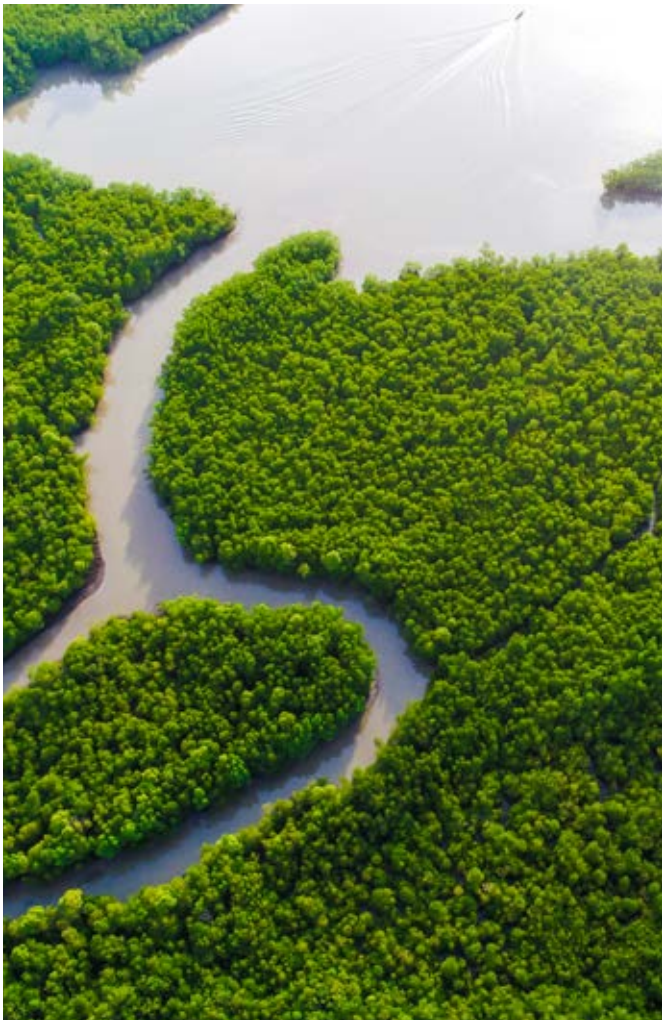
This outlook is primarily concerned with environmental sustainability, the health care workforce and the resilience and self-sufficiency of health care systems. Although fiscal sustainability of health care, or the financing of public and private spending on health care is an important topic in its own right, it falls outside of the scope of this trend.

Sustainable development goals

The 2030 Agenda for Sustainable Development highlights the responsibility of every sector to contribute to the SDGs. For health systems, this entails not only working toward health-related SDGs but also making a sectorial contribution to the achievement of other SDGs.

In January 2017, UAE's National Committee on SDGs was formed by decree of the UAE Cabinet.[6] The UAE aspires to create one of the best health care systems in the world and the National Agenda 2021 specifies a set of targets and indicators to achieve this.

Many of these targets are closely related to the health-related targets in the SDGs. The UAE's vision of "World-Class Healthcare" emphasizes the importance of disease prevention and a strong health care system, capable of responding efficiently to epidemics or health risks.[7]



DoH Abu Dhabi and the Partnership for Health System Sustainability and Resilience (PHSSR)[8]

In December 2022, the DoH announced that it would be the first health care regulator to collaborate with the PHSSR. The PHSSR is a global collaboration between academic, government, life sciences, health care and private sector companies that aims to strengthen global health ecosystem capabilities to prevent, respond to, and recover from public health and environmental crises.

The DoH has launched the Abu Dhabi PHSSR research, targeting the analysis of the resilience and sustainability of the health care system in Abu Dhabi and the UAE, and will share best practices and learnings from the successful management of the COVID-19 pandemic.

Health systems have a significant environmental impact

The WHO's vision of an environmentally sustainable health system improves, maintains or restores health, while minimizing negative impacts on the environment and leveraging opportunities to restore and improve it, to the benefit of the health and well-being of current and future generations.[9]

The scale of the sector means that the environmental footprint of health care systems is significant, using substantial quantities of resources and producing considerable waste. Globally, health care contributes to around 5% of worldwide greenhouse gas emissions.[10] In the US, 80% of emissions from the health care sector come from the supply chain of goods and services procured from third parties by health systems.[11]

The carbon-intensive manufacturing, packaging and supply chains of the pharmaceutical industry have been found to be more emission-intensive than the automotive industry.[12]

It is ironic that systems intended to heal can also have negative health effects as a result of the environmental effects of the production of health care. Thus, sustainability is an important target in a rapidly changing health care environment. In England, the NHS, for example, has committed to reaching a net-zero target across the entire scope of emissions by 2045.[13]

The Kings Fund, London, advances the view that "ultimately, the most sustainable system is one that minimizes unnecessary or ineffective use of resources (financial or natural) by delivering the right care, in the right place, at the right time and by preventing care needs from arising at all."[14]

Multiple indicators relevant to health outcomes include greenhouse gas emissions, particulate matter, air pollutants (nitrogen oxides and sulphur dioxide), the spread of vector-borne illnesses, reactive nitrogen in the water and the use of scarce water resources. Thus, influencing health outcomes demands transformative solutions rather than incremental change and requires cooperation across different sectors, industries and governments. The experience of the COVID-19 pandemic raised awareness of the need to invest in sustainable and resilient health systems, especially in public health to improve readiness for the next crisis.[15]

ESG business standards and principles cover the impact of decisions and actions have on the environment, society as a whole, and the workforce. This includes a focus on climate risk and environmental accounting, social concerns regarding diversity, inequity and access to health care and high-quality governance and oversight.

Creating Shared Value (CSV) is a framework aligned to ESG goals that creates economic value while simultaneously addressing societal needs and challenges. This can arise through building mutually beneficial relationships, redefining productivity in the value chain; and, building supportive industry clusters.

Within the ESG umbrella relevant to the health care industry, key areas to consider include:

1

Public perception

Under the social aspect of ESG, it has been shown that companies with ethical and socially responsible practices, are better perceived by potential customers and accordingly perform better than their less conscious competitors.

Regulatory incentives

Globally, regulators have incentivized enhanced environmentally conscious practices, providing subsidies and tax reductions that health care providers can benefit from by implementing mature ESG practices, reducing costs and enhancing government relationships.

2

3

Energy conservation

Globally, there have been numerous initiatives undertaken by businesses to reduce energy needs without requiring significant investments, mainly through enhanced building design.

Waste management

Efficient and safe practices in handling waste products in hospitals and pharmaceutical manufacturers are a major area of importance relevant to ESG, ensuring lower negative impacts on communities and the global environment, and preventing the major impact of inappropriate handling of harmful materials.

4

A deeper dive

Environmental, social and governance (ESG)

Sustainability and transformative technology can play a major role in enhancing the health system's economic, environmental and operating performance. The adoption of sustainable practices has been found to be successful in reducing costs across the value chain of health providers.

This topic is of increasing importance to stakeholders. Customers and employees are attracted to using and working for organizations that are mitigating their environmental impact. Incorporating environmental considerations into practices can impact shareholder value, and the ability to attract and retain customers is a lever to entice and attract skilled talent. [16]

Furthermore, adopting sustainable and transformative technologies, especially in logistical value chains and manufacturing practices, has resulted in improved resiliency to supply chain disruptions as well as enhanced productivity in health care and pharmaceutical manufacturing.

Globally, leading health care providers have undertaken several key initiatives under the ESG principles to enhance operations, and improve risk resilience, all while maintaining profitability and competitiveness in the marketplace. [17]

Some key initiatives include:

Low or no-cost energy conservation projects

By making all buildings require less energy (offices, factories, warehouses which are responsible for 40% of global greenhouse emissions).

LEED (Leadership in Energy and Environmental Design)

A leader in rating efficiency of green buildings and has defined a framework to achieve certification on site design which is recognized as a major ESG contribution.

Renewable energy

Hospitals, health care equipment and pharmaceutical manufacturers have undertaken major investments that rely on renewable energy sources such as solar and wind to power a high percentage of their energy and electricity needs.

Cybersecurity transformation projects

Enhanced cybersecurity practices including major investments in centralized and efficient controls over cybersecurity infrastructure in health care providers have helped achieve two related aspects of the ESG principles: maintaining data privacy and protection.

Social responsibility

Ensuring good practices to protect sensitive patient data ensures protection against reputational and legal risks which can arise from deficient ESG practices.

Enhanced governance

Through improved data governance, operational efficiencies and ease of access to important data have shown positive results in clinical studies. Enhancing the governance model can be achieved by including patients and the workforce in the model.

Smart supply chain and procurement

Reduction of carbon emissions in the global production chain of medical goods and pharmaceuticals by applying green procurement strategies. Innovative circular approaches are used to reimagine packaging, recycling waste, drug disposal and water and energy usage.

Digitization of health care

This includes accelerated digitization of paper-based processes and digitally enabled solutions and systems including virtual care and telemedicine to reduce patient-related travel and increase adherence. Introducing digital platforms and health information exchanges will connect stakeholders and enable remote consultations.

Workforce

Projections suggest that the demand for health workers will rise to 80 million by 2030, double the number in the workforce in 2013.[18] The WHO estimates that there will be a worldwide shortfall of around 10 million at that time.[19]

In the UAE there is a shortage of national health workers, a high reliance on expatriate staff, limited professional production capacity, a high turnover of expatriate staff and lengthy recruitment due to licensing regulations.[20]

Globally, the COVID-19 pandemic exacerbated existing workforce challenges in health care with stress, long hours and working in high-risk situations leading to burnout and high turnover rates. This occurred in the context of broader shifts in the general workforce in the wake of the COVID-19 pandemic, known as the "great resignation" when people re-evaluated their careers, work conditions and long-term goals and left the workforce in record numbers.[21]

Over the coming years, health systems will experience major workforce shortages due to an aging health care workforce which is not being sufficiently replaced and existing retention problems.

The workforce challenge is to refine productivity, reimagine clinical services and harness the power of disruptive technologies and AI. The NHS recognized this some years ago and commissioned the "Topol Review" which examines future health workforce demands and prepares the health care workforce to work in a digital future.[22]

Career Conversion Programme, Singapore[23]

The Career Conversion Programme appeals to mid-career individuals to acquire the training to switch to a career as an allied health professional in 14 professions, including diagnostic radiographers, occupational therapists, physiotherapists and social workers, among others.

Health care organizations can sponsor individuals, and applicants must meet age, residency and educational requirements. Graduates are required to fulfil a four-year bond with the sponsoring organization upon commencement of employment.

Key areas of activity intended to stimulate a sustainable health care workforce include:

Increasing labor participation rates

- Relax licensing or certification limitations and greater role flexibility within and between professional boundaries.
- Flexible employment policies aligned with life cycle requirements and workforce entry and re-entry.
- Benefits redesign, competitive salaries and supportive onboarding programs to improve retention and fill workforce gaps.
- Attract through immigration and employment policies and employment conditions that facilitate regional and international labor mobility to fill the workforce gap.

Resource utilization

- Increase the efficiency of resource utilization through collaborative multidisciplinary teams.
- Increase productivity through technology-enabled care models and automation through AI and robotics to assume administrative burden and free more time for patient care.
- Process redesign of care journeys and administrative procedures through standardization and elimination of non-productive and low-value activities.
- Service delivery model changes including scaling and strengthening primary care systems for prevention and better population health management.

Future pipeline

- Reforms in education and training that reflect changing roles and skill mix, capabilities to use digital health technology and work in a multidisciplinary team.
- Introduce new skillsets such as health informatics into training and education programs, including in pre-qualification training of health professionals.
- Capacity building of the leadership and governance capabilities to strengthen institutions' capacity for effective leadership and governance.
- Increasing the number of UAE nationals qualified in the full spectrum of health professions, ideally trained within the UAE health system, will build a more stable workforce and reduce dependence upon expatriates.

Supply chain

The COVID-19 pandemic exposed the many vulnerabilities in global supply chains with disruptions in essential supplies, including shortages of personal protective equipment and testing kits. Local solutions quickly emerged but in the long-term shifts are required in the production and distribution channels in health care. In particular, a questioning of the viability of global supply chains and whether onshoring or near-shoring presents more stable options to better address supply constraints and variable demand.[24]

Digitally enabled supply chains and sustainable procurement practices underpin the shift in health care to decentralized and data-driven health care models. In particular, using predictive analytics to streamline getting the products to consumers and to help achieve just-in-time delivery and minimize waste. As value-based payment models become increasingly adopted in health care, clear evidence of benefits and auditable data trails are important proof points for reimbursement for providers, payers and pharmaceutical companies.

Supply chain and logistics are the backbone of decentralized and personalized care

There has been considerable growth in direct-to-consumer services such as affordable DNA sequencing, which has created opportunities for highly personalized testing and treatment for a range of diseases.

Modernized supply chains are vital in home-based treatments, for example, managing delivery of gene therapy treatments between the patient and the lab under temperature-controlled conditions; micro-tracking and tracing of life-saving deliveries of small packages that require specialized compliance documentation; and capturing real-time data for outcomes-based reimbursement.

=These specialized services demand more complex logistics and inventory planning, demand forecasting and inventory management. This also demands a higher level of focus on safety, quality and compliance.

The future of supply chain: increase agility and resiliency

To ensure effective response, agility and resilience, health systems and organizations must look to the future of supply chain innovation. The supply chain is a prime area for artificial intelligence (AI) because of the sheer volume of products, invoices, contracts and utilization preferences that are tied to the supply chain.

In the future, AI technology has the potential to improve the supply chain in multiple ways, from optimizing inventory management to enhancing warehousing and storage processes to automating critical elements of the supply chain. It has proven to be cost-effective. Early adopters of AI in supply chain management saw a decrease in logistics costs of 15%, an increase in inventory levels of 35%, and a boost in service levels of 65%.[25]

Procurement is a specialized lever in the supply chain. The Organization for Economic Cooperation and Development (OECD) has estimated that hospitals account for approximately 40% of total health expenditures. Between 30% and 40% of a hospital´s budget is dedicated to supply chain costs, which can be reduced by up to 8% through the use of best practices.[26]

Tatmeen track and trace digital supply chain platform, UAE[27]

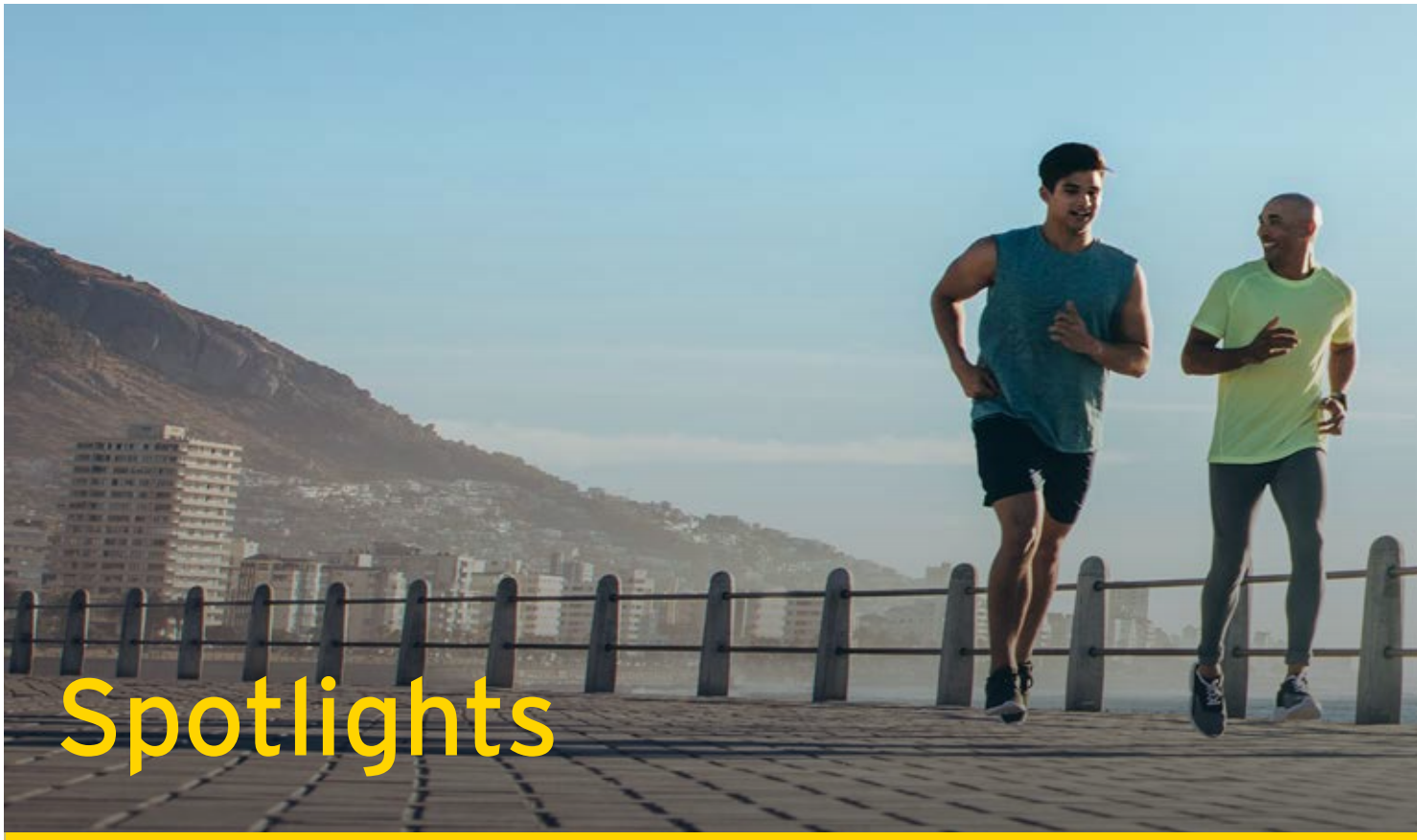
A national drug tracking system was officially launched in the UAE in January 2023. The platform is an electronic tracking service for medicines and medicinal products and was developed to enhance the reliability of the supply chains of pharmaceutical products.

It is a seamless electronic network connecting all actors in the pharmaceutical supply chain. Using advanced digital sequencing standards, a product can be tracked from its origin to its expiration date.

Since its operational launch in 2020, the platform has tracked and traced

1.2 million drug packages across the UAE and attracted

1,760 collaboration partners.



Spotlights

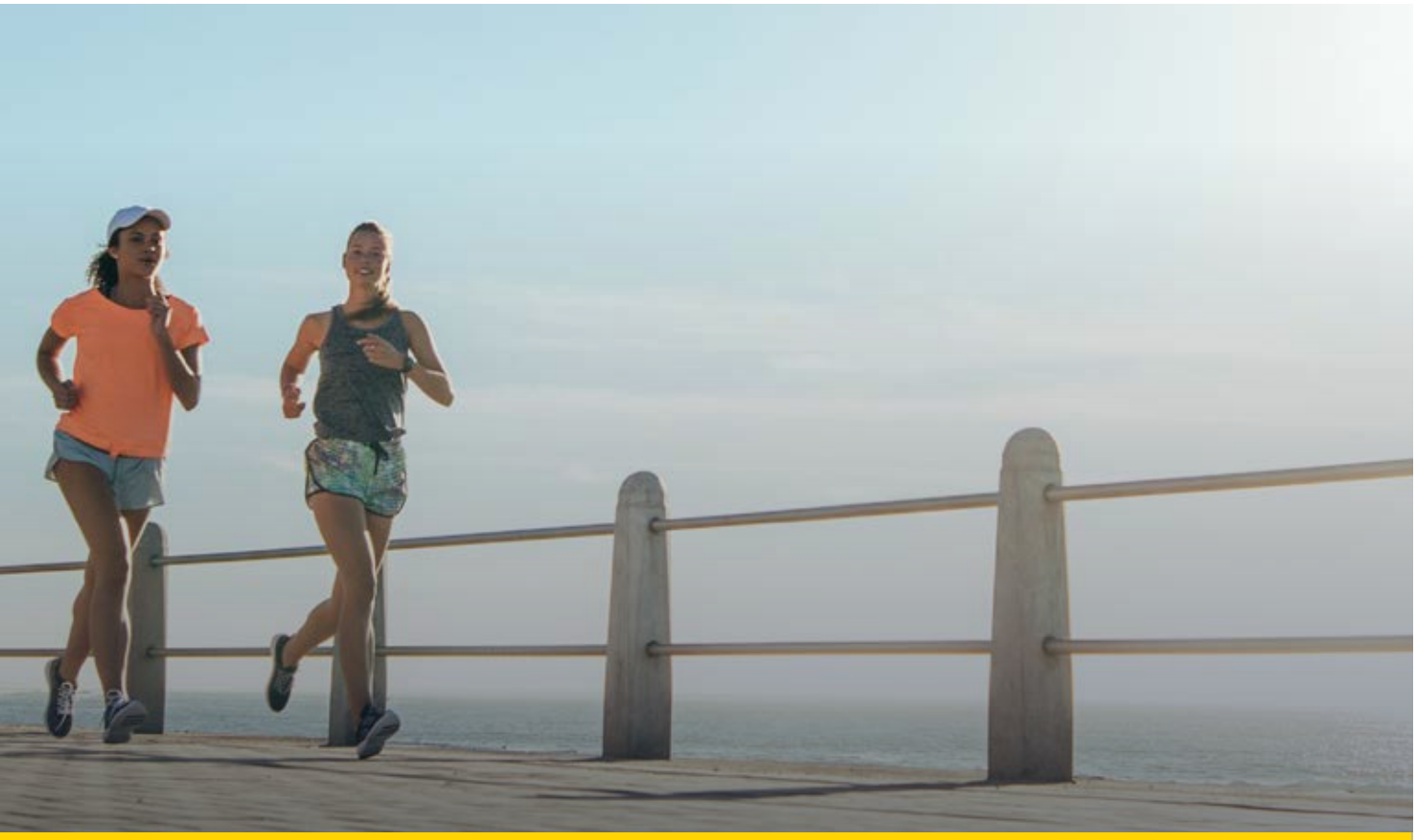
Environment-friendly hospitals

Globally, leading health care providers have undertaken several key initiatives under ESG such as energy conservation projects, utilizing renewable energy sources, improved cybersecurity transformation projects and remote and virtual care in the home.

Health care providers have initiated projects to reduce their carbon footprint by reducing energy needs throughout their facilities, as well as redefining more efficient supply chain routes through integrated value chains that reduce cost and protect against logistical risks.

The UAE aspires to create one of the best health care systems in the world, and the National Agenda specifies a set of ambitious targets and indicators to achieve this. Many of these targets align with the health-related targets in the SDGs. The UAE's Ministry of Health and Prevention leads the implementation of health-related targets in the SDGs.

- Emirates Health Services, Microsoft and Schneider Electric have partnered to launch EcoStruxure for Healthcare, a digital twin solution designed to increase health care operational performance and improve energy efficiency for hospitals across the UAE by up to 30%.
- SEHA, Abu Dhabi, announced a sustainability retrofit of SEHA's health care facilities to improve energy use, reduce water consumption, lower the environmental footprint and reduce overall maintenance costs for SEHA facilities.
- Boston Medical Center, (US) generates electricity and heat via natural gas, operates at 70% efficiency vs. 35% efficiency for traditional power plants and saves US$1.5m per year.



Digitizing clinical trials and AI

In 2022, 1,300 clinical trials included a virtual component supported by digital, a 28% increase compared with 2021.[28]

Breakthrough technologies in clinical trials include wearable technology, AI, big data analytics, synthetic biology, telemedicine, and mobile apps. AI technologies make innovations possible that are fundamental for transforming clinical trials, such as seamlessly combining phase I and II of clinical trials, developing novel patient-centered endpoints, and collecting and analyzing real-world data.

- **NVIDIA**, AstraZeneca and the University of Florida have collaborated on artificial intelligence research projects aimed at boosting drug discovery and patient care. MegaMolBART is a new drug-discovery model aimed at "reaction prediction, molecular optimization and de novo molecular generation."
- **Unlearn AI** (US) partners with pharma and biotech to accelerate clinical drug development. AI is used to simulate potential health outcomes for individual patients. A patient's AI-generated digital twin predicts how their health may change over time and digital twins serve as a control arm in a study and are used to simulate "what if?" scenarios to compare potential health outcomes and estimate relative treatment effects.
- Machine learning (ML) generates genetic insights through a better understanding of the underlying architecture and biology of disease. Predictive cell-based disease models are built to discover targets, patient groups and optimal drugs. ML is then used for clinical development strategies.

The UAE perspective

The UAE was the first GCC state to announce a national long-term climate strategy in 2017, titled the National Climate Change Plan 2017–2050. The strategy was designed around three objectives: managing greenhouse gas emissions while sustaining economic growth; minimizing risks and improving capacity for adaptation to climate change; and enhancing the UAE's economic diversification agenda through innovative solutions.

In October 2021, the UAE announced a net-zero emissions target for 2050. In 2022, the government revised the second nationally determined contributions (NDC) update of 2020. Originally forecasting a 23.5% greenhouse gas emissions reduction by 2030, this was updated to a reduction of 31% by 2030, relative to the business-as-usual scenario.

The UAE has unique environmental conditions and energy needs and balancing an ESG agenda with a financial sustainability agenda poses challenges. Initiatives in the health care sector to improve environmental sustainability include a focus on waste reduction and energy conservation through sustainable building design codes and certifications and emissions reduction in production and supply chains.

Key strategies target environment-related health risks arising from pollution and temperature, as well as identifying mental health, social cohesion, and happiness and well-being as national policy priorities. Along with indices of well-being and happiness, the policy landscape emphasizes social, environmental and economic development.

Globally, health care workforce shortages are of major concern. Policy responses in the UAE include targeting citizens to join the health sector, ideally trained within the UAE health system, to build a more stable workforce and reduce dependence on expatriates.

Sustainability is everybody's business. How will this play out in the UAE health care system?

The people we spoke with identified that to enable sustainability and transformative technologies, the UAE should consider:

1. Creating a favorable policy environment that leverages incentives for ESG for a sustainable health system.
2. Building a sustainable workforce through encouraging local citizens to acquire health industry skills and competencies and to support the development of new health workforce groups including data analysts, data scientists and epidemiologists.
3. Building system resilience to predict and respond to emerging epidemics.

Conclusion

The health care system of tomorrow will be quite different. Technologies are moving fast as they build a digital future.

A generational shift is underway as health systems around the world move away from legacy models that struggle to keep pace with the changing environment of today. The shift to digitally enabled systems is evident and this has been further accelerated by responses to the COVID-19 pandemic. This shift is unlikely to be rewound and is further underpinned by changing views on what health and care systems should look like and how they should perform. Individuals are becoming key players as health systems shift to being participatory, connected and technologically enabled.

The patients of tomorrow will benefit from an array of novel therapeutic approaches and modalities. These transform how patients and providers interact and give patients more control and input into their health and care than in the past. Tomorrow's health workforce will draw upon a very different range of skills and models of care. Technology brings capabilities to relieve burdens and free up the increasingly scarce health care professional resources for caring for people.

The five trends in the paper point the way. These trends lay the ground for the necessary shift in the health conversation toward reimagining health care with fresh eyes and setting the course for a radically different future.

As the UAE continues its journey to becoming a digitally advanced knowledge economy and global health hub, opportunity exists to deliver a unique experience of advanced, highly personalized health care. This closely aligns with broader strategies around smart cities and environments, putting in place a foundation of enabling infrastructure and partnering with prestigious international institutions. Building a competitive proposition for investment will accelerate the growth of a vibrant health economy, attracting investors, manufacturers, entrepreneurs and innovators.

Change is not a matter of "if", but "when".

Appendix

Thank you to all the industry executives who shared their thoughts and insights with the EY organization in the interviews and Wavespace session for this report.

Acknowledgments

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Glossary

Term	Description
Artificial Intelligence	An area of computer science that emphasizes the simulation of human intelligence processes by machines that work and react like human beings.
Big data	The emerging use of rapidly-collected, complex data in unprecedented quantities. The unique properties of big data are defined by four dimensions: volume, velocity, variety and veracity.
Climate-smart health care	An approach that sets forth both low-carbon and resilience strategies in an overarching framework to address the health impacts of climate change.
Digital-first	Digital-first access models direct patients to a virtual initial contact before being offered a face-to-face consultation, only when necessary.
Digital therapeutics	Evidence-based, clinically validated tools that use software and advanced technologies for health condition diagnosis, treatment, and prevention.
Digital twin	Digital twins are a digital replica of a physical asset or process, that provides nearly real-time monitoring without being in close proximity.
Generative AI and large language models	Generative AI is a category of AI algorithms that generate new content in the form of images, text and audio. LLMs are a new type of AI algorithm that look for patterns and relationships in large amounts of language data and generate new text based upon this training.
Immersive reality	Immersive technologies combine visual, auditory and other sensory data with the physical world, typically through a head-mounted display. VR is an entirely immersive, 3D synthetic experience with no sense of the real world. AR overlays digital information onto the real world, while MR combines both the real and the virtual realms.
Metaverse	A digital environment generated by computer technology that mimics the real world using concepts like augmented reality (AR), virtual reality (VR), blockchain and social media.

Abbreviations

Abbreviation	Description
AR	Augmented reality
CAGR	Compound annual growth rate
ESG	Environmental, social and governance
GHG	Greenhouse gas
HIE	Health information exchange
ML	Machine learning
MR	Mixed reality

Abbreviation	Description
N of 1	Single subject clinical trials; also used to refer to highly personalized care
NHS	National Health Service, United Kingdom
NLP	Natural language processing
SDG	Social and development goals
SaMD	Software as a medical device
VR	Virtual reality

Endnotes

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