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Disruptive EcoSystems

METAVERSE - CLOUD - BLOCKCHAIN - NANOTECH - 5G - APPS

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The Healthcare Metaverse: Innovating for a Future Beyond Limits

Dr. Harvey Castro, USA
The Transformative Role of VR and AR in Healthcare: Present and Future

Dr. Katarzyna Zarychta, Malta
Healthcare Solutions in an AI-Driven World: A Global Perspective

Ritesh Vajariya, USA
Transforming Healthcare Through AI and Generative AI: Opportunities and Challenges

Joerg Schwarz, USA
How Digital Clinical Quality Measures will Revolutionise Chronic Disease Management

Prof. Martin Curley, Ireland
Guided Open Collaborative Ecosystems as a Major Disruption in Health Systems

Yuri Vasilev, Russia I Anton Vladzymyrskyy, Russia, I Dr. Kirill Arzamasov, Russia
Transforming Diagnostics Through Artificial Intelligence: Insights from Moscow's Healthcare Integration

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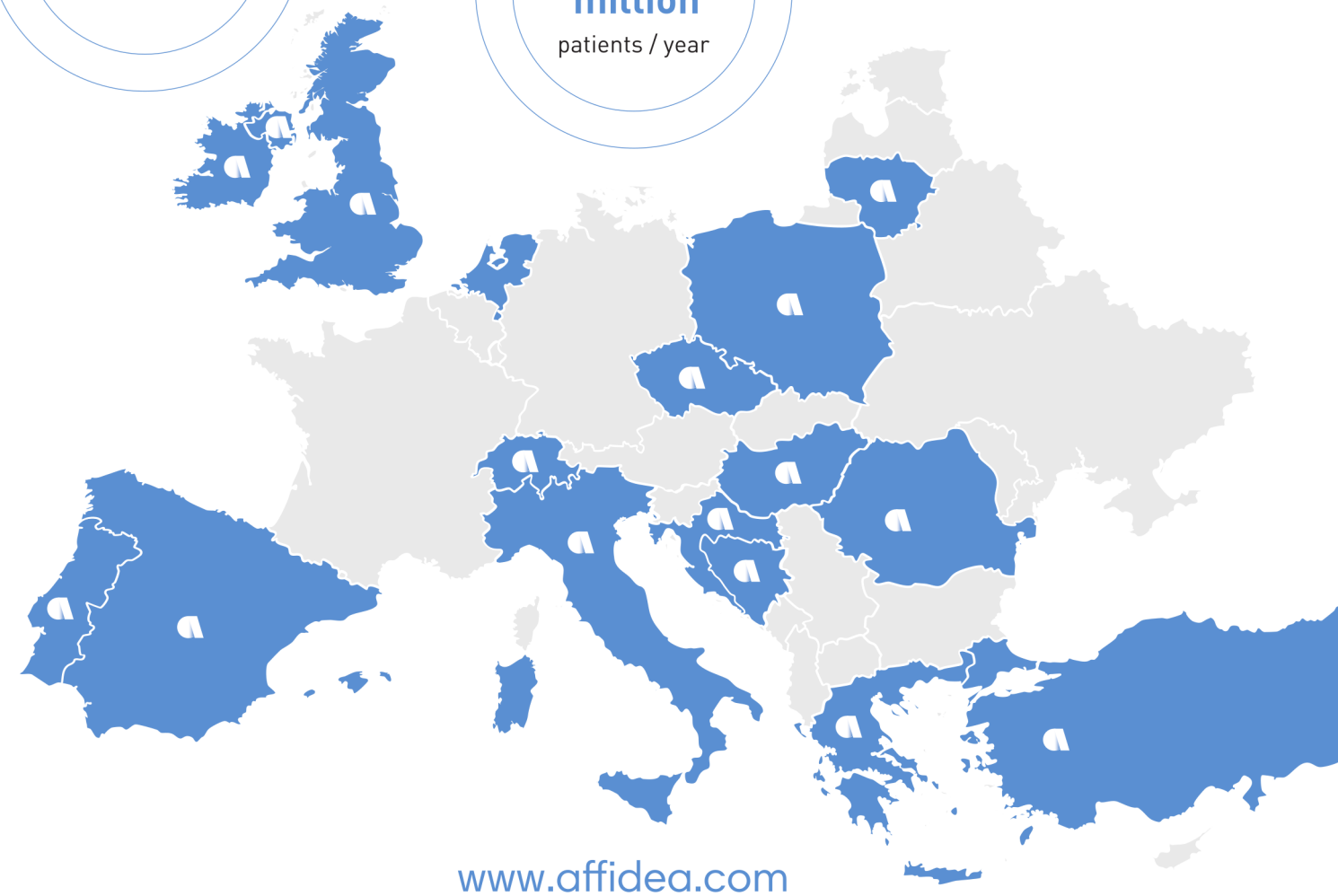

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Editorial

STEPHEN LIEBER

Chief Executive Officer I Alliance for Smart Healthcare Excellence I USA I Editor-in-Chief IT I HealthManagement.org - The Journal

Disrupting EcoSystems

The healthcare sector is experiencing a profound transformation, driven by the emergence of disruptive ecosystems that challenge traditional models and redefine what is possible. These ecosystems, fuelled by rapid technological advancements, innovative collaborations and a focus on patient-centric care, are reshaping the way healthcare is delivered, managed and accessed. In this issue, we delve into the dynamics of these changes, highlighting the groundbreaking innovations and strategies that are setting new standards for health management.

From digital health solutions and artificial intelligence to integrated care models and cross-sector partnerships, disruptive ecosystems are pushing the boundaries of conventional practices. They are creating opportunities to build more resilient, efficient and sustainable systems that prioritise outcomes over processes. Leaders in the field are leveraging these changes to address longstanding challenges, such as accessibility, affordability and quality of care. This issue examines the key trends, insights and success stories that illuminate the path forward.

Philippe Gerwill explores the way healthcare metaverse, powered by VR, AR, AI and blockchain, enhances patient care, transforms medical education and improves chronic disease management through innovative, data-driven technologies.

Dr. Harvey Castro explains how VR and AR are deeply transforming healthcare by advancing training, pain management, mental health therapies and surgical precision while addressing challenges like cost and privacy.

Ritesh Vajariya talks about the role of generative AI in enhancing healthcare efficiency, improving diagnostics, accelerating drug discovery and enabling more personalised patient care.

Joerg Schwarz offers his perspective on the way Digital Clinical Quality Measures transform chronic disease care, closing data gaps with real-time insights.

Aarthi Janakiraman and Ruplekha Choudhurie explain how AI reshapes biopharma, streamlines drug discovery, cuts costs and improves precision.

Bragadeesh Sundararajan outlines IoT and AI innovations that reshape health monitoring through real-time insights, personalised care and enhanced preventive measures despite challenges like data security and device accuracy.

Dr. Katarzyna Zarychta shows how AI is transforming global healthcare by enhancing diagnostics, personalised care and operational efficiency, highlighting each region's unique challenges in AI's adoption, regulation and infrastructure.

Prof. Martin Curley advises healthcare leaders to make a shift toward home-based care and guided collaborative ecosystems to reduce healthcare costs, enhance quality of life and address global disparities.

Yuri Vasiliev, Anton Vladzymyrskyy and Kirill Arzamasov emphasise how Moscow's AI-powered healthcare innovations enhance diagnostic accuracy, streamline medical workflows and prioritise preventative care, setting a global standard for effective technology integration in medicine.

Muhammad Mudassar Qureshi discusses recent advancements in AI, smart devices and health apps that enhance personalised healthcare and urban health.

Prof. Immanuel Azaad Moonesar studies how global strategies help enhance the well-being of the healthcare workforce through innovation, cultural integration and emerging technologies.

Dr. Fiona Kiernan reports on econometric models used to evaluate Value-Based Healthcare and Integrated Care Pathways' impact on outcomes and efficiency.

Begoña San José argues that true healthcare disruption requires addressing systemic issues through collaboration, equity and sustainable solutions, moving beyond quick fixes.

We hope you enjoy this issue and find it valuable. As always, we greatly appreciate your feedback.

Happy reading!

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Dr. Harvey Castro, USA

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Prof. Martin Curley, Ireland

Martin Curley is a Professor of Innovation at Maynooth University and Director of the Digital Health Ecosystem at the Innovation Value Institute in Ireland. He was CIO and Director of Digital Transformation for Ireland's HSE and Senior VP at Mastercard. He chaired the EC's Open Innovation Strategy Group, authored eight books and led global education. Awarded Irish Digital Leader (2024), he advances digital health with his «Stay Left, Shift Left-10X» paradigm.

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Everest Group, India

Everest Group is a leading global research firm helping business leaders make confident decisions. The firm provides actionable research into the world's cutting-edge Science & Technology innovations and delivers the tools to identify and understand upcoming innovations across R&D science and technology domains. Everest Group also investigates the enablers to effective innovation, including innovation processes and toolkits and critical mega forces for navigating a changing future.

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Philippe Gerwill, France

Philippe Gerwill is a TEDx speaker and Innovation Key Opinion Leader with over 30 years of experience across Specialty Chemicals, Pharmaceuticals and Biopharmaceuticals. As a top AI voice, he influences global conversations on AI in healthcare, sustainability and the metaverse. He also teaches digital health innovation at the Rome Business School.

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Prof. Dr. med. Mathias Goyen began his career as a diagnostic Radiologist working at Essen and Hamburg/Germany and was appointed Professor of Diagnostic Radiology at the University of Hamburg/Germany in 2010. He is currently the Chief Medical Officer EMEA for GE Healthcare, leading medical, clinical and evidence generation strategies for product modalities in Europe, the Middle East and Africa. Together with his team he provides leadership in healthcare economics and outcomes research and comparative effectiveness research to develop customer value propositions for new and existing products.

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Aarthi Janakiraman, India

Aarthi Janakiraman has more than 15 years of experience in technology research and strategic consulting. She has broad experience identifying and assessing the impact of emerging trends and technologies in the healthcare, F&B and CPG industries. Her expertise lies in opportunity assessment, IP management, R&D landscaping and technology road mapping and innovation ecosystem analysis.

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Dr. Fiona Kiernan, Germany

Fiona Kiernan is the founder and CEO of Zeumed, a health economic advisory company. She holds a medical degree and a PhD in Economics from University College Dublin, as well as a Master's in Health Economics, Policy & Management from LSE. With 16 years in medicine, including seven as a consultant anaesthesiologist, she advises payers, Ministries of Health and life sciences organisations. An experienced board member, she serves on two State Agency boards in the health sector.

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Prof. Dr. Immanuel Azaad Moonesar, R.D., Ph.D., UAE

Immanuel Azaad Moonesar, professor at Mohammed Bin Rashid School of Government in Dubai, is a public health expert specialising in healthcare quality, patient safety and health service delivery. With 255+ publications and $3.875M in grants, his research focuses on improving healthcare systems and outcomes, particularly in emerging economies. He is recognised for his contributions to teaching, research and policy advocacy worldwide.

Transforming Healthcare Excellence Through Strategic Workforce Well-being: A Global Perspective 491

Muhammad Mudassar Qureshi, Pakistan

Muhammad Mudassar Qureshi is a software developer and researcher with 19 years' experience in the field. He authored "IPC: Resource and Network Cost-Aware Distributed Stream Scheduling on Skewed Streams," published in Advanced Engineering Informatics, and "Modelling Distributed Stream Processing Systems under Heavy Workload," presented at the International Conference on Cyberworlds. His research focuses on optimising computing performance and network efficiency in high-demand environments.

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Begoña San José, PhD, is a Clinical psychologist with a PhD in epidemiology, leveraging over 20 years of experience in health insurance and health services. Founder and CEO of Beandgo, a company dedicated to boosting resilience across healthcare by addressing systemic challenges. Passionate about driving innovation and fostering sustainable healthcare solutions.

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How Digital Clinical Quality Measures will Revolutionise Chronic Disease Management 451

Bragadeesh Sundararajan, India

Bragadeesh Sundararajan, Chief Data Science Officer at Dvara KGFS, drives AI and ML solutions to improve financial services for rural households. With 14+ years' experience, he was named one of India's Top 100 AI Influential Leaders in 2023. His achievements include a Generative AI model and a COVID-19 vaccination slot system. He holds degrees in AI/ML from UT Austin, an MBA from IIT Madras, and a bachelor's in Computer Science from BITS Goa, with expertise in analytics and development.

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Ritesh Vajariya, USA

Ritesh Vajariya, Head of Generative AI Strategy at Cerebras Systems, is an AI thought leader with executive experience at AWS, driving global AI adoption through Amazon SageMaker and Bedrock. His work on projects like BloombergGPT and Falcon highlights his expertise in AI innovation. As founder of AI Guru, he has trained over 15,000 professionals in 18 countries, making advanced AI education widely accessible.

Transforming Healthcare Through AI and Generative AI: Opportunities and Challenges 447

Yuri Vasilev, Russia

Yuri Vasilev, PhD, is a senior radiology consultant for the Moscow Healthcare Department and Chairperson of the Subcommittee on AI in Healthcare. He heads the Department of Diagnostic Imaging at the Pirogov National Medical and Surgical Center and serves on the Moscow Regional Board of the Russian Society of Radiology. An author of over 135 publications and 79 patents, he holds degrees from the Military Medical Academy, ITMO University and multiple European radiology institutions.

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Dr. KaT Zarychta, Malta

KaT Zarychta, a Business Development Leader in Biomedical and Medical Devices, has 20+ years of global experience. She holds a PhD from Sorbonne Paris University, dual Master's in Physics and Biomedical Engineering and completed executive programmes at Harvard. An EU Commission Expert Advisor, she specialises in market access, commercialisation and funding, driving sales growth and AI-driven diagnostics adoption across Europe, APAC and the Middle East.

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Spotlight

RaySafe X2: Radiation Safety Redefined

The RaySafe X2 system simplifies radiation safety in diagnostic radiology by offering intuitive, accurate and comprehensive quality assurance testing. It helps ensure optimal equipment performance, reduce unnecessary radiation exposure and streamline calibration processes. Ideal for multi-facility use, it enables enhancements in patient and staff safety while maintaining high diagnostic standards.

CHRISTIAN MAROLT

Executive & Editorial Director I
HealthManagement.org I Limassol, Cyprus

key points

- The RaySafe X2 system's intuitive design simplifies radiation measurement and QA testing.
- The device helps reduce unnecessary radiation exposure while ensuring high diagnostic standards for both patients and staff.
- The system enhances measurement accuracy through automatic sensor detection and configuration.
- Designed for multi-facility use, it requires minimal setup, making it highly efficient.
- RaySafe offers a comprehensive service programme to ensure long-term reliability and safety.

In diagnostic radiology, the safety of patients and staff depends on precise quality assurance (QA) testing of X-ray equipment. Combining advanced technology with user-friendly features, the RaySafe X2 system provides a comprehensive and efficient solution for radiation measurement. By exploring the importance of QA testing, the benefits of the RaySafe X2 system and its application in diagnostic radiology, we can better understand its role in promoting safety and accuracy.

Why QA Testing Matters in Radiology

Quality assurance testing plays a critical role in diagnostic imaging by ensuring that X-ray equipment delivers consistent, high-quality results without unnecessary radiation exposure. Regular inspections ensure that equipment operates within optimal parameters, preventing excessive radiation doses and ensuring consistent image quality. This proactive approach helps minimising patient risk, improving diagnostic reliability and preventing costly equipment failures.

Key aspects of QA testing include monitoring kilovoltage peak, milliampere seconds, half value layer and dose measurements. By verifying these parameters, facilities can uphold high safety standards and ensure accurate diagnostics with minimal radiation exposure.

Features and Benefits of the RaySafe X2 System

The RaySafe X2 system stands out for its ease of use and accuracy in radiation measurements. Designed with a focus on user experience, it features an intuitive touch screen and automatic sensor detection, eliminating complex manual configurations.

Key features include:

- **Intuitive Interface:** the touch screen allows easy navigation and waveform analysis.
- **Orientation-Independent Sensors:** users can place the sensors in any orientation without compromising accuracy.

- **Comprehensive Measurement Capability:** the system supports various applications, including radiography, mammography, fluoroscopy, CT and light measurements.
- **Automatic Data Logging:** measurements are automatically stored and can be easily transferred to a PC for further analysis using RaySafe View software.

The system's precision and simplicity assist in reducing the time required for QA testing while ensuring consistent results. Its portability makes it ideal for professionals working across multiple facilities.

Real-World Application: Unilabs Case Study

Unilabs, a leading European diagnostics provider, has successfully integrated the RaySafe X2 system across its radiology departments in Sweden. Used for annual QA testing across various modalities, the system has enhanced efficiency and ensured compliance with radiation safety standards.

The RaySafe X2's portability and minimal setup requirements make it ideal for physicists working across multiple healthcare sites. Its automatic parameter detection and easy data transfer further contribute to its effectiveness, reducing both testing time and the likelihood of measurement errors.

Calibration and Long-Term Maintenance

The optimal performance of any device requires regular calibration. RaySafe offers a comprehensive service programme to help ensure that instruments remain accurate and compliant with safety regulations. Annual calibration, firmware updates and professional servicing help extend the lifespan of the equipment.

RaySafe's ISO-certified facilities provide expert calibration services to help ensure the equipment consistently meets regulatory standards. Participation in the service programme assists in extending the device's lifespan and reinforcing patient safety and regulatory compliance.

Conclusion

The RaySafe X2 system sets new standards for quality assurance testing by blending advanced technology with an easy-to-use design. Its intuitive operation, accurate measurements and wide range of sensor options make it an excellent choice for healthcare facilities that prioritise radiation safety. Regular QA testing with the RaySafe X2 helps ensuring diagnostic accuracy while safeguarding patients and medical staff from unnecessary radiation exposure.

Conflict of Interest

Point-of-View articles are the sole opinion of the author(s), and they are part of the HealthManagement.org Corporate Engagement or Educational Community Programme.

RaySafe X2

Effortless measurements of X-ray

Less effort. More insight.

Life is busier. There are more demands on your time. The RaySafe X2 X-ray QA measurement system is designed for ultimate user-friendliness with an intuitive interface and minimized need for interaction. The X2 R/F and MAM sensors are orientation independent so the only thing you need to do is to place the sensor in the X-ray beam and turn on the instrument.

Full range measurements

Ease-of-use means you get everything you need in one exposure, with one sensor – automatically. The RaySafe X2 offers sensors for R/F, MAM, CT, Survey and Light applications. Most sensors also measure waveforms that can be analyzed directly on the base unit. It´s a fully scalable system – choose the sensors you need today and add over time.

RaySafe helps you avoid unnecessary radiation. We offer quality assurance devices for X-ray equipment, a real-time dose monitoring system for medical staff as well as radiation safety measurements devices.

www.raysafe.com

RaySafe™

Düsseldorf: A Premier Congress Destination with a Personal Touch

Düsseldorf is a leading congress hub, combining professional excellence with cultural vibrancy. Centrally located in Europe, it offers world-class venues like Messe Düsseldorf, excellent connectivity and a thriving business environment. Rich cultural offerings, diverse accommodations and welcoming charm create a seamless and enriching experience for attendees. It has a unique blend of professional and personal appeal for a resident.

PROF. DR. MATHIAS GOYEN

Global Chief Medical Officer I GE Healthcare I Düsseldorf, Germany

key points

- Düsseldorf boasts a strategic European location with excellent global connectivity.
- Messe Düsseldorf offers state-of-the-art facilities for large-scale congresses.
- The city thrives as a hub for business, innovation and networking opportunities.
- Rich cultural attractions and vibrant nightlife enhance the congress experience.
- Hospitality and compact city layout ensure seamless and personal attendee experiences.

As a radiologist living in Düsseldorf, I have the privilege of calling one of Europe's most vibrant and dynamic cities my home. Nestled along the banks of the Rhine River, Düsseldorf is more than just a city of industry and art; it is a hub for innovation, culture and international events. Over the years, it has cemented its reputation as a top-tier congress destination, offering an unparalleled combination of location, infrastructure and cultural richness. Let me take you on a journey through what makes Düsseldorf a standout choice for hosting congresses, with a sprinkling of my personal experiences to illustrate its unique charm.

Strategic Location and Accessibility

Düsseldorf's geographical position is one of its most substantial assets. It is located in the heart of Europe and easily accessible from all major European cities. Düsseldorf International Airport, one of Germany's largest, offers direct flights to over 200 destinations worldwide. This ease of access is invaluable for international congress attendees, reducing travel fatigue and ensuring seamless connections. I've always appreciated the convenience of having a world-class airport just a short drive from my home, making both professional and leisure travel remarkably straightforward.

State-of-the-Art Infrastructure

The city's infrastructure is tailor-made for large-scale events. The Messe Düsseldorf Exhibition Centre is a world-renowned venue that hosts some of the largest congresses and trade fairs globally, such as the MEDICA, the world's leading trade fair for the medical sector. Its modern facilities are designed to accommodate the specific needs of various industries, providing ample space, cutting-edge technology and comprehensive services. As a radiologist, I've had the opportunity to attend numerous medical congresses at Messe Düsseldorf, each time marvelling at the seamless organisation and the facility's capacity to handle large crowds without a hitch.

A Thriving Business Environment

Düsseldorf is not just a city hosting congresses but a thriving business and innovation hub. It is home to many international companies, especially in telecommunications, advertising and fashion. For the healthcare sector, the city offers a rich environment for networking and collaboration. The presence of leading healthcare companies and a strong community of medical professionals, including specialists like myself, creates a fertile ground for knowledge exchange and partnerships. I often find that the professional opportunities here are as stimulating as the congresses themselves.

Cultural and Recreational Richness

Beyond its professional appeal, Düsseldorf is a city brimming with cultural and recreational activities. The city's art scene is particularly vibrant, with renowned institutions like the Kunstsammlung Nordrhein-Westfalen and the Kunstpalast offering world-class exhibitions. The Altstadt, known as "the longest bar in the world," is a lively district where congress attendees can unwind after a day of sessions. From my experience, a stroll along the Rhine promenade or a visit to the Japanese Quarter, with its authentic cuisine and shops, offers a refreshing break from the hustle and bustle of congress activities.

> "Düsseldorf is more than just a city of industry and art; it is a hub for innovation, culture and international events."

Hospitality and Accommodation

Düsseldorf's hospitality industry is well-equipped to handle the influx of visitors that congresses bring. The city offers many accommodation options, from luxury hotels to budget-friendly stays, ensuring that all attendees find suitable lodging. The level of service and the welcoming nature of the locals add a personal touch that makes every visitor feel at home. As someone who loves to showcase my city to colleagues and friends, I often recommend some of my favourite spots, like the charming boutique hotels in the MedienHafen district, which offer stunning views and a unique atmosphere.

Conclusion

Düsseldorf is more than just a city where congresses are held; it is a city that enriches these events with its unique spirit and vibrancy. Its strategic location, state-of-the-art facilities, thriving business environment, rich cultural scene and exceptional hospitality make it a top choice for congresses of all kinds. As a resident and a radiologist, I can confidently say that Düsseldorf offers the perfect backdrop for professional gatherings and an enriching experience beyond the conference halls. For those who have yet to visit, Düsseldorf awaits, ready to welcome you with open arms and a promise of memorable moments both in and out of the congress setting.

> "Düsseldorf offers the perfect backdrop for professional gatherings and an enriching experience beyond the conference halls."

A City with a Personal Touch

What truly sets Düsseldorf apart as a congress destination is its ability to blend the professional with the personal. The city's compact size means that most venues, hotels and attractions are within easy reach, creating an intimate setting where networking feels natural and effortless. There's something about the city's rhythm that fosters a sense of community among congress participants. Living in Düsseldorf means I get to experience this blend of professional excellence and personal warmth daily, and I am always eager to share it with visitors.

Conflict of Interest

Point-of-View articles are the sole opinion of the author(s), and they are part of the HealthManagement.org Corporate Engagement or Educational Community Programme.

United Imaging's Cutting-Edge Technology Arrives in Germany

United Imaging celebrates its first German installation with the uMI 550 PET/CT at Kliniken Essen-Mitte and Nukmed. Developed with MiE, this cutting-edge technology delivers ultra-high resolution, fast scanning and motion correction. Enhancing oncology diagnostics, the uMI 550 optimises precision and efficiency, supporting better outcomes and expanding access to advanced imaging at top cancer care institutions.

CHRISTIAN MAROLT

Executive & Editorial Director I
HealthManagement.org I Limassol, Cyprus

key points

- United Imaging installs uMI 550 PET/CT in Germany at Kliniken Essen-Mitte and Nukmed.
- uMI 550 offers ultra-high resolution and fast scanning for precision oncology diagnostics.
- Advanced features include motion correction, noise reduction and integrated oncology tools.
- Collaboration with MiE ensures cutting-edge imaging at leading cancer care institutions.
- Each installation improves global access to advanced molecular imaging technology.

Today marks a new chapter for United Imaging with the first installation of our advanced molecular imaging technology in Germany. Thanks to the close collaboration with Medical Imaging Electronics (MiE), a world-renowned company with over forty years of expertise in molecular imaging, the Kliniken Essen-Mitte Evang and the private nuclear medicine clinic Nukmed now have access to the uMI 550, our state-of-the-art digital positron emission tomography/computed tomography (PET/CT).

Delivering Precision Diagnostics at a Premiere Cancer Care Institution

Located in the heart of the Ruhr area, Kliniken Essen-Mitte Evang is a highly respected medical institution in Germany and part of the academic teaching hospital affiliated with the University of Duisburg-Essen. As a tertiary referral centre, it employs approximately 2,500 staff members to care for 1,000 beds spread throughout the numerous specialised departments. In 2018, the hospital was ranked 41st nationally among all 2,000 German hospitals.

Kliniken Essen-Mitte Evang is recognised worldwide for its expertise in oncology. The Hemato-Oncology & Stem Cell Transplantation department performs approximately 70 to 80 stem cell transplants each year. At the same time, the oncology centre, with decades of specialised experience across thirteen clinics, treats thousands of cancer patients annually. To elevate the diagnostic capabilities of its distinguished oncology centre, the hospital has opted for the industry-leading technology from United Imaging.

When Diagnostic Excellence Meets Accessibility

Designed with cutting-edge solutions, the uMI 550 delivers unparalleled imaging quality while remaining remarkably accessible to customers. The advanced Integrated Light-Guide Digital PET detector achieves an impressive 2.9 mm NEMA resolution for exceptionally detailed imaging, while the 80-slice CT system with a Z-Detector ensures high spatial resolution and enhanced low-contrast detectability. Together, these innovations make the uMI 550 a game-changer in molecular imaging.

Discover The Breakthrough Features Reshaping Molecular Imaging

Ultra-High Resolution. The point-spread-function (PSF) iterative reconstruction technique works in perfect harmony with other engineering solutions to obtain an effective spatial resolution of 1.4mm.

Improved Contrast-to-Noise Ratio. Thanks to the precise localisation of annihilation photons, the time of flight (TOF) technology delivers a significant acceleration during the image convergence, improving contrast-to-noise ratio and, thereby, the visualisation of complex pathologies.

Fast Scanning. A large axial field of view (FOV) enables a whole-body scan in 4-bed positions. Offering detailed imaging of multiple anatomical regions in a single session, uMI 550 stands out for its diagnostic efficacy, optimising workflow and allowing more patients to be scanned within the same timeframe.

Automatic Quality Control Workflow. Given that no radioactive source is required for automatic daily quality control (QC), the radiation exposure to the operator is considerably minimised. Moreover, periodic comprehensive QC supports both liquid 18F and solid 68Ge sources with lower storage condition requirements.

> "The uMI 550 delivers unparalleled imaging quality while remaining remarkably accessible to customers."

Integrated Oncology Application. uMI 550 can be fully integrated with a highly comprehensive package for improved tumour diagnosis and post-therapeutic evaluation on the operation console, empowering healthcare professionals to improve the management of oncological patients.

Innovative Head Motion Correction. The state-of-the-art data-driven motion correction technology based on a sophisticated algorithm effortlessly detects motion from list-mode data during patient scans and corrects motion blurring accordingly.

Intelligent Motion Artifact Reduction. Our digital self-gating technology automatically detects respiratory motions, ensuring accurate imaging even during patient movement. Additionally, our Metal Artifact Correction (MAC) technology helps reduce metal artefacts, leading to more reliable results.

Expanding Access to Advanced Imaging Worldwide: One Installation at a Time

Each installation of our technology brings us one step closer to our ultimate goal: improving global access to diagnostics. We are proud to see our solutions embraced by leading treatment institutions, where they contribute to enhancing diagnostic precision and supporting more informed treatment decisions.

"Each installation of our technology brings us one step closer to our ultimate goal: improving global access to diagnostics."

Our sincere gratitude goes to MiE for their invaluable collaboration in making this installation possible.

Experience a new standard of molecular imaging first-hand. Visit our website to learn more about the innovative features of the uMI 550: https://eu.united-imaging.com/en/product-service/products/mi/umi-550

Conflict of Interest

Point-of-View articles are the sole opinion of the author(s), and they are part of the HealthManagement.org Corporate Engagement or Educational Community Programme.

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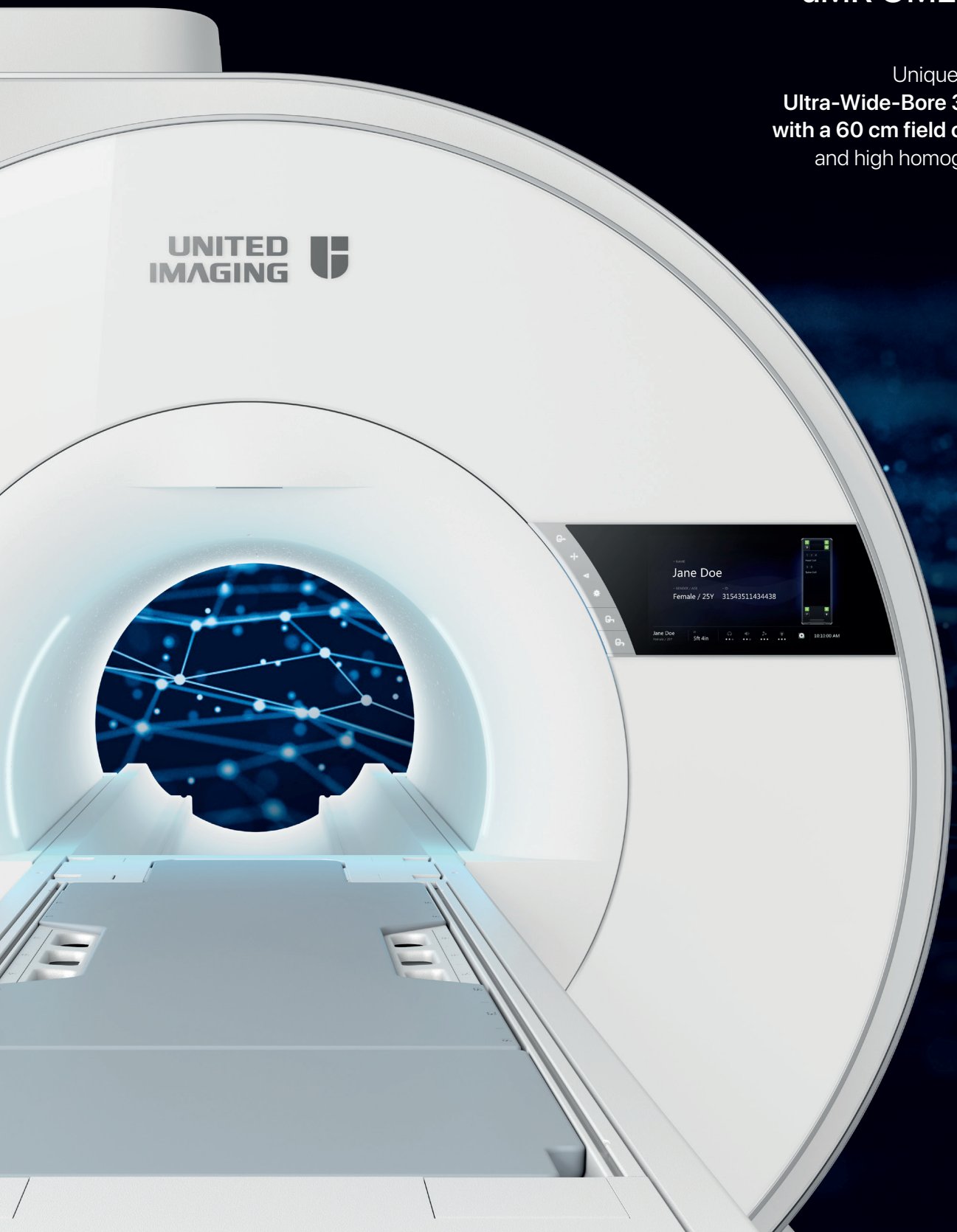
and high homogeneity.



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Cover Story

The Healthcare Metaverse: Innovating for a Future Beyond Limits

The healthcare metaverse blends virtual reality, augmented reality, AI and blockchain to revolutionise healthcare delivery. It enhances accessibility, affordability and personalisation through virtual clinics, AI-powered diagnostics and continuous health monitoring. The metaverse also transforms medical education with VR simulations, supports chronic disease management and enables global collaboration. Ethical data use and regulatory frameworks remain critical for its sustainable growth.

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key points

- Virtual clinics and AI tools improve healthcare accessibility in remote and underserved areas.
- Wearable IoT devices enable continuous health monitoring for better chronic disease management.
- VR simulations provide immersive, risk-free environments for advanced medical training.
- The metaverse fosters global collaboration, connecting experts for shared education and research.
- AI-driven insights leverage health data to personalise treatment and enable early interventions.

In today's fast-paced tech world, healthcare is gearing up for a major overhaul with the rise of the healthcare metaverse. This blend of virtual reality (VR), augmented reality (AR), artificial intelligence (AI), blockchain and other cutting-edge technologies is more than just a digital trend—it's a game-changer, offering fresh ways to deliver, access and experience healthcare. Unlike traditional improvements that tweak existing practices, the healthcare metaverse is shaking things up, creating a whole new world of care.

Putting Patients First

At its heart, the healthcare metaverse is all about the patient. It aims to make healthcare more accessible, affordable and personalised. Picture a patient in a remote village having a consultation with a specialist in a bustling city through a shared virtual clinic. This isn't just a video call; it's an immersive experience where the patient's avatar interacts with the doctor in a detailed, simulated environment. Plus, these virtual clinics come with AI-powered diagnostic tools for accurate, instant feedback.

Bridging the Gap

One of the metaverse's strongest points is its ability to bridge geographical and socioeconomic divides. Rural areas often lack advanced medical facilities, and the healthcare metaverse can fill this gap. Virtual clinics, equipped with AI diagnostic tools and supported by local health workers, can be the first point of contact for patients. For example, a rural health worker might collect vital signs and upload them to the virtual platform, where

AI analyses the data and connects the patient with a specialist. This model ensures timely care and reduces the burden on urban healthcare facilities.

AI-driven language translation tools make the metaverse even more inclusive. Patients and providers speaking different languages can communicate easily, breaking down linguistic barriers that have traditionally hindered global healthcare access. This could mean a patient in Latin America consulting with a Japanese cardiologist without any communication issues, all thanks to the metaverse.

> "The healthcare metaverse is all about the patient. It aims to make healthcare more accessible, affordable and personalised."

Managing Chronic Diseases Better

The metaverse is also a lifeline for patients with chronic diseases. Wearable IoT devices integrated into the metaverse ecosystem provide continuous health monitoring. These devices track real-time metrics like blood glucose levels, heart rates and blood pressure, feeding data into AI systems that analyse trends and predict complications before they happen. For instance, a patient with hypertension can get an alert about irregular patterns and schedule a virtual consultation to adjust their treatment plan—all from home.

Predictive analytics powered by AI is transforming chronic disease management. By identifying risk factors early, these tools enable timely interventions, potentially preventing hospitalisations. This proactive approach improves patient outcomes and reduces healthcare costs, benefiting both individuals and the healthcare system.

Revolutionising Medical Education and Training

The metaverse isn't just about patient care; it's also revolutionising medical education and professional training. Traditional methods, like using cadavers or limited simulations, are being replaced by immersive VR environments that mimic real-world complexities.

Learning Complex Procedures in VR

Medical students can practice surgical techniques in a virtual operating room where mistakes don't have life-threatening consequences. For example, a student performing a delicate neurosurgical procedure in VR can get real-time feedback on precision, technique and efficiency. AI algorithms analyse their movements and provide suggestions for improvement, ensuring they are well-prepared for real-life operations.

VR simulations can also replicate rare and complex scenarios that many medical professionals might encounter only a few times in their careers. These include intricate organ transplants, trauma surgeries or managing large-scale health crises like pandemics. Practising these scenarios in a controlled environment prepares healthcare workers to act swiftly and effectively in real-life emergencies.

Global Collaboration in Education

The healthcare metaverse fosters global collaboration in ways never seen before. Imagine a group of students from different countries attending a shared virtual lecture on cardiac surgery, where they can interact with the instructor and peers in real time. Beyond lectures, interdisciplinary teams can meet in virtual spaces to discuss patient cases, using AI to analyse data and simulate treatment outcomes. This level of collaboration ensures that medical education is not limited by borders, creating a truly global learning environment.

Ongoing education and professional development also benefit greatly. Specialists can attend international conferences or participate in live-streamed surgeries in the metaverse, staying updated on the latest advancements without the need for travel. This reduces time, costs and the carbon footprint associated with traditional professional gatherings.

The metaverse also enables virtual mentorship programmes. Senior professionals can guide and train young doctors or researchers remotely, bridging the gap between expertise and practice. This model ensures the transfer of knowledge and skills in an interactive and impactful manner.

Engaging the Younger Generation with Gamification

The metaverse's integration into healthcare aligns naturally with the younger generation, who are deeply entrenched in the gaming industry and digital culture. Growing up with immersive technologies, this generation is accustomed to gamification—a trend that transforms learning and interaction into engaging, interactive experiences.

Gamification as a Learning Tool

Young people have been using games to learn complex skills for years, from solving puzzles to mastering strategy and collaboration. In the healthcare metaverse, this approach can be leveraged for medical education and patient engagement. For example, medical students might participate in gamified surgical simulations where they earn points for precision and efficiency. These simulations could incorporate challenges that mimic real-life scenarios, encouraging critical thinking and quick decision-making.

Patients also benefit from gamification. Young individuals managing chronic illnesses like diabetes might use gamified platforms to track their glucose levels, earn rewards for meeting health goals and even compete in friendly challenges with peers. By making health management engaging, these tools increase adherence to treatment plans and improve outcomes.

Engaging Digital Natives in Preventive Care

The younger generation's familiarity with digital environments makes them ideal candidates for preventive care initiatives in the metaverse. Virtual wellness programmes can gamify activities like exercise, diet planning and mental health practices. Imagine a VR fitness programme that transports users to a virtual mountain trail or tropical beach, making exercise both enjoyable and immersive. These programmes can be tailored to individual needs, ensuring that participants stay motivated and achieve their health goals.

Immersive Career Preparation

For younger professionals entering the healthcare field, the metaverse offers unparalleled opportunities for immersive career preparation. Gamified training modules can simulate high-pressure situations, such as responding to a cardiac arrest or managing a multi-casualty incident. Trainees earn rewards for demonstrating competence, which fosters a sense of achievement while honing critical skills.

Beyond education, these environments foster collaboration. Young professionals from diverse backgrounds can join virtual research projects or case discussions, learning to navigate interdisciplinary teamwork. These interactions prepare them for the increasingly collaborative nature of modern healthcare.

> "Virtual clinics, equipped with AI diagnostic tools and supported by local health workers, can be the first point of contact for patients."

The Vast Data Potential of the Healthcare Metaverse

One of the most transformative aspects of the healthcare metaverse is the vast amount of data it generates. From patient health records to real-time metrics captured by IoT devices, the metaverse acts as a central hub for health-related data, creating unprecedented opportunities for AI-driven insights and personalised care.

AI-Driven Insights for Enhanced Healthcare

AI thrives on data, and the healthcare metaverse provides an abundance of it. With access to detailed patient histories, real-time health metrics and environmental factors, AI algorithms can uncover patterns that were previously invisible. For instance, predictive analytics can identify individuals at risk of developing chronic diseases based on subtle health trends, enabling early interventions that save lives and reduce costs.

Beyond individual care, this wealth of data can inform public health initiatives. Epidemiologists can use AI to track disease outbreaks in real time, model their spread and implement containment strategies. In a metaverse-driven healthcare ecosystem, data becomes a powerful tool for proactive, large-scale health management.

Personalised Care Through Data Integration

Personalised medicine reaches new heights in the healthcare metaverse. By integrating genomic data, lifestyle habits and real-time health metrics, AI can craft highly individualised treatment plans. Imagine a cancer patient whose therapy is tailored not only to their genetic profile but also to how their body responds to treatment in real time. The metaverse enables continuous monitoring and adjustments, ensuring optimal outcomes.

Patients also gain greater control over their health data. Blockchain technology ensures that individuals own their data and can decide who accesses it and how it is used. This transparency fosters trust while empowering patients to participate actively in their care.

Ethical Data Usage

The sheer volume of data in the metaverse necessitates robust ethical frameworks. Ensuring data privacy and preventing misuse are paramount. Stakeholders must collaborate to establish guidelines for data collection, storage and analysis, balancing innovation with individual rights. Transparency in AI decision-making processes is equally essential to maintain trust in this data-driven ecosystem.

Enhanced Patient Engagement and Personalised Care

A significant disruption introduced by the healthcare metaverse is the shift from reactive to proactive and personalised care. By integrating AI, blockchain and wearable technologies, the metaverse enables real-time health monitoring and tailored treatment plans.

Virtual Assistants and Personalised Health Guides

AI-powered virtual assistants play a pivotal role in this ecosystem. Acting as personal health guides, these assistants provide medication reminders, interpret lab results and even suggest lifestyle changes. For example, a diabetic patient might have an AI assistant that tracks their glucose levels, suggests meal plans and provides immediate feedback on health metrics. These assistants ensure continuous care, reducing the risk of complications and improving patient outcomes.

Immersive Therapeutic Environments

Therapy within the metaverse is another game-changer. VR-based rehabilitation programmes are designed for patients recovering from injuries or surgeries. A patient recovering from a knee replacement might engage in VR exercises that simulate real-world activities like climbing stairs or walking through a park. AI tracks their performance, providing real-time adjustments to the programme to ensure optimal recovery. Similarly, virtual mental health clinics offer therapy sessions in calming environments, such as a serene forest or tranquil ocean, enhancing treatment efficacy.

Mental health, often stigmatised, finds a unique ally in the metaverse. Patients can attend virtual support groups or cognitive-behavioural therapy sessions anonymously, ensuring privacy while receiving necessary care. These virtual environments also make it easier to engage children and adolescents, who might respond better to interactive and game-like settings.

Moreover, the metaverse facilitates group therapy sessions, where individuals with shared conditions can connect, offering a sense of community and mutual support. This collective approach can be particularly impactful for patients with rare diseases or chronic mental health issues.

Clinical Trials and Research Innovation

The metaverse offers unparalleled opportunities for clinical trials and research, significantly reducing costs and timeframes while increasing participant diversity.

Virtual Clinical Trials

Traditional clinical trials are often constrained by geographical limitations and participant availability. Virtual trials in the metaverse address these issues by allowing participants from around the globe to join without leaving their homes. AI analyses participant data, ensuring that trials are representative and inclusive. For instance, a trial for a new cancer drug can include patients from diverse demographics, offering insights into its efficacy across different populations.

These trials also accelerate the process by using digital twins of participants. A digital twin—a virtual replica of a patient—can simulate how a drug interacts with the body in real time, identifying potential side effects or optimal dosages faster than traditional methods.

Simulated Research Environments

Researchers can also benefit from the metaverse through simulated environments. Virtual laboratories allow scientists to test hypotheses and observe outcomes in controlled, risk-free settings. These simulations accelerate the pace of discovery, enabling rapid prototyping and testing of new drugs or medical devices.

Moreover, interdisciplinary research can flourish in the metaverse. For example, geneticists, epidemiologists and AI experts can collaboratively study genetic markers for diseases in a shared virtual lab, combining their expertise to uncover groundbreaking insights.

Simulations can also help researchers understand the long-term effects of treatments by modelling their impact over the years in a condensed timeline. This capability enhances precision medicine and accelerates breakthroughs.

Ethical and Regulatory Challenges

While the healthcare metaverse holds immense promise, it also introduces significant ethical and regulatory challenges. Ensuring data privacy, addressing AI biases and establishing robust regulatory frameworks are critical to its success.

Data Privacy and Security. The integration of blockchain technology provides a secure framework for managing sensitive health data. Patient records are stored as encrypted blocks, accessible only with explicit consent. This not only safeguards privacy but also fosters trust in the system. However, continuous audits and updates are necessary to counter evolving cybersecurity threats.

Bias in AI Algorithms. AI-driven tools must be trained on diverse datasets to avoid biases that could lead to disparities in care. Regulatory bodies must establish standards for AI development and deployment, ensuring that these technologies are inclusive and equitable.

Global Regulatory Collaboration. The metaverse operates beyond national boundaries, necessitating global cooperation on regulatory frameworks. Harmonised standards are essential to ensure safety, efficacy and ethical practices in this digital ecosystem.

Addressing the Digital Divide. Access to the healthcare metaverse must be equitable. Infrastructure investments and subsidies may be necessary to ensure that underserved regions are not excluded. This inclusivity is vital for the metaverse to fulfil its potential as a global healthcare solution.

Future Horizons: The Path Forward

As the healthcare metaverse evolves, its potential applications will only expand. Innovations such as

digital twins—virtual replicas of patients—could allow for precise simulations of treatment plans, ensuring optimal outcomes. Predictive analytics powered by AI will enable early detection of diseases, shifting the focus from treatment to prevention.

Empowering Underserved Communities. One of the most significant impacts of the metaverse could be its ability to empower underserved communities. By reducing the need for physical infrastructure, virtual healthcare can bring advanced medical services to remote and resource-limited regions. This democratisation of care has the potential to transform global health outcomes.

Interdisciplinary Collaboration for Holistic Care. The metaverse also encourages interdisciplinary collaboration, integrating inputs from medical professionals, technologists and policymakers. This holistic approach ensures that the ecosystem remains patient-focused while leveraging technological advancements.

Health Economics and Cost Efficiency. Virtual healthcare systems reduce overhead costs for providers by minimising the need for physical facilities and resources. Patients save on travel and accommodation expenses for specialised care. Over time, the economic benefits could lead to lower healthcare costs and broader accessibility.

Conclusion

The healthcare metaverse represents a disruptive yet profoundly promising shift in modern medicine. By harnessing the power of immersive technologies, AI and global collaboration, it offers a vision of healthcare that is more accessible, personalised and efficient. However, realising this vision requires addressing ethical challenges, establishing robust regulatory frameworks and ensuring inclusivity.

As we stand on the cusp of this digital revolution, it is essential to engage in collaborative dialogue, embracing the potential of the healthcare metaverse to create a future where healthcare is not just a service but an equitable, transformative experience for all. By reimagining the boundaries of possibility, the healthcare metaverse stands poised to redefine medicine for generations to come.

Conflict of Interest

None

ACCELERATE
TIME-TO-RECOGNITION
REVEAL SEPSIS BEFORE IT STRIKES

PSP EMPOWERS CAREGIVERS TO TRIGGER EARLIER SEPSIS BUNDLES,
INCREASING THE ODDS OF PATIENT **SURVIVAL**

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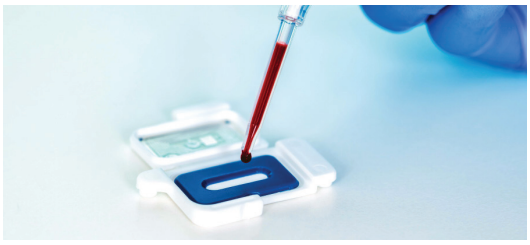

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The Transformative Role of VR and AR in Healthcare: Present and Future

VR and AR are transforming healthcare by enhancing medical training, patient care and public health. These technologies improve surgical precision, pain management and mental health therapy through immersive, tailored experiences. They also expand access to remote care and innovative training. While challenges like cost, privacy and adoption barriers persist, haptic feedback and AI advancements promise greater realism and accessibility, paving the way for a more inclusive healthcare future.

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key points

- VR and AR enhance medical training with risk-free, realistic simulations for improved skills.
- Immersive technologies aid pain management and reduce opioid reliance with tailored therapies.
- Mental health treatment benefits from VR-based controlled exposure and real-time customisation.
- AR improves surgical precision by overlaying real-time data and imaging in the surgeon's view.
- Challenges include cost, privacy and access; AI and haptic advances promise broader adoption.

Introduction: The Evolving Landscape of Immersive Technologies

Virtual Reality (VR) and Augmented Reality (AR) are not merely futuristic gimmicks; they have moved beyond gaming and entertainment to become powerful tools in healthcare. These immersive platforms foster innovation in medical training, patient care and clinical research. At their core, VR and AR offer an "experience-first" approach: instead of learning or healing through static texts or passive observation, individuals can engage with fully or partially simulated environments that elicit a deeper level of cognitive and emotional involvement.

For healthcare professionals, VR and AR promise to address some of the industry's long-standing challenges. Medical errors, for instance, often stem from incomplete information or limited exposure to certain clinical scenarios. By simulating a wide variety of experiences—from rare surgical procedures to common but tricky diagnoses, VR and AR can sharpen clinical acumen without risking patient safety. Patients, on the other hand, benefit from immersive therapies that reduce pain, alleviate anxiety or facilitate rehabilitation through interactive exercises.

The Current Applications of VR and AR in Healthcare

Pain Management

Pain is not just a physical sensation but is intrinsically tied to psychological and emotional factors. VR systems

harness the "attentional shift" concept to reduce patients' pain perception. A well-known example is the "Snow World" VR game developed at the University of Washington for burn patients. Users engage in a snowy landscape in this environment, throwing virtual snowballs at penguins and snowmen. Research has shown that such immersive play distracts burn patients from the intense pain of wound care, resulting in lower reported pain levels and reduced reliance on opioid analgesics.

Clinical evidence supports the effectiveness of VR in pain management. A study published in Pain (Hoffman et al. 2011) indicated that burn patients undergoing wound dressing changes while using VR reported up to a 50% reduction in pain intensity compared to those receiving standard care. Another research in JMIR Mental Health (Li et al. 2021) highlighted VR's broader potential, showing its ability to alleviate chronic pain in conditions like fibromyalgia and complex regional pain syndrome. This underscores VR's versatility as a complementary tool for pain management.

Mental Health Treatment

Traditional psychotherapy can be effective for conditions like post-traumatic stress disorder (PTSD), phobias and generalised anxiety, but often relies on imagination or verbal descriptions. VR revolutionises this approach by enabling controlled, graded exposure therapy in a digitally simulated environment. For instance, the "Bravemind" system, developed at the University of Southern California's Institute for Creative Technologies, helps veterans with PTSD by immersing them in virtual war-zone scenarios. In order to help patients gradually reprocess traumatic memories in a safe setting, therapists can adjust specific triggers, such as sounds and visuals. Similarly, phobias like fear of flying or heights can be addressed through carefully designed scenarios, allowing patients to confront their fears incrementally while receiving real-time therapeutic support.

VR environments can be customised to address each patient's specific triggers, enabling more precise therapy. During sessions, physiological measurements such as heart rate and skin conductance can be monitored, allowing for real-time feedback and adjustments to the treatment. Additionally, at-home VR setups provide an alternative for patients who face challenges travelling to specialised therapy centres. However, this emerging area requires careful supervision and the implementation of robust data security protocols.

Medical Training and Education

Medical education faces the challenge of providing realistic, risk-free settings for students and residents to practice. Cadavers, while invaluable, do not simulate living tissues or dynamic physiology. VR can fill this gap through interactive, high-fidelity simulations. Surgical trainees can rehearse procedures multiple times—whether it's a standard laparoscopic appendectomy or a complex neurosurgical approach—without putting patients at risk.

On the other hand, AR can overlay 3D models of organs or vascular structures onto a patient's body or a mannequin, allowing learners to "see" beneath the skin. This feature can be especially beneficial for ultrasound training, where AR guidance can highlight organ boundaries and assist novices in interpreting ultrasound images more accurately. It is also invaluable for practising emergency procedures like intubation, central line placement or trauma resuscitation protocols. As a result, it accelerates skill acquisition and reduces errors during novices' transition to real-world care.

Platforms like Osso VR and ImmersiveTouch exemplify how immersive technologies enhance medical training. Osso VR provides gamified, interactive modules for surgical trainees, allowing them to practice orthopaedic procedures and bridge the gap between theory and real-world application. ImmersiveTouch, a VR-based system, focuses on craniomaxillofacial and neurosurgery training, providing tactile feedback for a more realistic feel.

Surgical Assistance

High-stakes surgeries—such as neurosurgery, cardiac surgery or transplant operations—depend on pinpoint accuracy and a comprehensive understanding of a patient's anatomy. AR can project CT or MRI data onto a surgeon's field of view in real time, highlighting critical structures like tumours, blood vessels or nerves. Instead of consulting separate screens or memorising 2D images, surgeons have contextual information overlaid directly in their line of sight.

AR enhances operative precision by providing instant visual feedback, allowing surgeons to spend less time correlating imaging findings and potentially reducing overall operating room (OR) usage and anaesthesia time. It also helps minimise complications by visualising hidden structures, reducing the risk of accidental incisions into critical tissues. In neurosurgery, for instance, AR can highlight functional areas such as speech or motor cortex, helping to prevent post-operative deficits.

Patient Rehabilitation and Assessment

Traditional rehab often involves repetitive tasks that can be monotonous, leading to lower patient adherence. VR-based rehabilitation tools transform these exercises into interactive, game-like experiences. Stroke patients might practice picking up virtual objects that simulate everyday tasks (e.g., grasping a coffee mug) and receiving immediate feedback on accuracy and speed. This real-time feedback loop keeps patients motivated and engaged, ultimately improving outcomes.

The digital nature of VR and AR enables clinicians to quantitatively track motion metrics—like range of motion, balance and reaction times. By analysing these data points, therapists can personalise exercise regimens, focusing on areas of greatest need. This evidence-based approach fosters more targeted and efficient therapy programmes.

Increased accessibility is provided by telemedicine. Telehealth systems powered by AR provide remote clinics with real-time guidance from specialists, extending advanced care to underserved areas. Similarly, home-based VR programmes deliver mental health and rehabilitation therapies through consumer-grade headsets, expanding patient reach.

Personalised patient experience is made possible with customisable environments, where tailored VR modules or AR overlays address specific conditions, improving patients' engagement and satisfaction.

Limitations of VR & AR

High costs of headsets, specialised software and supporting infrastructure can be prohibitive for smaller practices. Additionally, rapid technological advancements result in frequent maintenance and upgrades, making hardware and software quickly outdated.

> "Individuals can engage with fully or partially simulated environments that elicit a deeper level of cognitive and emotional involvement."

Benefits and Limitations of VR and AR in Healthcare

Benefits of VR & AR

Improved clinical outcomes are achieved through enhanced precision and faster recovery. Surgeons equipped with AR overlays can make more informed incisions, reducing the margin of error. At the same time, VR-assisted rehab exercises improve compliance and speed the return to normal function.

Innovative training environments: high-fidelity simulations allow repeated practice in a zero-risk environment. VR platforms also facilitate remote collaboration, connecting trainees and experts globally to democratise access to specialised skill sets.

Reduced reliance on opioids: by providing effective pain distraction techniques, VR diverts patient's attention from pain and potentially curtails the use of prescription opioids, thereby minimising the associated risk of addiction.

Technical constraints: issues like latency and low-resolution imaging can lead to cybersickness and reduce the accuracy required for surgical or therapeutic applications. Furthermore, high-speed internet is often essential for smooth operation, limiting the feasibility of VR and AR in rural areas with poor connectivity.

Ethical and privacy concerns: immersive systems may collect sensitive physiological metrics, raising concerns about their potential breaches. Patients must also be fully aware of what data is collected and how it will be used, ensuring proper consent.

Regulatory hurdles: current healthcare regulations, such as those set by the FDA, lack clear guidelines for immersive medical devices. This, coupled with lengthy clinical trials and certification processes, can delay the adoption of innovative solutions.

User resistance and learning curve also hinder broader acceptance. Some healthcare providers are cautious or sceptical of new technologies that lack robust evidence, while frontline staff need formal instruction to operate VR/AR systems effectively and safely.

The Future of VR and AR in Healthcare

Enhanced Realism and Haptic Feedback

Haptic technology replicates the sense of touch through force feedback, vibration or even temperature simulations. Surgical trainees can feel the difference between healthy versus diseased tissue in a virtual environment, a leap forward in realism compared to purely visual simulations. As haptic suits and gloves mature, rehab programmes could become even more immersive, helping patients with sensory deficits relearn how various textures and resistances feel.

Future VR platforms may integrate machine learning (ML) algorithms to simulate soft-tissue movement in real-time, enabling users to watch how organs shift as they "move" the virtual patient. This can dramatically improve the fidelity of practice scenarios for procedures like laparoscopic cholecystectomy or partial nephrectomy, where manipulation of surrounding tissues is critical.

Deeper AI Integration

AI-enhanced VR platforms could monitor physiological data such as heart rate variability, eye tracking and muscle tension during sessions. Machine learning models would detect signs of stress or fatigue, automatically adjusting the difficulty or pacing of tasks. For instance, a stroke patient practising VR-based motor exercises might receive simpler tasks when fatigued, ensuring continuous but not overwhelming challenges.

Combining AI with AR in the operating room opens new dimensions for precision medicine. As surgeons visualise a patient's anatomy, AI algorithms could highlight suspicious tissue or inform them of potential complications based on preloaded patient data—surgical history, genomic insights or lab values. This integration may significantly reduce misdiagnoses and improve patient outcomes.

Wearable AR Devices

The next wave of wearable devices—such as Apple's evolving Vision Pro platform or Meta's Orion AR glasses—seeks to reduce the bulk and visual obstruction associated with older headsets. The goal is to make AR as natural as wearing a pair of eyeglasses while seamlessly delivering real-time overlays of patient data, drug interactions or surgical checklists.

For patients with conditions like diabetes or heart failure, AR glasses could display relevant health metrics (e.g., blood glucose levels, ECG readings) in their peripheral vision, nudging them to stay on top of their care. Over time, these unobtrusive notifications could improve adherence to treatment plans, preventing complications and hospital readmissions.

> "Customisable VR environments enable more precise therapy, addressing each patient's specific triggers."

Expanded Use Cases

Telemedicine 2.0. Current telemedicine solutions rely heavily on 2D video calls. AR can add an extra dimension—allowing remote specialists to annotate live video feeds, highlight a patient's anatomy or guide a local practitioner's hand movements. This transforms teleconsultations into interactive, hands-on experiences, ideal for rural or conflict-zone medical support.

Preventive Public Health. Immersive simulations could be harnessed to teach communities about infectious disease spread, vaccination benefits or dietary recommendations. Students might "walk through" a simulated virus transmission scenario in a classroom, providing a visceral understanding that fosters better compliance with public health guidelines.

Economies of Scale

As VR/AR hardware and software become mainstream, production costs should drop, making the technology more accessible. We may see philanthropic organisations or public-private partnerships subsidise devices for low-resource settings, bringing advanced telerehabilitation and training tools to clinics lacking specialised personnel.

Wider adoption of immersive technologies often depends on insurance companies recognising their therapeutic value. Successful pilot studies and positive clinical trial results may lead to more reimbursement options, encouraging healthcare facilities to invest in VR/AR solutions without worrying excessively about financial sustainability.

Ethical and Social Considerations

Data Privacy and Security

VR/AR platforms can collect data from eye-tracking to biometric sensors measuring skin conductance. This trove of information is potentially vulnerable to hacks or unauthorised usage. Therefore, healthcare providers must employ robust encryption standards, secure cloud storage and regular audits to ensure compliance with HIPAA, GDPR and other region-specific mandates.

Moreover, patients should be fully aware of the nature of data collection: what is being recorded, why and for how long. Transparent communication helps build trust. Clear disclaimers and consent forms—explaining the potential risks and the protections in place—are essential for ethically deploying these technologies.

Equity of Access

High-end VR/AR setups remain cost-intensive, and rural or underfunded healthcare systems often lag behind well-resourced urban centres. If not addressed, this gap could exacerbate existing health disparities. Policymakers, non-profits and industry stakeholders can collaborate on pilot programmes or grants that help resource-limited areas benefit from immersive solutions.

Just as cultural competence in healthcare is crucial, VR/AR platforms should reflect diverse patient populations, considering skin tones, body types and cultural contexts. Realism and relevance in virtual environments can significantly influence therapy outcomes for mental health treatments.

Human Interaction, Empathy and Psychological Impact

Healthcare is inherently human-centric. While immersive technologies can enhance diagnosis, surgical precision and therapy outcomes, they should complement face-to-face interactions, not substitute them. The empathetic bond between patients and providers remains crucial for healing.

While VR can be profoundly therapeutic, some individuals (e.g., those with psychotic disorders) may experience heightened confusion or distress in immersive environments. Clinicians must balance benefits and risks while screening patients for suitability and continuously monitor their psychological well-being.

Potential Overuse

Like any digital technology, VR can be addictive if misused. Patients or users who turn to VR for escapism might neglect face-to-face social interactions or real-world responsibilities. Setting session limits and ensuring clinical oversight where needed can mitigate these risks.

At the same time, over-reliance on AR overlays or AI suggestions might erode clinicians' ability to make independent judgments. Balancing digital tools with the continuous cultivation of clinical reasoning skills is vital to preserving the art of medicine.

From Headsets to Glasses: The Ongoing Evolution

Form Factor Revolution

One major barrier to mainstream VR/AR adoption has been the cumbersome design of first-generation headsets. The industry is moving toward more compact and ergonomic "smart glasses" that blend into daily routines. Meta's Orion AR glasses and anticipated successors to Apple Vision Pro exemplify this trend, offering portability, comfort and intuitive controls.

This evolution makes possible everyday medical applications of VR and AR technologies. Physicians could discreetly consult patient data in outpatient settings through AR glasses without stepping away from the bedside. Radiologists might overlay MRI or CT scan slices onto a real anatomical model, offering quick cross-referencing. Physical therapists could wear AR glasses to track patients' form during exercises, providing instant corrections.

> "AR can project CT or MRI data onto a surgeon's field of view in real time, highlighting critical structures like tumours, blood vessels or nerves."

Integration with Health Ecosystems

Future AR devices may integrate directly with EHR platforms, automatically pulling vital data and updating

treatment notes through voice commands or gestures. This seamless flow of information can reduce administrative burdens and free up more time for patient care.

Smartwatches, fitness trackers and blood glucose sensors generate continuous data streams. AR glasses could show real-time vitals—pulse, oxygen saturation or blood sugar—making it easier for patients and clinicians to spot deviations and intervene early.

The Road Ahead: Opportunities and Challenges

Democratising Access

Immersive technology can revolutionise remote healthcare. Imagine a scenario where a rural clinic lacking a surgical specialist is supported by an AR-equipped surgeon in a metropolitan hospital—real-time step-by-step instructions could save lives. Non-governmental organisations (NGOs) and government agencies may invest in placing VR/AR units in remote outposts to bolster telehealth and training services.

Public-private partnerships may accelerate the adoption of VR/AR across lower-income regions. Grants could help supply hardware while local universities or hospitals train staff. Coupling these efforts with robust internet infrastructure and data security measures is essential for sustainability.

Advancing Research

While numerous pilot studies suggest significant benefits, VR/AR must undergo large-scale randomised controlled trials (RCTs) to gather strong evidence on efficacy, safety and cost-effectiveness. Research should cover diverse populations and conditions, from paediatric to geriatric use cases.

Continual data collection from VR/AR interventions can feed into algorithmic refinements. Over time, artificial intelligence could identify the most effective parameters for certain procedures or therapies, iteratively improving outcomes.

Transforming Public Health and Education

Communities could “step inside” a VR simulation of viral transmission, seeing first-hand how infections spread when social distancing or hygiene measures lapse. This experiential learning can motivate more robust compliance with public health guidelines.

AR and VR modules can educate children about health topics, such as nutrition or mental well-being, in engaging and memorable ways. Early familiarity with immersive tech might also reduce future resistance to such tools in clinical settings.

Personalising Preventive Care

Smart AR glasses might display gentle prompts to take a break from the screen, drink water or stand up for a stretch if they detect prolonged sedentary behaviour. These mini "nudges" encourage healthier habits before problems escalate.

As precision medicine incorporates genetic risk factors, AR/VR experiences might show how certain lifestyle modifications could mitigate inherited risks. Personalised simulations could illustrate, for example, how an individual's lung function improves with smoking cessation based on their specific genetic predispositions.

Conclusion: Charting a New Course for Healthcare

VR and AR are reshaping the contours of modern healthcare—offering immersive solutions that elevate patient care, refine medical training and push the boundaries of what is achievable in public health and rehabilitation. From immersive pain distraction therapies and advanced surgical guidance to AI-powered personalised care, these technologies represent a monumental shift toward experience-driven medicine.

However, their implementation is not without challenges. High costs, lack of standardisation, data security issues and potential for user overreliance or misuse remain real concerns. The key to realising the full potential of VR and AR lies in a multi-stakeholder approach: clinicians must champion quality-of-care improvements, tech developers must create user-friendly and secure platforms, regulators must craft informed but flexible guidelines and policymakers must ensure equitable distribution of these cutting-edge tools.

Ultimately, the goal is not to replace human interaction but to augment it—enabling healthcare providers to deliver more empathetic, accurate and personalised care. As headsets evolve into lightweight glasses and AI algorithms grow smarter, the line between virtual and physical care will blur, ushering in an era where medical interventions are more proactive, immersive and inclusive.

The promise is significant: a future where the burdens of geography, cost or even certain physical limitations no longer restrict access to high-quality healthcare. If thoughtfully developed and equitably deployed, VR and AR technologies can help build a more efficient, patient-centred system where healing is both a scientific endeavour and a deeply human experience.

Conflict of Interest

None

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Transforming Healthcare Through AI and Generative AI: Opportunities and Challenges

AI and generative AI are transforming healthcare by improving clinical documentation, diagnostics, drug discovery and personalised treatment. These technologies enhance efficiency, reduce costs and address clinician burnout while accelerating medical research. Despite their potential, challenges like data privacy, cybersecurity risks and reliability issues remain. Careful implementation, human oversight and strong data governance are essential to maximise benefits while ensuring patient safety and regulatory compliance.

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key points

- AI reduces clinician workload by automating documentation, saving up to three hours daily.
- It improves accuracy in imaging and disease detection, enhancing medical diagnostics.
- With AI, drug discovery can be accelerated, cutting development time from years to months.
- Predicting treatment effectiveness with AI improves personalised care.
- AI adoption requires strong governance to address data privacy and cybersecurity risks.

The healthcare industry is at a crucial turning point as artificial intelligence and generative AI technologies transform the delivery, documentation and advancement of care. Healthcare systems around the world are facing significant challenges, such as ageing populations, rising costs and clinician burnout. In this context, AI technologies present promising solutions to some of the most pressing issues in healthcare.

Recent estimates suggest that generative AI could unlock nearly €970 billion ($1 trillion) in potential improvements within the sector, fundamentally changing areas ranging from clinical documentation to drug discovery. Market forecasts indicate that enterprise spending on AI and generative AI solutions is expected to grow substantially through 2028, highlighting the technology's increasing importance in the transformation of healthcare.

Key Applications Revolutionising Healthcare

The impact of AI and generative AI in healthcare spans multiple domains, with several key applications already showing significant promise. One notable area is clinical documentation, where AI-powered tools are dramatically reducing the administrative burden on healthcare providers. For instance, ambient AI scribes can automatically generate clinical notes from conversations between patients and physicians, potentially saving doctors up to three hours a day on documentation tasks. The Permanente Medical Group recently reported that their AI documentation tool was used in over 300,000 patient interactions. Remarkably, 81% of patients noted that their physicians spent more time making eye contact rather than looking at computer screens.

In medical diagnosis and imaging, AI systems are demonstrating impressive capabilities. Recent breakthroughs by Mayo Clinic and Microsoft Research demonstrate the power of generative AI in radiology, with new models that can automatically generate reports and evaluate chest X-rays. These advancements aim to improve clinician workflow and enhance patient care through more efficient and comprehensive image analysis. Additionally, researchers at Stanford University have developed AI systems that can accurately diagnose skin cancer, matching the performance of dermatologists. Other systems are also enhancing the detection of breast cancer and lung abnormalities in medical imaging.

> "Ambient AI scribes can automatically generate clinical notes from conversations between patients and physicians, potentially saving doctors up to three hours a day."

The field of drug discovery and development has seen perhaps the most dramatic acceleration through AI applications. Johnson & Johnson is leveraging AI agents to revolutionise drug discovery through the optimisation of chemical synthesis. These AI agents determine the optimal timing for solvent switches, which is a critical process in drug crystallisation. According to Jim Swanson, J&J's Chief Information Officer, this automation significantly speeds up processes that previously required multiple manual iterations by scientists, while still ensuring careful human oversight to prevent errors or bias. Similarly, other companies like Insilico Medicine have leveraged AI to reduce the time from target discovery to the selection of preclinical candidates from years to just a few months, all while significantly reducing costs.

Patient care and clinical decision support have also been significantly transformed by AI-powered solutions. In January 2025, Mayo Clinic and Cerebras Systems announced a breakthrough genomic foundation model that can predict treatment effectiveness for rheumatoid arthritis with 87% accuracy. This same model achieves 96% accuracy in predicting cancer predisposition and 83% accuracy in predicting cardiovascular phenotypes, demonstrating the potential of AI to revolutionise personalised medicine. Additionally, virtual health assistants can now provide 24/7 support for basic health queries, while advanced algorithms are used to predict patient risks and recommend preventive interventions.

Benefits and Transformative Impact

The benefits of AI integration into healthcare are becoming increasingly evident. Healthcare organisations that implement AI solutions are reporting significant improvements in operational efficiency, with some achieving cost reductions of up to 30% in administrative tasks. Additionally, the quality of care has improved due to more accurate diagnoses, a decrease in medical errors and the development of more personalised treatment plans.

Clinician burnout is a significant concern in healthcare, and AI-powered tools are being developed to help address this issue by automating routine tasks. Research shows that physicians can spend as much as 62% of their time on administrative work. By utilising AI automation, this burden can be greatly reduced, enabling healthcare providers to dedicate more time to patient care.

The timelines for research and development have been significantly shortened due to the use of AI applications. Traditional drug development cycles, which typically last 10 to 15 years, could potentially be reduced by as much as 50% with AI-assisted processes. Additionally, costs may be lowered by up to 70%, as indicated by industry analysts.

Challenges and Considerations

While the potential of AI in healthcare is promising, there are significant challenges that must be addressed for widespread adoption. Data privacy and security are major concerns, especially due to the sensitive nature of healthcare information and strict regulatory requirements such as HIPAA. Healthcare organisations need to ensure strong protection of patient data while also making the most of AI capabilities.

As AI agents become more autonomous in healthcare settings, concerns about cybersecurity are growing. Gartner predicts that by 2028, 15% of daily business decisions will be made autonomously by AI agents, while 25% of enterprise breaches will be linked to the misuse of these agents. This highlights the critical need for strong security measures and human oversight in the implementation of AI in healthcare.

The accuracy and reliability of AI systems remain critical concerns. While AI models have shown impressive capabilities, they can sometimes produce incorrect or biased results, particularly when trained on limited or non-representative data sets. This "hallucination" problem in generative AI models highlights the need for careful human oversight and validation of AI-generated content. An example of this is Johnson & Johnson's systematic review process for the outputs of their AI agents.

Implementation barriers also persist, including technical infrastructure requirements, staff training needs and integration with existing systems. Healthcare organisations must carefully consider how to implement AI solutions while maintaining operational continuity and ensuring staff adoption.

Looking Ahead

The future of AI in healthcare is expected to involve the growing use of autonomous AI agents collaborating with human professionals. However, as shown by leading organisations like Johnson & Johnson and Mayo Clinic, achieving success will require a careful balance. It is essential to leverage AI's efficiency while ensuring consistent human oversight to prevent errors and protect patient safety.

Organisations should consider several key recommendations as they move forward:

1. develop comprehensive AI strategies that align with organisational goals and capabilities;
2. invest in robust data infrastructure and security measures;
3. ensure proper staff training and effective change management;
4. maintain strong human oversight of AI systems;
5. collaborate with experienced technology providers and ensure compliance with regulations.

As healthcare organisations gain more experience with AI technologies, we can expect to see increasingly sophisticated applications. The convergence of different AI technologies – ranging from natural language processing to computer vision – will likely lead to the development of even more powerful solutions for healthcare.

> "Traditional drug development cycles, which typically last 10 to 15 years, could potentially be reduced by as much as 50% with AI-assisted processes."

Conclusion

AI and generative AI represent transformative technologies for healthcare, offering solutions to long-standing challenges in efficiency, quality and access to care. While significant challenges remain, particularly around data privacy, accuracy and implementation, the potential benefits are too substantial to ignore. Achieving success will require careful planning, robust governance frameworks and a commitment to maintaining human oversight while leveraging AI's capabilities. As these technologies continue to evolve, healthcare organisations that thoughtfully integrate AI solutions while addressing key challenges will be best positioned to deliver improved patient care in the coming years.

Conflict of Interest

None

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How Digital Clinical Quality Measures will Revolutionise Chronic Disease Management

Digital Clinical Quality Measures (dCQMs), powered by standards like HL7 FHIR and USCDI, will revolutionise chronic disease management. By integrating real-time clinical and claims data, dCQMs can identify care gaps at scale, supporting preventive care and improved outcomes. This approach requires a robust ecosystem of regulatory frameworks (eg TEFCA), advanced data standards and automated quality measures, enabling a shift from retrospective benchmarking to proactive patient care in value-based models.

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key points

- dCQMs leverage real-time FHIR data to detect care gaps and improve chronic disease outcomes.
- Regulatory frameworks like TEFCA enable seamless clinical and claims data exchange and aggregation.
- USCDI sets high-level standards, aligning data exchange with HL7 FHIR for better interoperability.
- Automated CQL-based dCQMs scale chronic disease management by codifying best practice guidelines.
- Integrated ecosystems transform data into actionable insights for proactive value-based care.

Digital Clinical Quality Measures (dCQMs) have the potential to transform chronic disease management within a well-integrated healthcare ecosystem. By standardising data from across the care continuum in Fast Healthcare Interoperability Resources (FHIR) and combining it with rules derived from clinical quality measures like CQL (Clinical Quality Language), healthcare providers can identify and address care gaps in chronic disease management. While this sounds like a bold claim, this approach is critical for maintaining the affordability of healthcare systems in ageing societies. Over the past decade, the United States has made significant strides in building a disruptive ecosystem of technologies and regulations to enable this transformative change towards preventive care.

Part 1 – The Problem

According to the U.S. Centers for Disease Control and Prevention (CDC 2024), 90% of healthcare costs in the United States, totalling €4.3 trillion ($4.5 trillion), are directed towards chronic and mental health conditions. It represents a staggering €3.8 trillion ($4.05 trillion) annually, equating to roughly 16% of the U.S. GDP.

The top chronic diseases, according to the CDC, are heart disease and stroke, cancer, diabetes and obesity. Common to all four is that they are well researched, medications are readily available and effective if risk factors are identified early in the disease progression, and drugs are prescribed and taken regularly. As an example, statins are highly effective in preventing cardiovascular disease (CVD) in adults between 40 and

75 years old with at least one risk factor (U.S. Preventive Services Task Force et al. 2022). Knowing this, we could scan all 40–75-year-olds for CVD risk factors and, if they are not currently on a statin, flag them for consideration of a regular statin regime. It is way cheaper to detect these risk factors early, prescribe effective drugs such as statins and prevent health escalations such as heart attacks than to deal with the consequences of untreated chronic diseases such as strokes, terminal cancer and the effects of uncontrolled diabetes and obesity. The Centers for Medicare and Medicaid Services (CMS), one of the largest government health insurers in the world, has therefore declared it a priority to shift from fee-for-service models to value-based care by 2030 (Berger 2024). The transition to value-based care marks a significant shift towards prevention and primary care by incentivising providers to detect and manage chronic diseases early rather than focusing on treating costly complications. An important tool in this model is clinical quality metrics (CQMs), which offer insights into how effectively a provider's organisation manages its assigned population against a wide array of quality goals. For example, in the MIPS (Merit-Based Incentive Payment System) Star rating, providers are benchmarked based on their performance relative to top performers in their category and receive higher reimbursement if they are doing well (U.S. Centers for Medicare and Medicaid Services).

At this point, let's postulate two hypotheses. First, the underlying problems described here, such as the high cost of chronic disease management versus the need to detect risk factors and prevent complications, are not unique to the United States but are common across most advanced societies with ageing populations. Therefore, similar trends could be observed in the UK, the Middle East, Australia and most EU countries. However, since health systems are funded differently worldwide, the shift towards value-based care is at varying stages of development. While the United States is not a pioneer, it has made significant progress supported by a variety of laws and regulations such as the Affordable Care Act of 2009, the 21st Century Cures Act of 2016 (U.S. Food & Drug Administration 2024) and subsequent regulations by CMS and the Office of the National Coordinator of Health IT (ONC) which merit close examination in this context. Second, since many countries share the problem, they could also share the solution. However, since healthcare data regulations vary significantly between nations —and even between states in countries like Germany —implementing regulatory and data ecosystems will require careful adaptation to each region's legislative framework.

> "Digital Clinical Quality Measures (dCQMs) have the potential to transform chronic disease management within a well-integrated healthcare ecosystem."

Part 2 – Solution: Regulatory and Data Ecosystems

Step 1 – Constructing a longitudinal patient record

The most important ingredient for successful data analytics is the availability of high-quality and specific data. In the context of chronic disease management, this necessitates collecting data from across the care continuum. Depending on the specific chronic disease and potential comorbidities, a variety of care providers could be involved in patient care. To detect care gaps, it is important to gather data from all these providers, including some non-traditional ones that influence social determinants of health (AMA Ed Hub 2022).

The data required falls into two main categories: clinical data, collected during care delivery, and claims data, submitted to payers for reimbursement. Globally, healthcare systems vary significantly–single-payer systems that also manage care delivery, systems with single payers and private providers and those with multiple payers and providers. The United States, with its complex network of multiple payers (government, for-profit and non-profit) and diverse private providers (both for-profit and non-profit), has, over the last decade, developed a robust infrastructure to collect and integrate both clinical and claims data. This system is supported by a carefully designed regulatory framework aimed at improving care coordination:

- Trusted Exchange Framework, Common Agreement (TEFCA) is a regulatory framework designed to facilitate health data exchange. It enables different "onramps" or QHINs (Qualified Health Information Networks) to allow providers to exchange clinical data for treatment purposes. QHINs can include networks of Electronic Medical Records (EMRs) from vendors like EPIC or Cerner, as well as regional or national Health Information Exchanges (HIEs) such as the eHealth Exchange. Initially, TEFCA implementations utilised XML-based Consolidated Clinical Document Architecture (C-CDA) documents to exchange clinical summaries. However, the framework will switch to FHIR-based data exchange by 2025.

- Beneficial Claims Data API (BCDA) is an interface provided by CMS that allows providers to download claims data for CMS members in their care, already formatted in FHIR.

- ONC also made it mandatory for certified EMRs to provide Bulk-FHIR access since 2022, which is very helpful for population health data purposes. Bulk-FHIR allows the export of discrete data for a cohort of patients.

Once the data is normalised, cleansed and transformed, it can form the basis for creating a longitudinal patient record. This record, containing both clinical and claims data elements, provides a comprehensive, up-to-date view of the patient's health. However, this is merely the foundation needed to mine for care gaps.

Step 2 – Creating a high-level data content standard with USCDI and FHIR

One of the drawbacks of clinical data aggregation in the past has been the inconsistency in the formatting and coding of HL7 v2 data. HL7 FHIR has addressed this challenge by creating a stricter standard with narrowly defined resources, enabling the exchange of specific data elements on demand and as required. This improvement also enhances the technology's suitability for data aggregation.

In order to maximise the utility of such data for population health management, ONC also introduced the U.S. Core Data for Interoperability (USCDI) (HL7 International 2024). It defines the type of data that every certified EMR must record and share as discrete

> "HL7 FHIR has addressed this challenge by creating a stricter standard with narrowly defined resources."

In summary, healthcare providers aiming to identify care gaps and improve chronic disease management can take several steps to leverage data effectively. They can download bulk FHIR-formatted data from their own EMR systems, combine it with claims data received via BCDA and utilise the TEFCA framework to request additional data from other providers. Providers within an Accountable Care Organisation (ACO)—groups that contract to deliver comprehensive care for a population—often agree to share data amongst themselves, utilising the same data exchange technologies such as C-CDA, FHIR or Bulk-FHIR.

While most of the data exchanged through TEFCA is in CDA format, CDA documents can also be parsed and transformed into FHIR, allowing data from different sources and formats to be integrated into a unified FHIR Server. With TEFCA's planned transition to FHIR payloads, the need to exchange and then parse CDA documents will eventually be eliminated.

resources. These can be accessed through a FHIR API for individual patients, a Bulk FHIR API for groups or cohorts of patients, or as C-CDA XML documents, with "USCDI defining high-level data requirements and FHIR US Core providing detailed FHIR-based profiles for meeting those requirements." (Health Level Seven International 2024) This means the ecosystem ensures the ability of its participants to share patient data, as well as adherence of the data to a stricter content standard, in this case, USCDI.

Over different generations, currently at version four, USCDI has incorporated more and more data to cover wider aspects of health, such as social determinants of health. For example, USCDI v4 introduces important elements for chronic disease risk assessments, including alcohol use, substance use, physical activity and average blood pressure (in addition to point-in-time measurements). As USCDI evolves, HL7 FHIR has adapted alongside it to ensure that all defined data

elements can be exchanged between providers and, when necessary, between providers and payers. Other countries or regions can define their own core data standards for interoperability and likewise align their regional FHIR implementation accordingly.

Step 3 – Digital Clinical Quality Measures

The final component of the proposed chronic disease management solution is digital Clinical Quality Measures (dCQM). Clinical Quality Measures (CQMs) have a long history that can be traced back to the work of Florence Nightingale, Ernest Codman and Avedis Donabedian (Chun et al. 2014). More recently, in the 1980s, the National Care Quality Association (NCQA) developed a set of HEDIS™ measures. These were initially developed for payers to measure provider effectiveness based on claims data, formatted in the U.S. according to the ANSI EDI standard X-12 and required by HIPAA for provider-to-payer claims submission (Department of Health and Human Services 2009).

Adopting Peter Drucker's famous principle, "If you can't measure it, you can't improve it", CMS made HEDIS measures mandatory for Health Management Organisations (HMOs) in 1991. Later, this requirement was extended to Accountable Care Organisations (ACOs) participating in Medicare shared savings programmes.

While these metrics codify best practices in chronic disease management and incentivise providers by awarding higher scores when a greater percentage of their population adheres to care guidelines, their original claims-based design posed limitations.

Claims data-based CQMs, often months old by the time they are processed, are better suited for performance measurement and reporting, such as determining Merit-Based Incentive Payment System (MIPS) rankings. However, this approach is less effective for actively managing individual patient care. The retrospective nature of claims data means it cannot support real-time adjustments to care plans, making it insufficient to directly manage patients against the very guidelines these measures promote.

This dynamic started to change very recently due to two major technology advancements. The first is the development of Clinical Quality Language (CQL), an ANSI standard championed by HL7 in 2020 (HL7 International 2020). CQL enables the standardised expression of clinical quality measure rules and the parsing of clinical data based on these rules. Tasks that previously required manual effort—such as determining whether a patient meets the inclusion or exclusion criteria for a measure and verifying if clinical requirements are fulfilled—can now be automated at scale.

> "Clinical Quality Language enables the standardised expression of clinical quality measure rules and the parsing of clinical data based on these rules."

The second advancement is FHIR data aggregation. Clinical data, when captured as part of a longitudinal patient record, can now be updated almost in real time, offering unprecedented data currency. Meanwhile, the claims data component of the longitudinal record can provide historical depth. For instance, determining whether a patient meeting risk criteria (age, gender, other risk factors) had a colon cancer screening within the past five years could be confirmed through a combination of recent FHIR clinical data and claims history.

This means that now hundreds of clinical quality measures can be digitalised with CQL and executed against an aggregated longitudinal patient record, thereby identifying care gaps at scale.

In 2023, the NCQA published a subset of their HEDIS™ measures in CQL for the first time. Committed to transitioning their entire measure set to CQL, the NCQA is also working on converting additional measure sets into CQL code (National Committee for Quality Assurance 2024). The measure sets align with the content requirements of the USCDI and are designed to parse FHIR resources as input.

With these advancements, we now possess all the necessary components to build a data ecosystem capable of aggregating clinical and claims data and constantly measuring this data against chronic disease management best practices expressed through CQM-based dCQMs. These core elements include:

- A framework and infrastructure for clinical and claims data aggregation. Tools like TEFCA, HIPAA and data use agreements within ACOs enable data exchange across the care continuum, whether for individual patients (using FHIR APIs or C-CDA documents) or patient cohorts (Bulk-FHIR). EMRs are mandated to support this interoperability.
- A high-level data content standard (USCDI) aligned with a data transfer and aggregation standard (HL7 FHIR).
- Codified chronic disease management standards. CQL enables the automation of chronic disease management standards, processing aggregated clinical and claims data (in FHIR format) at scale to identify care gaps for individual patients.

The combination of these technologies in a coordinated ecosystem allows us for the first time to identify care gaps in population cohorts at scale and in real time. This capability is instrumental in advancing preventive care goals, improving patient outcomes and accelerating the transition towards value-based care.

Conclusion

dCQMs, when applied to real-time clinical data, hold transformative potential for chronic disease management. By uncovering care gaps for individual patients within larger populations, they help providers to close these gaps, significantly improving health outcomes. However, achieving this requires the establishment of two types of ecosystems:

- A technical and regulatory framework for data exchange and aggregation. This framework must enable healthcare providers and payers across the care continuum to share and aggregate data. Data aggregation could occur within a group of providers (such as an Accountable Care Organisation), within integrated provider-payer networks (e.g. Kaiser Permanente, Clalit in Israel or the NHS in the UK) or at the payer level.
- Integration of robust data standards and aligned quality measures. High-level healthcare data requirements, such as those defined by USCDI, must align with modern standards for data exchange and aggregation, such as HL7 FHIR. Additionally, a comprehensive set of dCQMs should correspond to the data resources provided by these standards.

If such an ecosystem doesn't exist or its essential components are missing, as have been in the past, technologies like HL7 FHIR alone will not be able to provide the data foundation of the required quality. Conversely, CQMs measured solely against claims data and/or limited to samples serve merely as tools for reporting and benchmarking but are not sufficient to guide providers in the detection of care gaps for individuals within the population. The integration of these two ecosystems is thus indispensable for attaining the full potential of dCQMs in chronic disease management.

Conflict of Interest

The author is involved in developing a turn-key solution for care gap detection based on FHIR data and dCQMs.

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Transforming Biopharma: Gaining Prominence of AI Across the Value Chain

AI is revolutionising the biopharma industry by transforming drug discovery, development and manufacturing processes. It accelerates drug discovery, reduces costs and improves precision in disease modelling and drug design. AI enhances workflow efficiency, optimises manufacturing and refines supply chains while supporting vaccine design and precision medicine. However, challenges like regulatory transparency and data biases remain critical for broader adoption across the sector.

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key points

- Drug discovery can be accelerated by reducing timelines and costs with the help of AI.
- Better precision in disease modelling and drug design can be achieved with AI.
- AI improves manufacturing efficiency and supply chain optimisation.
- AI aids vaccine design and precision medicine advancements.
- The adoption of AI faces challenges with data bias and regulatory transparency.

Artificial Intelligence (AI) is reshaping the way the biopharma industry functions, transforming how drugs are discovered, developed, manufactured and delivered. From shrinking drug discovery timelines to optimising biomanufacturing processes and making supply chains more transparent and resilient, AI has shown promise in closing the translational gap from bench to clinic. Its transformative impact across the biopharma value chain has witnessed steady growth, driven by advances in machine learning algorithms, computational power and the availability of large datasets. Newer AI platforms are extensively working towards eliminating the gaps in data-driven drug development, clinical trials, bioprocessing and supply chain to make it an integral part of the biopharma value chain. Everest Group is a global research firm guiding business leaders with tailored strategies for operational and

financial success through expert insights in technology, business processes and engineering. Its advanced SciTech service line (AST) provides actionable research on cutting-edge science and technology innovations, focusing on R&D trends, innovation processes, toolkits and critical future drivers.

medicine. Large pharma and biopharma companies are establishing themselves as pioneers in using AI in drug discovery, either with internal programmes or collaborating with AI-driven drug discovery platform developers to identify novel targets and hit-to-lead identification. Recent examples include Healx, which will use its AI-based drug discovery technology to analyse proprietary Sanofi compound data and identify potential rare disease targets. At the same time, integrating AI with in vitro disease models like organ on chips and organoids can bring out nuances and guide precision medicine strategies.

> "AI (…) makes its mark in drug discovery, disease modelling, target discovery and precision medicine."

Drug discovery and development is notoriously complex and daunting, characterised by long timelines, exorbitant costs and high attrition rates. While the most apparent impacts on cost reduction and compressing timelines remain the most significant advantages, its use in accurate disease modelling, novel target discovery and de novo drug design to design drugs with desired drug-like properties is garnering traction. The following figure depicts the evolving role of AI in biopharma applications.

AI for Enhanced Workflow Efficiencies

With its advanced learning models to analyse large amounts of complex and disparate data in crunched timelines, AI makes its mark in drug discovery, disease modelling, target discovery and precision

AI has been heavily exploited for its role in improving understanding of PPIs, protein-ligand interactions and protein folding. In 2024, Google DeepMind's latest launch, AlphaFold3, has further expanded the scope of AI to predict protein folding and interactions accurately. It is now an open-source model that is being used by thousands of scientists globally.

The use of multimodal AI is becoming increasingly crucial across the pharmaceutical value chain. It provides unprecedented insights into hidden linkages in pathways and helps understand disease progression

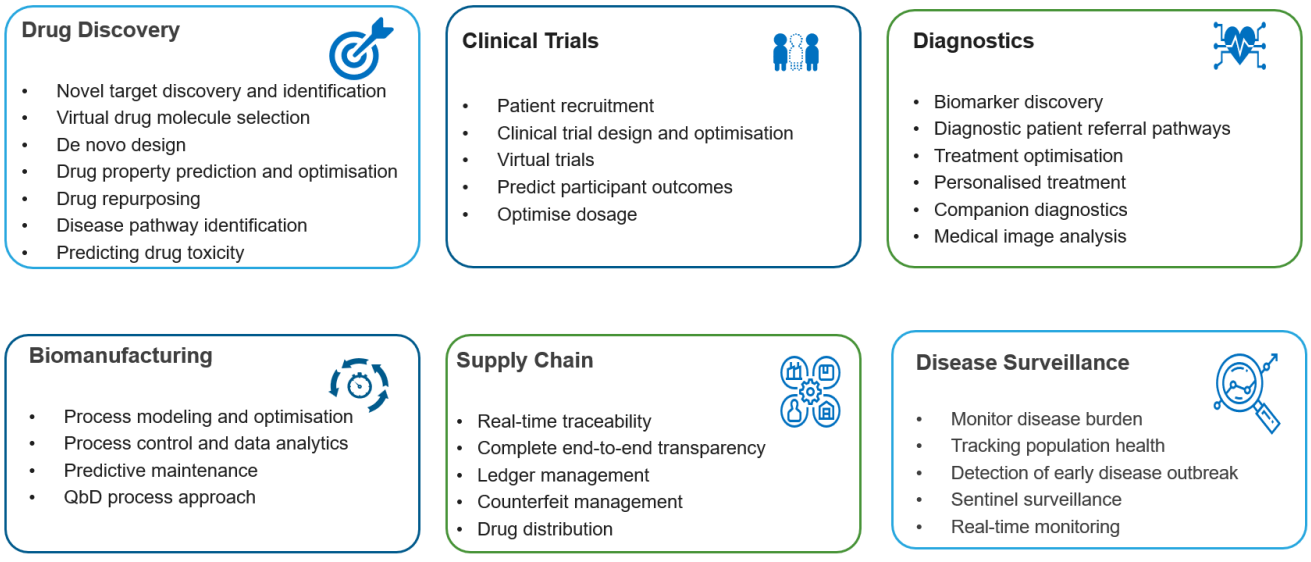

Figure 1. Applications of AI in the biopharma industry

that human eyes might miss. The integration of diverse datasets (omics, imaging, clinical outcomes) reveals deep connections and helps understand from a more holistic perspective. Sophia Genetics and Astra Zeneca have recently collaborated to use Multimodal AI for precision oncology (lung cancer patient stratification).

vaccines, biologics and advanced therapeutic modalities is progressing considerably. Sanofi and other companies have used generative AI to accelerate the design of new mRNA vaccines and to optimise their delivery and formulation. Leveraging AI in vaccine design and development is also promising, as it can accelerate

> "To fully exploit AI's potential, the sector must take proactive steps to address technical, ethical and regulatory challenges."

AI is also useful for designing synthetic pathways that minimise the number of steps and chemicals required and increase yields. Elsevier and Iktos recently collaborated to use AI-driven synthetic chemistry automation to accelerate the Design-Make-Test cycle in drug discovery.

While most solutions address specific aspects such as virtual screening or lead optimisation, companies are also developing integrated solutions that can be used across the drug discovery and development continuum. One such solution is Merck's Addison software, launched in December 2023. It is the first AI solution to integrate discovery and synthesis in a single platform. It uses generative AI to identify the most suitable drug-like candidates from a vast chemical space of 60 billion options and to provide an optimal synthesis route.

De novo synthesis is one of the most exciting frontiers of AI, and generative AI models are being used to design both small molecules and biologics, with the latter being at a more nascent stage. The use of GAN (generative adversarial networks) in Generative AI in drug discovery workflows is expected to grow steadily and be most impactful, though developments are still nascent. Qure.ai, Niramai Health, Owkin and InSilico Medicine are some companies advancing GenAI to create large quantities of synthetic data for de novo drug design, novel drug target discovery, design precision clinical trials and prediction of drug responses, which will have a radical impact. InSilico Medicine is one of the pioneers in this space, developing one of the world's first GenAI-developed drugs for Idiopathic Pulmonary Fibrosis that entered Phase 2 trials in 2023.

Broadening Scope of AI Across Modalities

While AI is broadly adopted and used for small molecule discovery and design, its application in the design of

immunogen design and antigen selection as well as predict immune responses. Sanofi, Moderna, GSK and several other biopharma companies have adopted AI to accelerate mRNA vaccine design and are partnering with AI platform companies to streamline their discovery efforts.

Evolving Role of LLMs

The integration of Large Language Models (LLMs) into drug discovery and development is unlocking new possibilities across the entire value chain. LLMs represent a significant opportunity for companies that goes beyond discovery. AI-powered LLMs can analyse vast amounts of unstructured data and fine hidden patterns from large datasets for data integration and triangulation, providing predictive insights.

These platforms have also been democratised, opening up opportunities for pharmaceutical companies to develop innovative solutions, improve drug discovery, clinical operations, commercialisation, clinical trials and, finally, therapeutic outcomes. Insilico Medicine is using Microsoft's BioGPT, a LLM model, to predict dual-purpose targets, while ConcertAI and NIH's National Library of Medicine (NLM) are deploying a platform called TrialGPT for rapid patient selection and recruitment in clinical trials. Moderna has also collaborated with OpenAI to utilise its ChatGPT platform to accelerate mRNA vaccine development. Google's recent launch of the drug discovery-specific LLM platform, TxLLM, is a refined version of MedPALM2, which can predict interaction and screen compounds and is expected to gain traction. The following figure represents the role of AI in drug discovery and development.

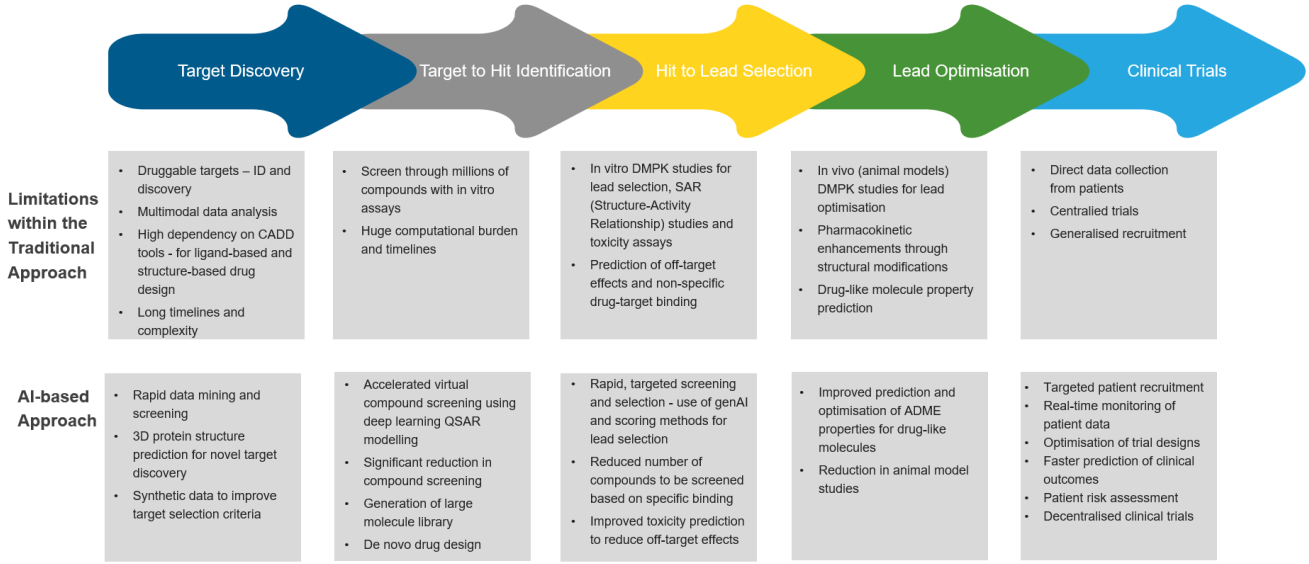

Figure 2. AI In Drug Discovery and Development Paradigm

Expanding Role of AI Beyond Drug Discovery and Development

AI is revamping the pharma manufacturing and innovation process with its ability to enhance efficiency, drive precision and reduce time across the drug development and manufacturing lifecycle. Its applications include such options as:

Process Optimisation and Control. AI algorithms can analyse complex datasets to optimise manufacturing processes, ensuring consistent product quality and reducing production costs. LLM and GenAI models can help accurately predict process parameters, enabling real-time adjustments, minimising variability and optimising production processes. AI-driven advanced process control (APC) systems are being explored to dynamically manage pharma manufacturing to ensure product consistency and achieve desired outputs.

Predictive Maintenance and Quality Control. One of the key advantages of AI implementation in pharma manufacturing is predictive maintenance, which helps anticipate risks and plan to overcome potential pitfalls. AI-integrated sensors can prevent unexpected downtime and extend equipment lifespan. AI models can accurately detect anomalies and deviations in real time and identify patterns that can lead to potential quality issues, allowing for immediate corrective actions. This is a boon for an industry governed by stringent regulatory standards. AI-driven digital twins enable companies to predict how changes in process parameters affect product quality and yield, facilitating continuous improvement and innovation.

Supply Chain Optimisation. One of AI's key advantages is its ability to optimise supply chain management by predicting demand, managing inventory and identifying potential disruptions. Machine learning algorithms can analyse market trends, historical data and external factors to forecast demand and plan production schedules. They can also track the movement and distribution of drugs and other products, ensuring transparency and preventing counterfeiting.

With proven advantages and implementation use cases, several pharmaceutical players are actively integrating AI into their manufacturing and supply chain processes. The application segment has also seen companies collaborate to form innovation networks and encourage the start-up ecosystem. One example is AION Labs, an Israeli venture studio focused on adapting AI and machine learning in the pharmaceutical industry. With Tier 1 companies such as AstraZeneca, Merck KGaA, Pfizer and Teva Pharmaceuticals being active participants, AION Labs has ventures like DenovAI, which utilises AI for antibody discovery.

Reducing AI Black Boxes to Navigate Regulatory Pathways

The bias surrounding the use of AI tools greatly limits their value and reliability. To keep pace with AI advances, regulatory bodies need to develop regulatory frameworks to guide the application of AI in the biopharma sector. Several stakeholders, including platform developers and pharma companies, are focused on determining how to make AI tools more precise and predictable.

Developing algorithms using Explainable AI, which can break into the "AI black boxes" and provide a rationale for AI algorithm decisions and outcomes. These transparent models can meet regulatory standards and help build stakeholders' trust. Building models based on biological mechanisms, which consider pathways and interactions, can be useful to align AI predictions. Regulatory bodies can use such transparent reasoning for predictions and recommendations for AI-developed drugs.

The transformative potential of AI and other digital technologies is also recognised by governmental organisations that actively participate in creating regulations and guidelines for AI use in the pharma industry, facilitating its integration into the sector. In May 2023, the FDA initiated two discussion papers on Artificial Intelligence and Machine Learning in Drug Discovery and Manufacturing, inviting industry feedback to understand the necessary elements for implementing AI-based models in a cGMP environment. This aims to establish guidelines for AI's safe and effective use in pharmaceutical manufacturing. Similarly, the European Union (EU) is also developing regulations to ensure AI's safe, reliable and ethical use.

bodies are receptive to AI tools, they demand transparency and validation. Consequently, it is the responsibility of stakeholders and technology developers to ensure that AI models are:

- **Explainable:** ensuring AI models are interpretable and explainable for regulatory approval;
- **Adhering to data privacy:** implementing secure measures to protect patients' or stakeholders' data privacy;
- **Mitigating bias-related issues:** addressing datasets' biases to ensure equitable outcomes.

Addressing the above issues requires a collaborative approach from various stakeholders to strengthen the data infrastructure and build AI expertise within all walks of the industry. This includes building robust AI models and standardising data infrastructure, fostering collaboration and enhancing data quality. It also requires upskilling the workforce and fostering multidisciplinary collaborations. In order to facilitate AI adoption in the industry, it is necessary to address ethical concerns, which include standardising reporting procedures, mandating ethical frameworks and employing data privacy measures, such as advanced encryption and de-identification methods. It is also important to understand that the use of AI tools is an iterative process that requires continuous monitoring, evaluation and conducting of pre- and post-deployment audits, as well as establishing and implementing feedback loops.

> "AI algorithms can analyse complex datasets to optimise manufacturing processes, ensuring consistent product quality and reducing production costs."

Future Outlook

The biopharmaceutical industry is at a transformative phase, driven by the convergence of digital technologies with traditional innovations. The critical need for drug development, manufacturing and patient care innovation offers unprecedented opportunities for AI to accelerate discovery, reduce costs and personalise treatments, making it a pivotal tool for addressing the industry's challenges. Its ability to democratise healthcare by acting as a lever for accessible care, globalising health applications and optimising resources makes its role inevitable in the future of the healthcare industry.

Its adoption in healthcare, especially in biopharma applications, depends on ensuring it navigates the regulatory and ethical challenges. While regulatory

In conclusion, while the future of AI in the biopharma industry is exciting, it is also complex. To fully exploit AI's potential, the sector must take proactive steps to address technical, ethical and regulatory challenges.

Conflict of Interest

None

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How IoT and AI Are Transforming Personal Health Monitoring and Healthcare

Recent advancements in IoT and AI have revolutionised health monitoring, enabling individuals to track vital metrics like heart rate, blood pressure and sleep patterns through smart devices. These technologies allow for real-time, personalised insights and predictive analytics, improving preventive care and chronic condition management. Remote monitoring reduces hospital visits and enhances patient outcomes. However, challenges in data privacy and device accuracy must be addressed for broader adoption.

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key points

- IoT devices provide real-time monitoring of vital health metrics.
- AI enables predictive insights for proactive health management.
- Remote monitoring reduces hospital visits and enhances outcomes.
- Wearable tech supports early detection of chronic conditions.
- Data security and device accuracy remain key challenges.

In recent years, personal health monitoring Internet of Things (IoT) technology has deeply transformed how individuals manage their well-being. From extremely simple fitness trackers to smartwatches, intelligent scales and even more advanced IoT-enabled medical devices, the innovation has empowered people to control their health data like never before. By eliminating the constraints of traditional doctor visits, health monitoring has become natural, tailored procedures that continuously gather information. This technology provides excellent insights that enable individuals and professionals to make better health-related decisions.

IoT in healthcare goes beyond merely tracking steps or calorie intake. Instead, it aims to provide a comprehensive health profile for the population. Wearable devices and other health-focused IoT instruments can monitor a variety of metrics, including heart rate, blood pressure, oxygen saturation and sleep patterns. Some devices can even perform basic electrocardiograms (ECGs). This flow of data allows users to detect subtle changes in their health, helping them identify potential issues in a timely manner. As a result, individuals can gain a customised perception of their health—something that would have been unbelievable just a few years ago.

Types of IoT Health Devices and the Data They Collect

Wearable Fitness Trackers are among the most widespread IoT health gadgets available today. They typically offer advanced monitoring features, including tracking heart rate, daily steps, calories burned and sleep patterns. By providing valuable insights into daily activities, these trackers inspire users to adopt healthier lifestyles.

Smartwatches are a type of advanced fitness tracker with enhanced health-monitoring features. Some can even conduct ECGs and track blood oxygen saturation (SpO_2 levels), potentially alerting the wearer to irregular heartbeats or hypoxemia.

Smart Scales not only weigh the patient but also measure body fat percentage, muscle mass and even water retention. This provides a comprehensive view of body composition and general fitness.

Medical-grade IoT Devices, such as continuous glucose monitors and remote patient monitoring (RPM) systems, are particularly helpful for patients with chronic diseases. These devices communicate directly with healthcare providers, ensuring that any abnormal readings of vital health parameters, like blood glucose and blood pressure, are addressed immediately.

Predicting Heart Attacks. The slight variations in machine learning algorithms can be used over time to analyse heart rates. Unusual patterns in this data may indicate potential heart issues that necessitate urgent attention, alerting either the user or the medical professional to seek early treatment. For example, a sudden spike in resting heart rate, accompanied by low heart rate variability (HRV), may indicate heart strain and suggest a possible cardiovascular risk.

Detecting Sleep Apnea. A sleep-monitoring device using AI algorithms can identify patterns associated with sleep apnea, such as irregular breathing or disrupted sleep cycles. By measuring oxygen levels and monitoring breathing, this device can help users detect the condition early, encouraging them to seek professional testing or treatment.

> "IoT in healthcare goes beyond merely tracking steps or calorie intake. Instead, it aims to provide a comprehensive health profile for the population."

Sleep Monitors track the duration and quality of sleep, detect potential disturbances and even recognise patterns that may indicate sleep apnea, enabling users to take proactive steps against sleep-related health issues.

With all these technologies, data collection is ongoing and essentially real-time. Continuous monitoring of a person's health provides insights that would otherwise be difficult to discern through traditional medical check-ups.

Transforming Data into Predictive Insights

With the data collected from IoT devices, the domain of AI and machine learning algorithms comes into play. AI excels at processing large volumes of information and identifying patterns, making it particularly effective in healthcare for detecting trends, correlations and possible risks.

AI-driven predictive analytics can examine detailed metrics such as heart rate variability and blood pressure, as well as broader factors like sleep quality. By doing so, it can identify warning signs and alert patients to potential future medical events. A few examples explored later will illustrate these applications.

Managing Chronic Conditions. Continuous glucose monitors constantly check the blood sugar level for diabetic patients. Machine learning can analyse these levels to predict when they might drop or rise, allowing patients to take immediate action. Not only does it improve their quality of life but also helps prevent serious health issues, such as diabetic comas.

The Impact of Predictive Analytics on Preventive Care

Predictive analytics and the use of IoT devices have led to a new trend in health: preventive care. These technologies can effectively identify potential risks in real time, allowing for timely interventions and preventing severe situations from arising.

Early Detection of Chronic Conditions. Most chronic diseases, such as diabetes, hypertension and heart diseases, can take decades to develop and are mostly symptomless in their early stages. Signals for these diseases can be detected by IoT devices that continually monitor relevant health data. In this way, individuals can either make lifestyle adjustments or seek treatment well before serious issues arise.

Customised Lifestyle Recommendations. IoT devices can monitor day-to-day habits such as physical activity, sleep and stress levels. This data allows AI algorithms to provide personalised recommendations for improving health outcomes. For example, suggestions might include getting more sleep, practising mindfulness exercises to reduce stress or increasing daily step counts.

Continuous and Remote Monitoring. The IoT opens doors to effective chronic disease management by enabling real-time data delivery to healthcare professionals. As a result, office visits will become less frequent since providers would monitor patients' vital signs remotely and receive alerts whenever values fall outside safe parameters.

How IoT and AI Enable Remote Monitoring and Continuous Care

Another groundbreaking advancement in healthcare provided by IoT and AI is continuous remote care. This technology allows vital health data to be collected through IoT devices and shared with healthcare providers. As a result, doctors can stay informed about a patient's condition even when the patient is unable to visit in person. This has been particularly transformative for the elderly and individuals with mobility limitations.

The Benefits of Continuous Remote Care

Reduced Hospital Visits. Chronic-disease patients prefer remote monitoring as it reduces hospital visits and unnecessary testing. This approach also alleviates patient anxiety and saves health professionals from increased fatigue.

Improved Patient Outcomes. Ongoing monitoring can facilitate timely interventions. For example, if a patient's blood pressure or glucose levels start to deviate from established norms, adjustments can be easily made to the treatment plan to prevent complications.

> "Remote monitoring empowers patients to manage their health independently and confidently."

Enhanced Quality of Life. Remote monitoring empowers patients to manage their health independently and confidently. This system actually allows users to monitor their own health while involving healthcare providers only when necessary. As a result, patients can focus on their daily lives while staying proactive about their health.

Challenges and the Road Ahead

Despite its phenomenal potential, there are still several challenges surrounding the use of IoT and AI in health monitoring. One of these concerns is data privacy and security, as health data is highly sensitive, and a robust system must be in place to prevent any breaches. Additionally, not all IoT devices are accurate; inconsistencies can lead to unreliable health insights.

On the bright side, improvements in data security, device accuracy and regulatory oversight are expected to address these issues in the coming years. As IoT devices evolve, they will offer more advanced and precise monitoring capabilities, paving the way for a new level of personalised care and preventive health measures.

The integration of IoT-enabled health devices, AI and predictive analytics has introduced a new dimension to personal health monitoring. These technologies empower individuals to take a proactive approach to their health, encourage preventive care and facilitate real-time, continuous support from healthcare providers. This transformation in healthcare promises improved health outcomes, more customised care and ultimately, a healthier and more empowered population.

Conflict of Interest

None

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Healthcare Solutions in an AI-Driven World: A Global Perspective

AI is transforming global healthcare by improving diagnostics, personalised medicine, telehealth and operational efficiency. While regions like Europe and the US lead in regulation and innovation, the Middle East emerges as a key player with significant investments in smart healthcare. Challenges remain, including algorithmic bias and infrastructure gaps, but AI's potential for enhanced patient care and efficiency continues to grow across diverse global healthcare landscapes.

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key points

- AI enhances the accuracy and speed of disease detection with advanced diagnostic tools.
- Personalised medicine advances with AI-driven genomic analysis and faster drug discovery.
- AI-powered telehealth platforms improve remote care access and patient monitoring.
- Operational efficiency in healthcare is increasing as AI streamlines workflows and resource management.
- AI adoption varies by region, as Europe, the US, Asia and the Middle East face distinct challenges and uncover new opportunities.

The integration of artificial intelligence (AI) into healthcare is revolutionising the industry globally, presenting unprecedented opportunities to elevate patient outcomes, optimise operational efficiency and propel innovation. AI-driven solutions are transforming various facets of healthcare, from diagnostics and treatment to patient care and operational management. However, the adoption and implementation of AI in healthcare vary significantly across different regions, each facing its own unique challenges, regulatory environments and technological landscapes. This article examines the global landscape of AI-driven healthcare solutions, comparing approaches in Europe, the United States and Asia, finally highlighting the unique potential of the Middle East.

Introduction

For those sceptical of artificial intelligence (AI) in healthcare, mounting evidence demonstrates its transformative potential. For example, a recent randomised clinical trial (Goh et al. 2024) revealed that ChatGPT-4 outperformed physicians in diagnostic accuracy, scoring 90% when analysing case reports, compared to 76% for doctors using the chatbot and 74% for those without it. These results underscore not only the chatbot's superior performance but also its potential to augment clinical decision-making and revolutionise healthcare delivery.

Despite the promise of AI in healthcare, challenges remain. A key concern is the potential for algorithmic bias, which can exacerbate existing health disparities

Figure 1. AI-Generated Image for Healthcare Solutions in an AI-Driven World: A Global Perspective. (Credit: K. Zarychta)

(Muralidharan et al. 2024). A scoping review of FDA-approved AI medical devices revealed significant reporting gaps related to demographic and socioeconomic data, raising concerns about the potential for bias in these devices. These findings underscore the importance of transparency, rigorous testing and ongoing monitoring to ensure that AI applications are safe, effective and equitable for all patients.

Transformative AI Innovations in Healthcare

Advanced Diagnostics and Imaging

AI is revolutionising diagnostics with innovations that enhance the speed and accuracy of disease detection. Algorithms trained on extensive datasets can analyse medical images such as X-rays, CT scans and MRIs with precision that often exceeds human capabilities.

One notable example is *Neo* Q, which is advancing radiology through its white paper, *Sustainability in Radiology: Impact of Guided Reporting and AI*. Neo Q's "RadioReport® Automatic AI" solution offers guided reporting developed from the radiologist's perspective, improving diagnostic accuracy, reducing reporting times and addressing broader sustainability challenges in radiology (Jansen et al. 2024).

new compounds. For instance, *Insilico* Medicine rapidly discovered a promising drug candidate for idiopathic pulmonary fibrosis (World Economic Forum 2024).

Similarly, *Deep Genomics* is leveraging AI to identify genetic mutations that contribute to diseases and developing RNA-based therapies to target those mutations. Their AI Workbench platform accelerates drug discovery and ensures precision in therapy design.

"AI-driven solutions are transforming various facets of healthcare, from diagnostics and treatment to patient care and operational management."

Other companies are also making significant strides in AI diagnostics and imaging:

- **Aidoc:** focused on creating AI solutions for radiology, Aidoc provides software that helps detect critical conditions, such as intracranial haemorrhages and pulmonary embolisms, from medical images. Their solutions integrate seamlessly with radiology workflows, enabling faster and more accurate diagnoses.

- **Zebra Medical Vision:** known as one of the pioneers in AI diagnostics, Zebra Medical Vision offers AI tools that analyse imaging data to detect a wide range of conditions, such as osteoporosis, fatty liver and cardiovascular diseases. Their AI-powered radiology solutions are designed to assist clinicians in early detection and treatment planning.

- **HeartFlow:** specialising in cardiovascular imaging, HeartFlow uses AI to create detailed 3D models of a patient's coronary arteries based on CT scans. This technology enables clinicians to assess blood flow and plan interventions more effectively, thereby reducing the need for invasive procedures like angiograms.

These advancements exemplify how AI is not only improving clinical outcomes but also addressing systemic inefficiencies, making diagnostics more sustainable and accessible.

Personalised Medicine

AI is driving breakthroughs in genomics and precision medicine by analysing genomic data to tailor treatments to individual patients. Companies such as Tempus and Foundation Medicine are at the forefront of this field. Additionally, AI is accelerating drug discovery by exploring vast chemical libraries to predict the efficacy of

Another leader in the field is *Recursion Pharmaceuticals*, which combines biological data with AI to discover and develop treatments for rare and complex diseases. Recursion's platform uses machine learning to analyse high-dimensional biological data, enabling faster identification of treatment candidates.

These companies, along with others like *Tempus and Foundation Medicine*, are exemplifying the potential of AI to revolutionise precision medicine and drug discovery by making treatments faster, more accurate and personalised to individual patients.

Telemedicine and Remote Monitoring

AI-enhanced telehealth platforms are providing 24/7 patient support, triaging symptoms and offering preliminary diagnoses through AI-powered chatbots and virtual assistants, like *Babylon Health's* AI chatbot. Remote patient monitoring, supported by wearable devices and IoT sensors, collects real-time patient data examined by AI algorithms to predict potential health issues (Muralidharan et al. 2024). Notable examples are:

- ***Ada Health*** uses AI-powered symptom assessment to provide personalised insights and guidance to users about potential health conditions, helping them make informed decisions about seeking medical care.

- ***Livongo*** *(now part of Teladoc Health)* utilises AI to analyse patient data from connected devices and provide personalised coaching and insights for individuals managing chronic conditions like diabetes, leading to improved health outcomes.

- ***Woebot***, an AI-powered chatbot, provides on-demand mental health support through evidence-based practices, such as cognitive behavioural therapy

techniques (CBT). It makes mental wellness resources more accessible and convenient for users seeking help.

Operational Efficiency

AI is optimising hospital workflows by predicting patient flow, managing resources and reducing wait times. Companies like *Epic and Cerner* are integrating AI into electronic health record (EHR) systems to enhance operational efficiency (Castro et al. 2024).

> "Despite the promise of AI in healthcare, challenges remain. A key concern is the potential for algorithmic bias, which can exacerbate existing health disparities."

Robotic Process Automation (RPA) tools, such as those offered by *UiPath and Automation Anywhere*, automate administrative tasks, freeing up healthcare professionals to focus on patient care (World Economic Forum 2024). For example, *EBO.ai* uses AI virtual assistants to manage repetitive patient processes, continuously learning and improving responses to save valuable time.

Patient Engagement and Experience

AI-powered patient portals, such as *MyChart by Epic*, provide personalised health insights, appointment scheduling and medication reminders. Furthermore, AI is being used in mental health care to analyse patient data, identify issues and provide tailored interventions. For instance, the already mentioned Woebot Health utilises a mental health chatbot to deliver accessible, personalised care (Lamb 2024).

> "AI-powered patient portals, such as MyChart by Epic, provide personalised health insights, appointment scheduling and medication reminders."

We are also witnessing a rise in Women's Health applications and platforms. Companies like *Esme SX* are leveraging AI to advance health by addressing specific health concerns and improving overall well-being. Similarly, *My Anna Health* focuses on overlooked symptoms in women's healthcare, ensuring no concern falls on deaf ears (Rowlison, 2024).

Regional Perspectives: Europe, the United States, Asia and the Middle East

Europe leads in safeguarding data privacy with stringent regulations like the General Data Protection Regulation (GDPR). These measures foster collaborative research and development while navigating regulatory hurdles and fragmented healthcare systems.

The United States is at the forefront of advanced AI research and development, driven by robust federal funding and venture capital investments. However, challenges such as data silos and regulatory uncertainty remain significant barriers to widespread adoption.

Asia demonstrates rapid adoption and scalability of AI solutions, fuelled by strong government support and investments in telemedicine and digital health. However, the region faces challenges in infrastructure limitations and data privacy concerns.

The Middle East is a region of untapped potential that emerges as a global hub for AI innovation in healthcare. Strategic government investments in smart healthcare initiatives, coupled with a focus on addressing region-specific health challenges, are fostering regional growth.

As Khanam et al. (2024) highlight, AI's telemedicine, remote monitoring and diagnostics capabilities align perfectly with the region's needs, especially following

the pandemic-driven acceleration of virtual care. International collaborations with leading healthcare and technology companies are further bolstering the development and implementation of cutting-edge AI solutions. This combination of factors positions the Middle East as a key player in shaping the future of AI-driven healthcare.

Saudi Arabia is also making significant strides in AI, with plans for a €97.63 billion ($100 billion) AI powerhouse to rival the UAE's tech hub (Bloomberg 2024). This initiative aims to build upon the kingdom's existing efforts to become a leading AI centre, potentially modelled on the Public Investment Fund's partnership with Google AI. In addition, NEOM, a futuristic city project in Saudi Arabia, is prioritising technological disruption to create a seamless society and bridge the digital divide (NEOM n.d.). This includes fostering innovation in AI and other digital technologies to drive economic growth and improve quality of life.

This addition provides concrete examples of Saudi Arabia's investment in AI and its broader vision for technological advancement. It fits well within the existing discussion of the Middle East's emerging role in AI-driven healthcare.

Conclusion

Artificial intelligence is transforming healthcare globally, from enhancing diagnostics and personalised medicine to improving patient engagement and operational efficiency. However, regional disparities in regulation, infrastructure and adoption rates highlight the varying challenges and opportunities in integrating AI into healthcare systems.

As AI continues to revolutionise healthcare, regions like the Middle East are poised to play a pivotal role in driving innovation and shaping the future of AI-driven healthcare solutions. By fostering global collaboration and leveraging AI's transformative potential, healthcare systems worldwide can achieve unprecedented advancements in patient care and operational excellence.

Conflict of Interest

Dr. Katarzyna Zarychta serves as the Chief Medical Advisor in Esmé SX.

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Guided Open Collaborative Ecosystems as a Major Disruption in Health Systems

Healthcare systems face challenges like rising costs and limited access, but a focus on prevention, early intervention and digital innovation can transform outcomes. A shift toward home-based care and collaborative ecosystems involving governments, industries and patients can reduce costs, enhance quality of life and address global disparities. This proactive strategy fosters innovation and systemic improvement, meeting the growing demands of healthcare.

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key points

- Proactive health measures reduce costs and improve quality of life globally.
- Collaborative ecosystems drive innovation and systemic healthcare transformation.
- Early intervention and home care enhance outcomes and efficiency in healthcare systems.
- Digital tools enable better, faster and cost-effective patient care and diagnostics.
- Shifting resources to prevention addresses global healthcare access challenges.

Introduction

Over the past two centuries, we have made unprecedented progress in health outcomes, with the average life expectancy more than doubling due to major advancements in public health, pharmacological treatments, surgical techniques and medical device innovations. Most of these advances have occurred somewhat independently of each other. Imagine the progress that could be achieved if collective innovation efforts were guided in the same direction, with a common vision and a shared innovation agenda, using an ecosystem approach. This is what this paper proposes: a common Innovation agenda, “Stay Left, Shift Left-10X” (the what) and a directed or guided open collaborative ecosystem (the how). Before diving into the details, it’s essential to understand the necessity of this approach. As my former Intel colleague Cyndi Breazeale often noted, “80% of innovation comes from a stated need”.

Despite the major advances that have enabled significant health improvements, global healthcare systems face serious challenges. These include rising waiting lists and costs, workforce shortages and a demographic time bomb: for the first time in history, there are more people over the age of sixty-five than under the age of five. Additionally, half of the world’s population still lacks access to affordable healthcare (WHO 2017).

Stay Left, Shift Left-10X

In order to drive coherent, complementary and compounding innovation, I propose a new strategic direction or doctrine called "Stay Left, Shift Left-10X (SL2-10X)". This strategy has its origins in software engineering, where data shows that early detection of bugs or design flaws dramatically reduces lifecycle costs and improves product quality. The Intel Digital Health division has also adopted the "Shift Left" as an innovation strategy. While applied to healthcare, this thinking is manifested as:

- **"Stay Left"** emphasises the importance of maintaining wellness and managing chronic illnesses or rehabilitation effectively at home.
- **"Shift Left"** focuses on transitioning patients from the hospital to their homes as quickly as possible.
- **"10X"** represents the aspiration, backed by real-world empirical evidence, that the application of digital tools and data in healthcare can provide benefits that are ten times or ten-fold better, cheaper, earlier and at a higher volume.

> "Early diagnosis and treatment is better for patients, clinicians and the healthcare system in terms of outcomes, costs and experience."

The concept of "Shift Left" emphasises the benefits of tacking or moving tasks earlier in a process timeline, such as disease progression, to improve efficiency and effectiveness. Proactive health management, earlier detection and intervention allow dramatically improved survival rates and lower costs across many diseases. The diagram below illustrates that the aim of every digital health intervention should be to implement a "Shift Left" strategy, leading to cost savings as well as improved outcomes, experiences and quality of life. A simple example of this is the "hospital-at-home" model, where patients receive treatment and care in their own homes instead of in an acute care hospital. This

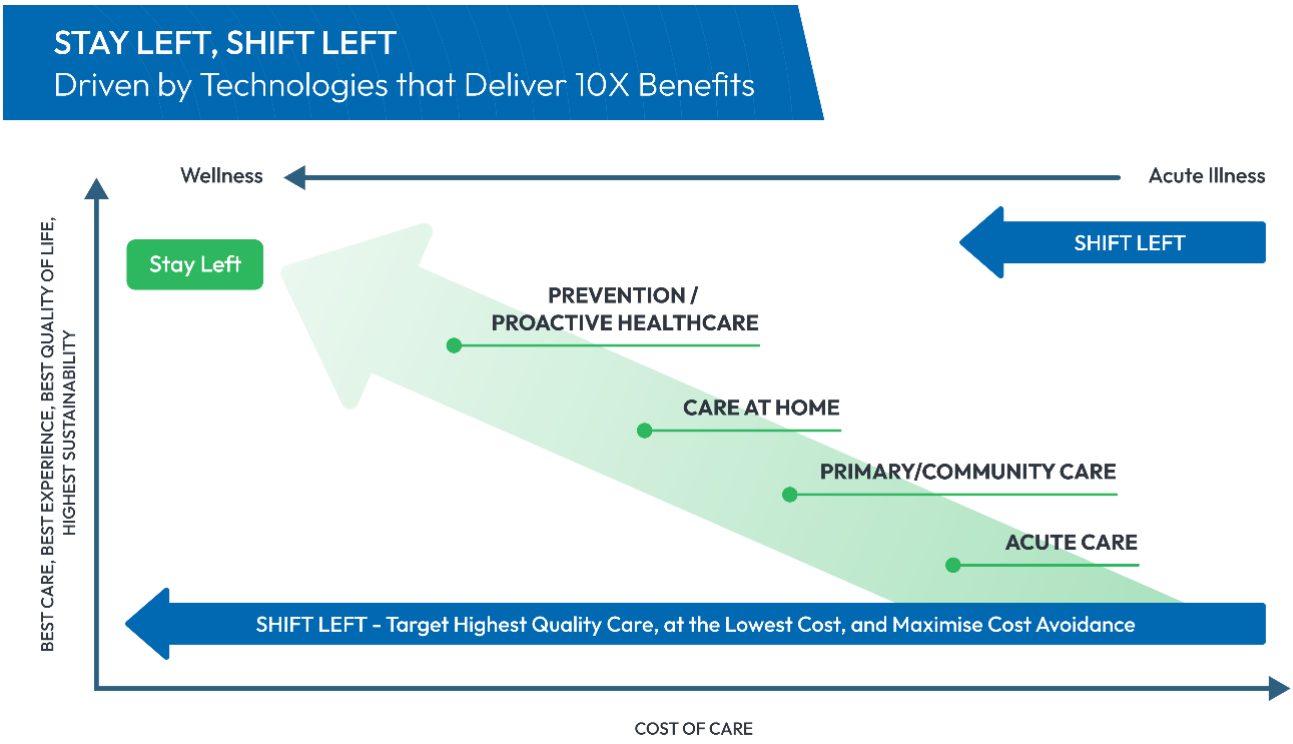

Figure 1. Stay Left, Shift Left-10X. Source: M. Curley

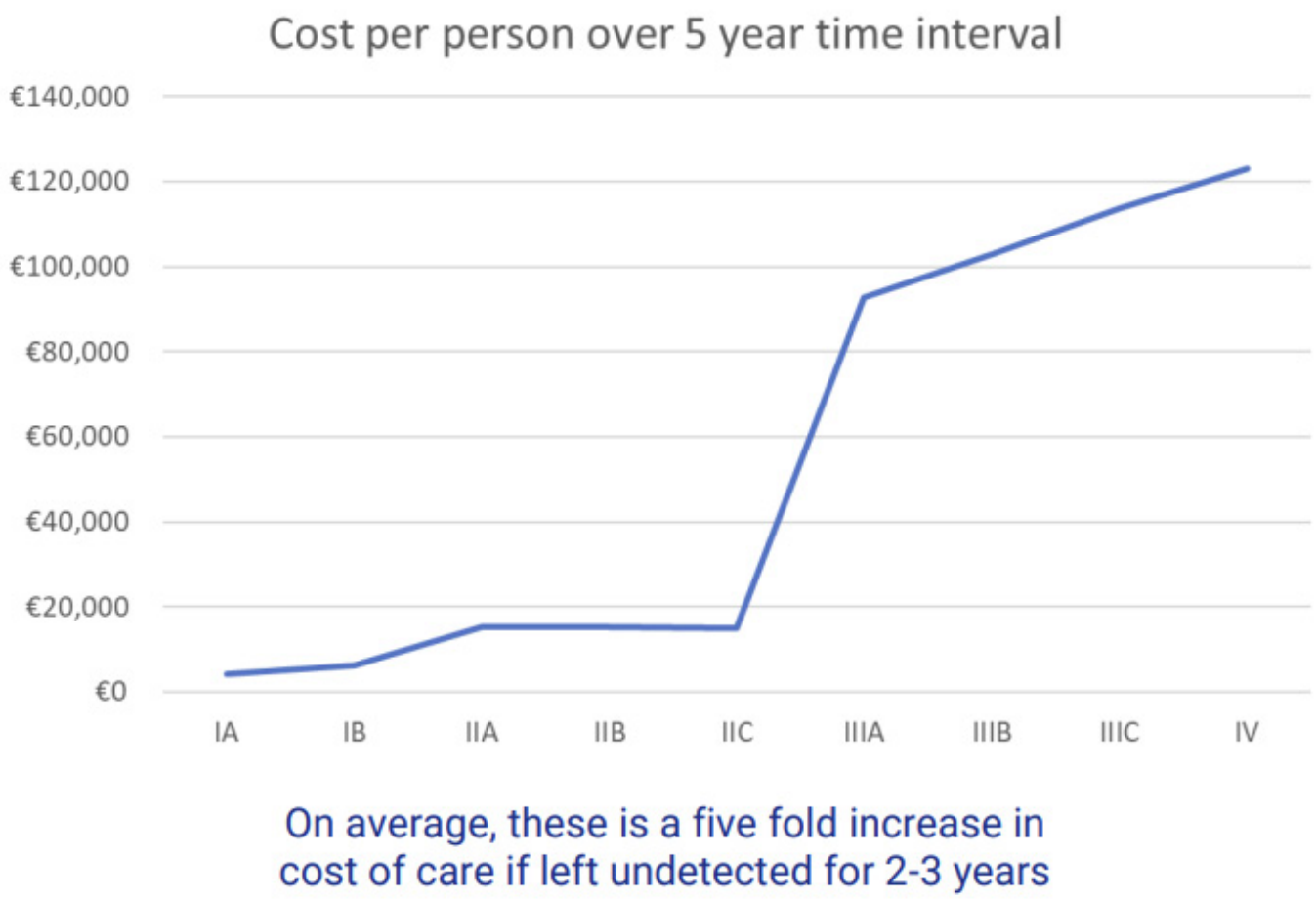

Figure 2. Skin Cancer Care Cost per Disease Stage. Source: AllView Healthcare

approach not only reduces costs but also offers a better experience and higher quality of life for both patients and, often, clinicians.

SL2-10X introduces a new perspective challenging the 'rule of rescue' that seems to guide modern health systems. Not only does it advocate for a shift in the care paradigm to the left, but it also emphasises the need to reallocate budgets and resources closer to home. UK Health Secretary Wes Streeting encapsulates this new paradigm when he suggests that the NHS should stand for a neighbourhood health service rather than a National Hospital Service.

Unfortunately, over the past decade, the UK has witnessed a trend where over 10% of resources and budget have been redirected towards hospitals. SL2-10X promotes a new mindset focused on proactive and preventative health measures, advocating for the reallocation of more funds and care to the left to proactively create and maintain health. This vision and business model aligns closely with the ideas presented by former NHS England CEO Nigel Crisp in his excellent book "Home is for Health, Hospitals are for Repairs: Building a Health and Health-Creating Society".

The financial consequences of failing to shift left can be illustrated by examining a specific disease. The cost per person of treating a class one disease is significantly lower than the expense of remediating and treating a stage four skin cancer. In Ireland, Allview Healthcare has introduced a digital dermatology service that allows patients to quickly visit an AllView centre to have high-quality digital photographs of their skin issues. These images are then reviewed by a panel of expert dermatologists within just a few days. Compare this to the average waiting list of over nine months for a standard public hospital appointment. Early diagnosis and treatment is better for patients, clinicians and the healthcare system in terms of outcomes, costs and experience.

Shifting Budget to the Left

In Europe, 97% of health budgets are focused on restoring ill health, while only 3% are allocated to proactive health and wellness (OECD 2021). Imagine the benefits to all if we could increase proactive health spending to 10%. Today, primary care in many Western countries, primarily provided by general practitioners (GPs), accounts for the majority of healthcare services but often receives only a small fraction of the total budget. For instance, in the UK, GP practices reportedly provide 90% of the care while receiving only 6% of the total budget.

> "The aim of every digital health intervention should be to implement a "Shift Left" strategy, leading to cost savings as well as improved outcomes, experiences and quality of life."

Simple digital innovations such as the Wilmslow GP triage system (Ahmed 2023) allow patients to submit their symptoms and information online. A clinician promptly reviews this data and determines the most appropriate next step: online, face-to-face or telephone consultation. This simple system helps ensure patients who need urgent care are seen promptly, while others can be managed without the need for a more expensive in-person consultation.

These kinds of solutions are win-win-win for the patients, clinicians and the overall system, providing better resource allocation, as well as more timely and more cost-effective care. Dr. Amar Ahmed says of the system: "A combination of modest tech with psychology, this approach has reduced unnecessary appointments, freeing up time for GPs to focus on more complex cases, improving patient satisfaction and improving psychological safety for our staff."

Shift Left of Resources and Workload

Shifting more care to the pharmacy would be a hugely untapped part of the health system. Dermot Twomey, former President of the Irish Pharmacy Union, suggests this as a key intervention to help ease the burden on the overall health system and improve access to care. In many countries, pharmacies account for the majority of clinical encounters. This is evident from the statistics in Ireland in 2021. There is an opportunity to empower and educate pharmacists to take on a greater role, which could lead to improved patient care and a better balance between supply and demand.

Empowering pharmacists to take on greater responsibilities, such as through the new prescribing legislation introduced in Ireland in 2024, is a step in the right direction. Steve Barclay, the former UK Health Secretary, drove a "Pharmacy First" approach in the UK. This initiative allowed community pharmacies to provide NHS consultations and prescribe prescription-only medications for common ailments such as sore throats, sinusitis, shingles and even simple urinary tract infections in women.

One significant outcome of the Pharmacy First initiative was quicker access to care for minor ailments, which alleviated pressure on the primary care system. This shift enabled GP practices to focus on more urgent and complex issues. As a result, the "Shift Left" approach not only increased the capacity of the healthcare system but also improved its effectiveness, benefiting patients, pharmacists and GPs.

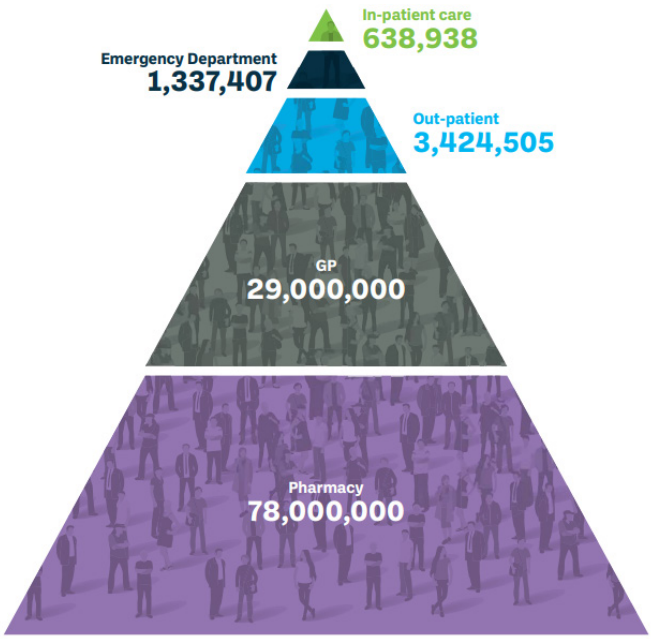

Figure 3. Patients Interaction Ireland – 2021. Source: Irish Pharmacy Union

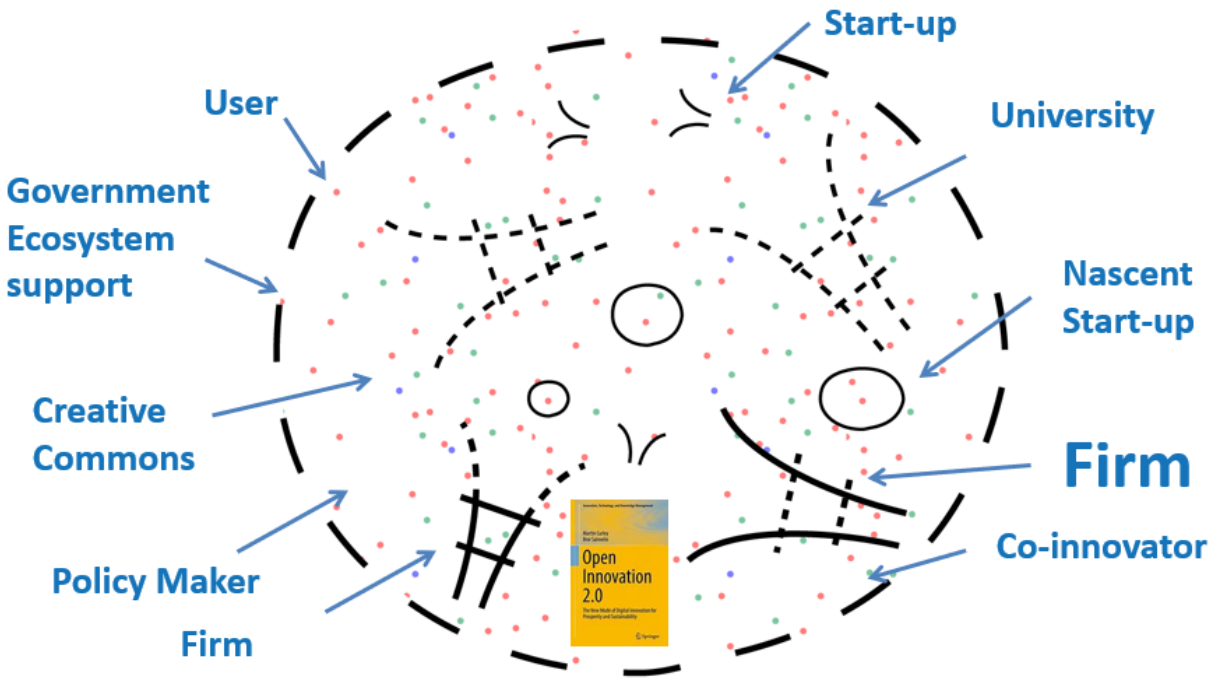

Figure 4. Open Collaborative Ecosystem. Source: M. Curley, B. Salmelin.

In the UK, this initiative saw widespread adoption, with over 95% (more than 10,000) of community pharmacies participating in the scheme. Additionally, a less recognised yet important benefit was that it allowed pharmacists to work at the top of their license, leading to increased job satisfaction and a more fulfilled career.

In cases where an OCE operates with a shared vision, such as "Stay Left, Shift Left-10X", we refer to it as a directed or guided OCE. A key phenomenon of OCEs is emergence, in which the interaction of organisations is aligned with an agreed-upon top-down vision, leading to new, higher-order functionalities and configurations. The following diagram depicts such a configuration where a multitude of actors working together can achieve far more than any one actor working on their own.

> "A combination of modest tech with psychology (…) has reduced unnecessary appointments, freeing up time for GPs to focus on more complex cases."

Use of a Directed or Guided Open Collaborative Ecosystem (D-OCE, G-OCE)

A new type of business configuration has emerged, known as an open collaborative ecosystem (OCE). According to Gastaldi et al. (2015), OCEs represent a fundamental shift in the competitive landscape of business. This concept was independently developed by Curley & Salmelin (2013) and Baldwin & von Hippel (2011). An OCE is characterised by a high level of trust and capability, where intensive interaction and innovation occur among participants across the quadruple helix—government, industry, academia and citizens/patients. These actors work interdependently to achieve aligned, amplified and accelerated transformation and results.

When these actors unite around a common vision and collaborate interdependently based on shared values, they can create significant collective value. This collaborative effort can lead to structural changes far greater than any single actor, regardless of their size, could achieve alone.

The distinction between a directed and guided OCE is significant. When an OCE is organised by a country's national health authority, we refer to it as a directed OCE (D-OCE). As the National Director for Digital Transformation at Ireland's Health Service Executive

(HSE), I established and led a D-OCE that achieved many transformational results (Curley 2024a).

Partly inspired by the ideas of Gastaldi et al. (2015), who argue that academics are well-positioned to serve as orchestrators of continuous innovation ecosystems, I transitioned and morphed the D-OCE into a guided OCE in response to ongoing organisational friction and resistance. This change coincided with the leadership of the OCE being transferred to the Innovation Value Institute (IVI) at Maynooth University. After a transition period, the guided OCE has continued to thrive and prosper (Curley 2024b), operating free from the inertia and resistance often imposed by bureaucratic public sector organisations.

A key question is which configuration—D-OCE or G-OCE—is more effective for driving system-wide healthcare change? The answer, of course, depends on various factors. Public sector organisations are typically designed for stable, steady-state operations, and their cultures are not often oriented toward adopting radical and disruptive innovations. However, when there is strong support from the Board and CEO, along with a dedicated budget, a D-OCE can be very effective in driving transformational change.

Health systems are inherently complex adaptive systems. Therefore, orchestrating change from the outside, such as in a G-OCE, can also yield significant results. Perhaps this is the key factor distinguishing which configuration more effectively achieves coordinated and cohesive commitment and action among various stakeholders toward a shared transformational vision.

Architectural and Disruptive Innovation

D/G-OCEs do not only facilitate disruptive innovation but also enable an architectural innovation approach, as described by Henderson and Clark (1990). This type of innovation can often be the most challenging to defend against and can yield significant industry disruption. In architectural innovation, new and existing components are reconfigured and connected/integrated in different ways, resulting in significant increases in functionality or even structural change within an industry.

A good example of architectural innovation is the simultaneous introduction of the iPod and iTunes. This shift fundamentally transformed the music industry by creating a new platform and an innovative business model for how music is sold and distributed. Similar transformations are not only possible but even inevitable in the healthcare industry. Erik Topol, a renowned cardiologist, notes that while medicine is historically resistant to change, the influx of data flowing through the system will inevitably drive transformation. He believes that mobile phones will play a key role in this shift, empowering patients.

In Ireland, a unique collaboration of eleven organisations worked together in a high-trust, high-capability framework to deliver a new service called the ‘Health Elevator’. This service allows citizens to visit their local pharmacy for a fifteen-minute health check to identify any significant risk factors. After this assessment, participants receive a personal electronic health record and a fitness device, such as a Fitbit.

The Health Elevator service exemplified the concepts of “Staying Left” and “Shifting Left” in healthcare. It involved leading companies like CarePlus pharmacies, Roche, Fitbit, AWS and notable small and medium enterprises (SMEs) such as PatientsKnowBest and FullHealthMedical. While the Health Elevator solutions provided great benefits to patients at a cost comparable to a PCR test, they faced strong resistance from the Strategy Division of Ireland’s national health organisation, HSE. This resistance highlights the difficulties often encountered in achieving adoption, even when clear tenfold benefits are available.

Lead User Innovation

In addition, such a D/G-OCE can be greatly enhanced by the democratisation of innovation through digital technologies, as noted by MIT’s Erik von Hippel (2006). This allows individual clinicians or even patients to develop innovations themselves using increasingly advanced digital tools and technologies rather than depending solely on innovations developed by manufacturers. Von Hippel refers to this process as Lead User Innovation.

According to Von Hippel (2006), user-centred innovation offers great advantages over manufacturer-centric innovation. With amazing developments in digital technology and data, users are increasingly able to innovate for themselves. This enables them to create exactly what they need or want, particularly in the realm of information products such as electronic health records.

We are witnessing a growing trend towards a ‘Lead User’ approach (von Hippel 2006), where clinicians co-design and co-develop products with significant patient involvement. Lead users are those who are often significantly ahead of the majority of users in their populations regarding an important unmet need or

Digital Transformation Capability Maturity Framework

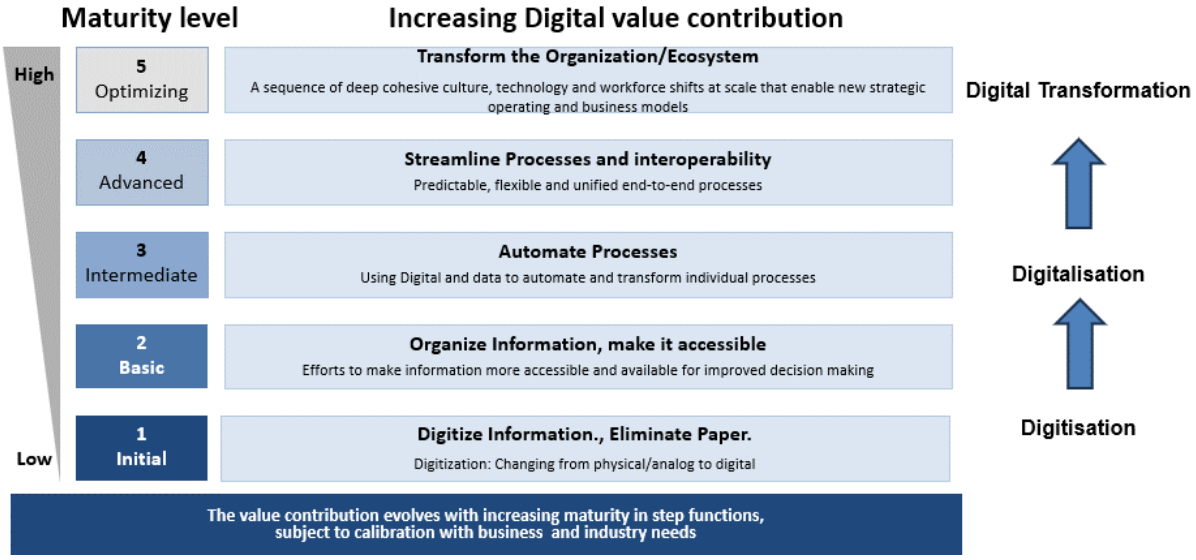

Figure 5. Digital Transformation Journey CMF. Source: M. Curley et al.

significant market trend. According to von Hippel, the ability of a user to innovate is improving radically and rapidly due to several factors:

1. Continuously improving the quality and capabilities of software, networks and hardware.
2. Increasing access to components (often API-enabled) and easy-to-use tools such as Low-Code platforms.
3. Access to ever-expanding and richer innovation commons.

On the island of Ireland, lead users such as Dr. Roisin Molloy (non-contact infrared thermometer), Eoin O'Reilly (Digital Dermatology) and Aonghus Shortt (Foodmarble Digital Digestive Measurement Device and App) are all examples of this trend. Their innovations are aligned in the same direction within the SL2-10X paradigm, contributing collectively to the acceleration of the shift towards a more efficient, effective and improved health system. The cumulative effect of their digital health innovations enhances this movement, promoting better overall healthcare experiences.

Capability Maturity Frameworks as Effective Management Tools for Improvement

Capability Maturity Frameworks (CMFs) are breakthrough management tools. They represent various levels and stages an organisation, ecosystem or industry goes through as it defines, implements, measures, controls and improves its process and outcomes. CMFs can be used to structure and codify best practices and invent new methods to drive structural change within an industry when applied systematically through Capability Improvement Programmes (CIPs).

Unlike Maturity Models, CMFs focus on both process and outcome maturity rather than process maturity. As Peter Drucker pointed out, "The problem for managers

> "When these actors unite around a common vision and collaborate interdependently based on shared values, they can create significant collective value."

often is not how to do, but what to do". CMFs offer leaders and managers a roadmap for improvement, along with assessment tools and a compilation of best and next practices based on the collective intelligence of the industry that developed the CMF. A good example of a CMF is the IT Capability Maturity Framework (Curley et al 2016) which has been widely used across multiple industries, including healthcare, to improve IT capability and the returns generated from IT investments.

Digital Health and Wellness Capability Maturity Framework

Digital transformation presents one of the best opportunities for health systems to address the myriads of existing challenges. The figure below sketches an evolutionary improvement path for these systems, which progresses through moving through phases of digitisation, digitalisation and, ultimately, full digital transformation. This final stage represents a broad, coordinated transformation at scale. As shown in the figure, digital transformation involves deep shifts in culture, workforce and technology that enable new operating and business models. Vial (2019) defines digital transformation as a "process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication and connectivity technologies".

There is significant hope that digital and data technologies can serve as a radical transformative force for health systems and improve individual health globally. We can be inspired by Peter Diamandis's quote: "When something is digitised, it starts to perform like an exponential technology". At the Innovation Value Institute at Maynooth University in Ireland, efforts are underway to build a Digital Health and Wellness Capability Maturity Framework (DHW-CMF). This framework aims to help leaders and managers assess their progress on the digital transformation journey and offer recommended next steps and actions based on their current level of maturity.

The proposed DHS-CMF will provide a set of integrated design patterns and associated assessment tools that will enable leaders and managers to select the right digital interventions, significantly increasing the likelihood of their success. The use of the DHW-CMF should help accelerate the path to achieving these goals. As Seneca the Elder once said, "The way is long if you follow precepts (rules); the way is short if you follow patterns".

Conflict of Interest

None

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Transforming Diagnostics Through Artificial Intelligence: Insights from Moscow's Healthcare Integration

Moscow's AI healthcare initiative transforms diagnostics and treatment, using advanced tools to detect conditions like lung cancer, pneumonia, breast cancer, spine osteoporosis, stroke, gallstone disease etc. AI improves accuracy, speeds workflows and prioritises preventative care. Public performance evaluations and regulatory standards ensure safety and effectiveness, setting a global standard. This initiative showcases the synergy of technology and medical expertise for accessible, precise and efficient healthcare systems.

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key points

- AI enhances healthcare in Moscow, improving accuracy in radiology.
- Automated tools optimise radiology workflows.
- Preventative care with AI improves early detection, reducing burdens on healthcare workers.
- Rigorous testing and public evaluations ensure safe and effective AI deployment.
- Moscow sets a global standard for AI integration in healthcare.

The Center for Diagnostics and Telemedicine of the Moscow Healthcare Department is a leading scientific organisation within the Social Development Complex of the Moscow Mayor's Office. It focuses on the integration of artificial intelligence in medicine, advancement of radiology, management of medical departments, research and education of healthcare professionals.

The Center is at the forefront of integrating artificial intelligence (AI) into healthcare, marking a significant milestone in medical innovation. From detecting gallstones with precision to enhancing the early diagnosis of breast cancer, AI applications are profoundly transforming diagnostics and treatment. This technological advancement is not limited to a single use case but spans multiple domains, improving diagnostic accuracy and enabling early interventions for various medical conditions. These pioneering efforts highlight AI's potential to modernise healthcare systems around the world.

Innovative AI Tool Enhances Abdominal CT Scan Analysis for Cholelithiasis

A new artificial intelligence service for the detection of gallstone disease on CT scans has been launched in Moscow. This advanced neural network automates the identification of gallstones in the gallbladder, accurately measuring their size and accelerating the diagnostic process. Such technological innovation is expected to enhance the likelihood of successful treatment and patient recovery.

Anastasia Rakova, Deputy Mayor of Moscow for Social Development, remarked on the initiative, highlighting the city's active integration of artificial intelligence into its healthcare system. She explained that an algorithm designed to detect gallstone disease on CT scans of abdominal organs had been deployed for the first time. According to her, this condition affects one in five adult patients on average and often remains asymptomatic for long periods, which poses challenges for timely diagnosis. In this case, radiologists can resort to computed tomography (CT), a highly regarded diagnostic tool, especially when initial assessments are inconclusive or require confirmation. Computer vision technology is a crucial support mechanism for radiologists, drawing their attention to the presence of gallstones and providing automatic size measurements, thereby enhancing diagnostic efficiency.

Prior to implementation in real patient cases, the AI service underwent rigorous testing to ensure its efficacy in identifying gallstones without mistakenly interpreting other conditions as anomalies. The integration of computer vision technology in medical practice aims to reduce diagnostic time and enhance accuracy.

Yuri Vasiliev, Chief Consultant for Radiology and CEO of the Center for Diagnostics and Telemedicine of the Moscow Healthcare Department, explained that developing artificial intelligence capabilities within the healthcare sector aims to automate processes, freeing radiologists from repetitive measurements. These algorithms also serve as tools for validating clinical assessments, enabling physicians to cross-verify their evaluations. Vasiliev expressed satisfaction that the capital's innovations would soon be accessible to regions nationwide. At the beginning of 2024, the Moscow artificial intelligence platform 'MosMedAI' was launched for healthcare professionals, offering 17 AI services designed to assist radiologists in detecting various conditions, including osteoporosis, breast cancer, pneumonia and other diseases.

The Moscow Experiment: Advancing AI in Healthcare

Moscow was among the first cities globally to integrate computer vision technologies into healthcare. Initiated in 2019, the experiment is managed by the Center for Diagnostics and Telemedicine in collaboration with the Moscow Social Development Complex and the Department of Information Technology. It represents the world's largest prospective scientific study in this field.

> "AI reduces the time required to interpret mammograms by over eight times while maintaining high diagnostic accuracy."

When a patient undergoes an imaging procedure, the results are automatically uploaded to the Unified Radiological Information Service (URIS) of the Unified Medical Information and Analytical System (UMIAS). Neural networks analyse the images in real time, detecting signs of pathology, making measurements and highlighting findings for radiologists. Radiologists receive both the original and AI-processed studies to form their final report.

Currently, 150 medical facilities in Moscow, including children's hospitals, use these technologies. Moscow specialists develop and test services, ensuring rigorous control over their performance. Current algorithms are nearing the high level of precision typically associated with medical professionals.

Neural networks assist in identifying signs of lung cancer, pneumonia, spine osteoporosis, aortic aneurysm, ischaemic heart disease, stroke and pulmonary hypertension. AI significantly supports physicians by streamlining workflows and enhancing diagnostic accuracy while maintaining the physician's leading role in patient care.

The Moscow experiment ensures strict oversight of AI solutions, with doctors and scientists closely monitoring their performance. Algorithms undergo continuous evaluation, and any underperforming service is revised. The testing and subsequent refinement of services constitute a vital phase of the experiment. Notably, the experiment integrates public and open assessment of the algorithms' quality from the outset. Since 2023, algorithm performance has been publicly assessed through a "maturity matrix," offering quarterly reports that track accuracy and improvements (Center of Diagnostics and Telemedicine 2024).

This approach allows medical institutions to evaluate service effectiveness and provides developers with benchmarks to refine their products. In summary, these public quarterly reports offer a comprehensive analysis of the performance of all AI solutions utilised by radiologists. Using the matrix, specialists from medical institutions can evaluate the accuracy of specific services and monitor their quality improvement over time. Moreover, algorithm developers can compare their products against similar offerings, facilitating improvement to meet industry standards.

"Gallstone disease (…) affects one in five adult patients on average and often remains asymptomatic for long periods."

To establish a regulatory framework for AI in medicine, national standards (GOSTs) have been developed by the Center for Diagnostics and Telemedicine. These standards outline requirements for the technical and clinical trials of AI in radiology, culminating in a registration certificate that authorises their use in hospitals. Beyond these standards, experts emphasise the need for robust regulations on methodology for clinical trials, data requirements and ongoing software quality control to ensure safe AI deployment.

Effective regulation of software quality control methods post-state registration is essential, along with timely updating of registration certificates as new

software versions are released. Ensuring the safety of AI applications in medicine is a top priority for the Center for Diagnostics and Telemedicine of the Moscow Healthcare Department.

> "The integration of artificial intelligence into Moscow's healthcare system exemplifies how technology can deeply transform medical practices."

To date, radiologists in Moscow have access to over 50 different AI services supporting imaging studies' interpretation. Of these, nine integrated solutions are actively operational in the healthcare sector, with the neural network designed to detect multiple diseases on a single medical image. This development aligns with Moscow's healthcare strategy, which outlines initiatives extending through 2030.

Preventative Imaging and AI in Routine Mammograms

Breast cancer is currently one of the most prevalent cancers among women. Various social, demographic and economic factors contribute to delayed diagnoses. To address this issue, radiologists advocate for the early identification of potential signs of breast cancer through screening. This approach entails mass examinations of the population, including asymptomatic individuals, utilising the safest and most straightforward method available—mammography. Mammography is a safe and effective method, exposing women to a minimal radiation dose of approximately 0.25 mSv, well within the annual safety limit of 1 mSv for preventative procedures.

According to Russian normative documents, mammography results must be reviewed by two radiologists to ensure diagnostic accuracy and minimise the risk of missed pathologies. This double reading is particularly critical during screening, where timely identification of abnormalities is essential for early intervention. However, mammography is a complex diagnostic modality requiring significant expertise and experience, especially for detecting early-stage disease. Since 2019, the Ministry of Health of the Russian Federation has mandated biennial mammography screenings for women aged 40 to 75 years, with the goal of achieving 100% population coverage within the recommended age group. Meeting this demand poses significant challenges for the healthcare system, including financial costs and a shortage of qualified radiologists. As the demand for this type of imaging study continues to rise, there will inevitably be a shortage of radiologists available to conduct mass screening programmes.

The Role of AI in Screening Programmes

One potential solution to this challenge lies in the implementation of artificial intelligence and automation. Artificial intelligence offers a transformative solution to these challenges by automating and streamlining key aspects of the screening process. Neural networks can analyse large volumes of medical images far faster than humans, flagging those that require immediate attention.

In Moscow, AI is now integrated into several stages of the radiology workflow:

1. **Radiology Decision Support System.** AI simplifies and accelerates radiology report preparation by providing pre-filled templates with standardised descriptions of common pathologies. Radiologists review and finalise these protocols, significantly reducing their workload.
2. **Automated Measurements:** AI performs precise morphometric analyses, including length, area and volume measurements. These routine tasks, now significantly automated, are conducted with greater accuracy than manual methods. In other words, it works like a kind of ruler.
3. **First Opinion in Mass Screening:** Artificial intelligence has progressed beyond experimental phases and is now being integrated as a practical healthcare service within the framework of compulsory health insurance. Since early 2023, the double-reading of mammograms for residents of Moscow has been conducted by both artificial

intelligence and a radiologist. This AI-powered medical device is fully authorised for use under Russia's regulatory framework and is integrated into the national compulsory health insurance system. Moscow has reported positive outcomes from this implementation.

Proven Benefits

Moscow's implementation of AI in mammography has yielded significant benefits. Research by the Center for Diagnostics and Telemedicine demonstrates that AI reduces the time required to interpret mammograms by over eight times while maintaining high diagnostic accuracy. This efficiency enables faster results delivery to patients and allows radiologists to allocate their time more effectively.

AI integration has also encouraged a shift in focus towards preventative medicine. Early detection through screening significantly increases the chances of successful treatment and reduces the overall burden on the healthcare system. Additionally, AI-driven tools provide consistent, high-quality results that help eliminate variability caused by human error, ensuring equitable healthcare outcomes.

By combining AI's speed and precision with radiologists' expertise, Moscow has set a benchmark for leveraging technology to enhance early detection and improve breast cancer outcomes in large-scale preventative healthcare.

Conclusion

The integration of artificial intelligence into Moscow's healthcare system exemplifies how technology can deeply transform medical practices. The deployment of AI systems in identifying gallstones and breast cancer, among other conditions, showcases the versatility and effectiveness of AI in addressing diverse healthcare challenges.

Furthermore, AI enables the prioritisation of preventative measures, such as the early detection of conditions that might otherwise go unnoticed until advanced stages. AI also promotes consistency and quality in diagnostic practices, minimising the variability introduced by human error and fostering equitable healthcare for all.

The public transparency of algorithm performance, coupled with stringent regulatory standards, ensures that these technologies remain safe and effective. The Center's commitment to innovation, rigorous testing and continuous refinement sets a benchmark to follow. As these AI systems expand to other regions, they have the potential to redefine global healthcare norms.

By blending technological innovation with medical expertise, Moscow exemplifies the transformative potential of AI when applied thoughtfully and systematically. The city's achievements in healthcare technology serve as an inspiring model for the integration of AI into medical systems worldwide, promising a future where healthcare is more precise, accessible and impactful.

Conflict of Interest

None

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The Role of Emerging Technologies in Health Management: From AI to Smart Health Solutions

Advancements in AI, smart devices and digital health tools have transformed healthcare, enhancing personalised management, early diagnostics and system efficiency. These innovations improve fitness monitoring, mental health support and urban health systems with smart gym equipment, fitness apps, AI-powered trainers and telehealth platforms. Smart city concepts use AI and sensors to monitor and enhance urban well-being. This integrated approach promotes efficient, accessible and inclusive healthcare.

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key points

- AI and smart devices enhance personalised healthcare and diagnostic accuracy.
- Smart gym equipment and apps enable real-time fitness tracking and chronic disease management.
- AI-powered trainers provide customised workouts and support rehabilitation and injury prevention.
- Digital tools like telehealth and AI chatbots improve mental health support, especially for the elderly.
- Smart city technologies optimise public health through real-time monitoring and urban planning.

In recent years, technological advancements have significantly transformed various aspects of healthcare, leading to improvements in personalised health management and overall system efficiency. The integration of tools such as artificial intelligence (AI) and smart devices enables healthcare professionals, patients and administrators to tackle complex challenges with greater precision and effectiveness. These innovations are not only enhancing the quality of care but also broadening the scope of preventive health measures, early diagnostics and patient engagement. By using AI-powered solutions, smart health equipment and digital health applications, the healthcare industry is witnessing transformative improvements in areas such as fitness, mental health management and the development of healthier urban environments.

AI and Bias Mitigation in Healthcare

Artificial intelligence offers great potential for the healthcare industry, but concerns regarding AI biases have been a critical issue (Lee et al. 2022). These algorithm biases can significantly affect patient outcomes, as decisions made by AI directly impact healthcare. Fortunately, recent advancements have introduced methods to mitigate these biases. Techniques such as algorithmic audits, diverse training datasets and human oversight help ensure that AI-driven diagnostics and treatment recommendations are fair, accurate and inclusive.

Artificial intelligence can detect subtle patterns in medical data, improving diagnostic accuracy and enabling personalised treatment plans. Algorithms

designed to minimise biases are especially valuable in identifying patterns among diverse patient populations, promoting healthcare equity. This capability is essential in fields such as cardiovascular care, diabetes management and early cancer detection (Obermeyer 2019).

Transforming Fitness and Healthcare through AI-Powered Technology and Personalisation

Advancements in fitness technology, particularly with the integration of smart home gym equipment and wearable devices, have transformed the way users engage with their health. These AI-powered tools allow real-time monitoring and tracking of various health metrics, such as physical activity and heart rate variability. This innovation opens new avenues for health management professionals, enabling more personalised healthcare and informed patient support. In the context of chronic disease management, these tools are invaluable, allowing ongoing health monitoring at home, which can reduce hospital readmissions and improve patient outcomes (Khowaja 2023).

Alongside smart equipment, fitness-tracking apps have gained popularity for their ability to help users set, track and achieve health-related goals. Equipped with advanced data analytics and user-friendly interfaces, these apps are essential for those managing fitness, chronic conditions or overall well-being. Healthcare professionals increasingly recommend these apps as part of comprehensive health management plans, providing patients with accessible and engaging ways to monitor key metrics like calorie consumption, sleep patterns and workout intensity. As these apps integrate with broader health systems, they play a growing role in preventive health management and enhance patient engagement.

AI-powered personal trainers further revolutionise the fitness landscape by offering customised workout programmes based on real-time data analysis (Chui 2020). These trainers adapt exercise routines to users' fitness levels and health statuses, assisting with rehabilitation programmes, injury prevention and overall physical well-being. Additionally, AI-driven fitness platforms reduce barriers to exercise by enabling users to engage in workouts from their homes, making fitness more accessible. Health management professionals can incorporate AI personal trainers into rehabilitation or fitness plans, ensuring continuity of care outside the clinical setting and promoting long-term health improvements (Chen 2017).

Technology's Role in Mental Health Management

As mental health becomes a growing global concern, technology is playing an essential role in addressing these issues, especially among older adults. AI-powered chatbots, wearable devices and telehealth platforms are increasingly being utilised to provide mental health support. For example, wearable sensors can monitor stress levels and sleep patterns, alerting users and healthcare providers when intervention may be needed.

AI-driven mental health tools allow for personalised care by analysing behavioural and emotional data. This enables mental health professionals to intervene earlier, preventing more serious conditions from developing. The ability to offer remote mental health care is particularly valuable for elderly patients who may have limited access to traditional in-person services (World Health Organisation 2021).

"AI-powered personal trainers further revolutionise the fitness landscape by offering customised workout programmes based on real-time data analysis."

Smart Cities and Public Health Management

The concept of smart cities includes a variety of health-related applications designed to enhance urban health management (Smart Cities Council 2022). By leveraging advanced technologies, urban planners can develop more efficient healthcare systems and create healthier living environments. Tools such as AI-driven platforms, smart sensors and comprehensive

data analytics systems are central to these efforts. These technologies allow for real-time monitoring of environmental and health-related factors, such as air quality, traffic emissions and water safety, which are critical to safeguarding public health. By integrating these smart solutions into city planning, urban populations experience a significant improvement in their overall well-being, with efficient healthcare services, quicker emergency responses and healthier living conditions. This holistic approach to urban planning not only boosts public health outcomes but also sets the foundation for sustainable and resilient cities.

> "The concept of smart cities includes a variety of health-related applications designed to enhance urban health management."

The integration of advanced technologies such as AI, smart devices and digital health applications has profoundly transformed healthcare. These innovations have enhanced personal health management, improved diagnostic accuracy and expanded preventive measures, making healthcare more effective and accessible. From managing fitness and chronic disease to providing mental health support and planning for urban health, these tools offer healthcare professionals new ways to deliver tailored and timely care.

Embracing these advancements not only empowers patients to take a proactive role in their health but also paves the way for more equitable, efficient and inclusive healthcare systems. With the development of these technologies, the healthcare industry must commit to integrating them thoughtfully to optimise patient outcomes and promote healthier communities.

Conflict of Interest

None

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Talent Management

Transforming Healthcare Excellence Through Strategic Workforce Well-being: A Global Perspective

Global strategies to improve healthcare workforce well-being focus on combating burnout and stress through innovative approaches. Examples include India's telemedicine mental health systems and Denmark's data-driven digital tools. Financial investment, cultural integration and emerging technologies are highlighted as key components for fostering workforce resilience. Prioritising well-being not only enhances staff satisfaction but also ensures improved patient care and sustainable healthcare outcomes.

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key points

- Workforce well-being improves healthcare outcomes and staff satisfaction.
- Global programmes showcase scalable, cost-effective strategies for workforce well-being.
- Financial investments yield savings via reduced turnover and improved productivity.
- Cultural integration ensures success, blending traditions with modern methods.
- Emerging technologies like AI and VR enhance resilience and mental health support.

Introduction

The evolution of the healthcare sector increasingly relies on the resilience and adaptability of its staff. Healthcare workers face immense challenges, including long hours, emotional strain and high-pressure environments. Recent data indicates a troubling trend: in the United Arab Emirates, mental health disorders among healthcare personnel have risen by 14%, while New Zealand reports a burnout rate of 21% among physicians. In Europe, the situation mirrors these troubling trends. Sweden has documented that 30% of healthcare workers endure considerable occupational stress, while over 25% of medical professionals in Germany exhibit clear signs of emotional exhaustion. These statistics underscore the urgent need for comprehensive and sustainable workforce well-being strategies across the globe.

Insights from Global South: Integrating Modern Technology with Traditional Practices

Healthcare systems across the world, particularly in developing nations within the Global South, are adopting innovative programmes tailored to address unique cultural and systemic challenges. India's National Digital Health Mission, for instance, has pioneered a telemedicine-based mental health support system that focuses on rural healthcare workers. Launched in 2021, this initiative has reduced burnout rates by 25% among workers in rural areas, benefiting over 150,000 healthcare professionals across 18 states. The programme provides 24/7 multilingual mental health support in 12 regional languages, using AI-powered tools for initial assessments and peer support networks to connect rural workers with urban professionals. By integrating virtual counselling through mobile

applications, mental health webinars and emergency response protocols, India has created a cost-effective solution at just $2 per healthcare worker per month.

traditional Eastern medicine with modern therapies while emphasising family-centred support systems. In Indonesia, a "Digital Wellness" platform utilises

> "In the United Arab Emirates, mental health disorders among healthcare personnel have risen by 14%."

Similarly, South Africa's Department of Health has embraced a mobile-first approach through the "Healthcare Heroes" initiative. This innovative programme reaches 70% of healthcare workers through mobile devices, achieving a 40% reduction in reported stress levels. Implemented in 350 healthcare facilities nationwide, it engages 85% of registered participants through daily wellness check-ins, mindfulness tools and career development resources. The initiative's success lies in its accessibility and integration with existing national health worker support systems.

In Brazil, the "Saúde Integral" programme blends traditional healing practices with modern psychological approaches. With a network of 5,000 community health workers operating across 15 states and 200 municipalities, Brazil has seen a 35% improvement in worker satisfaction scores. Local support circles, cultural celebration activities and traditional stress management techniques are combined with modern therapies like cognitive behavioural therapy. The programme's family-inclusive systems ensure healthcare professionals receive community-driven support, promoting resilience and connection.

Kenya's "Afya Bora" initiative focuses on peer support programmes that are both impactful and cost-effective. By training 2,000 peer supporters across 47 counties, the initiative has reached 15,000 healthcare workers while reducing implementation costs by 60% compared to conventional support programmes. Peer-to-peer counselling networks, monthly group meetings and crisis intervention teams provide a sense of community and practical mental health assistance.

Southeast Asian countries, including Thailand, Vietnam and Indonesia, have also adapted Western frameworks for workforce well-being while respecting local traditions. Thailand's "Mind-Body Balance" programme integrates Buddhist mindfulness practices with Western psychological approaches, successfully reaching 80% of public hospital staff and reducing burnout by 30%. Vietnam's "Harmony in Healthcare" initiative blends

European digital tools adapted to cultural and linguistic contexts, incorporating support in five major dialects and Islamic wellness practices.

The success of these programmes highlights the importance of cultural integration, cost-effective models and the utilisation of technology. By embracing local traditions, leveraging existing infrastructure and building sustainable capacity, these initiatives demonstrate that workforce well-being can be achieved in diverse healthcare settings.

Insights from Europe: Data-Driven Well-being Approaches

The role of data and technology in workforce well-being has become increasingly prominent, particularly in developed healthcare systems. In Denmark, a comprehensive digital well-being monitoring system has significantly reduced burnout rates by 18%. Real-time sentiment analysis through digital platforms allows for the early identification of stress indicators, enabling timely interventions. Wearable devices provide continuous monitoring of healthcare professionals' stress levels, offering objective data for analysis. AI-powered chatbots deliver immediate mental health support in multiple languages, while automated tracking systems integrate with electronic health records to ensure comprehensive monitoring.

Similarly, the Netherlands has implemented evidence-based measurement tools through its "Healthcare Worker Well-being Index." This initiative utilises validated psychological assessment instruments and WHO-aligned well-being metrics to measure and track staff satisfaction and productivity. Regular employee engagement surveys, performance impact analyses and environmental factor assessments provide a holistic understanding of workforce well-being. Such data-driven approaches ensure that organisations can make informed decisions to address workforce challenges effectively.

Person-centred support systems further enhance these efforts. Finland's "Comprehensive Care for Carers" programme offers individualised mental health assessments and interventions tailored to each healthcare professional's needs. By providing culture-specific support options and career-stage appropriate resources, the programme addresses the diverse challenges faced by healthcare staff. In the United Kingdom, the National Health Service (NHS) has developed an accessible psychological support framework featuring 24/7 virtual counselling, hybrid in-person and digital services, and multi-language support. This ensures that healthcare workers across the NHS can access assistance whenever and wherever needed.

technology leasing options and leveraging grants or government funding opportunities can further mitigate the financial burden of these programmes. The impact of these data-driven and person-centred approaches is measurable. German hospitals report a 15% improvement in patient satisfaction scores, while French healthcare systems have reduced medical error rates by 20%. Spanish medical centres have seen a 25% increase in staff retention, highlighting the significant benefits of workforce well-being programmes. Organisational metrics further underscore the importance of these efforts. Swedish hospitals have reported a 30% reduction in absenteeism, while Norwegian healthcare providers have experienced a 40% decrease in staff turnover. Danish medical facilities have seen a 20% improvement in productivity measures, demonstrating the wide-ranging benefits of implementing these initiatives.

"Wearable devices provide continuous monitoring of healthcare professionals' stress levels."

Organisational frameworks also play a crucial role in workforce well-being. Switzerland, for example, has demonstrated success by aligning workforce support strategies with national health policies and organisational excellence metrics. Executive-level accountability, regular programme evaluations and adaptive improvement processes have been key to sustaining the success of these initiatives.

Financial Investment and Returns

Implementing workforce well-being programmes often requires substantial initial investment. For example, digital infrastructure costs can range from €50,000 to €200,000 per facility, while training programmes may cost €1,000 to €5,000 per employee annually. Support system setups can require organisation-wide investments of €100,000 to €500,000. However, these costs are often offset by significant returns. Savings from reduced staff turnover can amount to €50,000 to €100,000 per retained employee. Productivity gains of 15% to 25% and annual savings of €500,000 to €1 million from reduced medical errors further highlight the financial benefits. Additionally, organisations can achieve insurance premium reductions of 10% to 15% annually, adding to the overall return on investment.

Cost-effective solutions such as tiered implementation approaches, resource sharing across facilities,

Implementation Strategies and Challenges

While success stories abound, implementing workforce well-being programmes, particularly in developing countries, comes with unique challenges. Resource constraints often pose the biggest hurdle. Countries like Kenya and India have addressed this issue by adopting phased implementation strategies, focusing on high-impact, low-cost initiatives in the initial stages. Public-private partnerships and grants have been essential in securing funding for these programmes.

Technological infrastructure remains another barrier, particularly in rural or underserved regions. Hybrid systems that combine digital and analogue approaches have proven effective. For instance, smartphone applications for stress tracking can be complemented by paper-based resources to ensure inclusivity. Partnerships with technology providers can further reduce costs through subsidised solutions.

Staff resistance to change is also a common challenge. Change management programmes that include training, peer champion networks and incentive systems can help overcome this barrier. Demonstrable quick wins, such as visible improvements in stress levels

or workplace satisfaction, build trust and encourage wider participation.

Cultural competency frameworks are essential for ensuring the effectiveness of well-being initiatives. In the Middle East, gender-sensitive and faith-aligned support systems play a critical role, while in Asia-Pacific, collective well-being and hierarchical respect are prioritised. African countries focus on community-based support and the integration of traditional healing practices. Regular stakeholder engagement, cultural advisory boards and feedback mechanisms ensure that these programmes remain relevant to local needs.

"AI-powered predictive analytics can identify burnout risks before they escalate."

Future Directions

In the future, emerging technologies are expected to play an even greater role in workforce well-being. AI-powered predictive analytics can identify burnout risks before they escalate, enabling organisations to implement proactive interventions. Blockchain-based platforms offer secure and anonymous support systems, ensuring confidentiality for healthcare workers. Virtual reality technologies can provide resilience-building training, simulating real-world stressors in a safe environment. IoT devices will enable real-time monitoring of physical and mental health indicators, integrating with smart hospital systems to create a supportive ecosystem for healthcare workers.

Research priorities for the future include long-term impact studies to understand the sustainability of well-being programmes across different healthcare settings. Cost-benefit analyses will provide insights into the economic returns of these initiatives, encouraging greater investment. Additionally, cultural adaptation research and cross-border collaborations will foster innovation and knowledge sharing, strengthening global workforce well-being efforts.

Concluding Remarks

The enhancement of healthcare quality through workforce well-being signifies a pivotal shift in organisational talent management. Evidence from healthcare systems in Europe, the UAE, New Zealand and the Global South demonstrates that comprehensive well-being programmes deliver measurable improvements in both staff satisfaction and patient care outcomes. Healthcare organisations that embrace data-driven methodologies, person-centred support systems and strong organisational frameworks position themselves as leaders in an increasingly competitive sector.

By prioritising workforce well-being, healthcare institutions not only create sustainable environments for their staff but also ensure the delivery of high-quality patient care. The integration of emerging technologies and innovative well-being strategies will set new benchmarks for organisational excellence. Ultimately, the future of healthcare depends on recognising and nurturing the human capital that drives its success, fostering a resilient, satisfied and high-performing workforce.

Conflict of Interest

None

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Care Optimisation

Evaluating Value-Based Healthcare: The Role of Econometric Models in Integrated Care Pathways

Value-Based Healthcare (VBHC) adoption in Europe faces barriers, including conflicting priorities on outcomes and limitations in traditional economic models like Health Technology Assessment. Econometric methods such as Difference-in-Differences and Synthetic Control offer solutions by evaluating interventions like Integrated Care Pathways (ICPs). These models assess clinical, operational and societal value, linking improvements in outcomes and efficiency to sustainable, evidence-based healthcare decisions.

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key points

- VBHC in Europe struggles with conflicting priorities and inadequate traditional evaluation models.
- Econometric methods like Difference-in-Differences improve VBHC impact assessment.
- Integrated Care Pathways streamline care, enhancing outcomes and operational efficiency.
- Econometric models link interventions to clinical, operational and societal healthcare value.
- Evidence-based approaches support sustainable, scalable VBHC initiatives across systems.

The adoption of Value-Based Healthcare (VBHC) in Europe is progressing slowly, and there are valid reasons for this hesitancy. One significant issue is the lack of consensus on which health outcomes should be prioritised and the methods used to measure them. Patients, payers and society often have differing priorities, which complicates the task of aligning these perspectives within a unified framework. Moreover, existing economic modelling approaches, such as those used in Health Technology Assessment (HTA), tend to focus narrowly on individual therapies. This narrow focus makes them poorly suited for evaluating the broader dynamics of care delivery, including the interplay between acute care, community-based treatment and coordinated pathways. Adopting an econometric approach, rather than relying solely on traditional HTA, presents a promising way to bridge these gaps. This article explores how econometric modelling can be utilised to evaluate VBHC initiatives, using Integrated Care Pathways as a practical example.

Integrated Care Pathways (ICPs) are structured, evidence-based frameworks designed to streamline care delivery for specific conditions or clinical processes (van der Feltz-Cornelis et al. 2023). ICPs can be implemented in both acute care settings and community-based environments. By standardising interventions, promoting multidisciplinary collaboration and coordinating care across different settings, they aim to improve clinical outcomes, enhance operational efficiency and reduce healthcare costs. Their relevance to Value-Based Healthcare (VBHC) lies in their systemic approach, encompassing multiple interventions rather than focusing on a single treatment or diagnostic procedure. This makes their evaluation more complex but critical for understanding the broader creation of value in healthcare.

Economic Modelling Approaches

Econometric approaches offer a unique advantage in determining value because they address causality, ie quantify the degree of deviation in outcomes attributable to a particular treatment or pathway (Angrist 2022). By establishing a causal relationship between the intervention and the observed outcomes, these methods provide an evidence-based starting point for assessing value. This approach firstly shifts the focus to outcomes, allowing providers and payers to subsequently assess the financial and operational implications within a business context.

In contrast, Health Technology Assessment (HTA) often begins with a life sciences organisation setting a price for a therapy. Following this, the HTA process evaluates whether this price aligns with the payer's willingness to pay, using cost-effectiveness thresholds as a framework. While HTA excels in assessing whether a specific intervention justifies its cost (Mundy et al. 2024), econometric modelling is more suitable for a broader VBHC framework. In this context, the priority is to understand how coordinated care interventions create value across systems and stakeholders without being tied to predetermined pricing.

Furthermore, econometric methods are inherently more useful for assessing the value of indirect innovation in healthcare. For example, tools that improve workflow efficiency can indirectly enhance patient outcomes by enabling faster access to treatment. However, it is challenging to link these improvements to measurable outcomes like quality-of-life scores. Similarly, an overly narrow focus on disease-specific outcome measures or patient experience metrics risks undervaluing innovations that, while not directly therapeutic, play a critical role in enhancing the overall healthcare ecosystem or in identifying deteriorations in patient health (Mantovani et al. 2023). Without a more comprehensive approach, significant advancements in areas such as diagnostics, coordination and system efficiency may fail to receive the recognition they deserve.

Two particularly valuable approaches to VBHC initiatives evaluation are Difference-in-Differences (Card et al. 1994) and the Synthetic Control Method (Abadie et al. 2010). These methods are widely used to isolate the specific impact of an intervention in complex, real-world healthcare settings. Both of these econometric models rely on panel data, which follows multiple individuals over time. In healthcare, this data is often derived from electronic health records, which include remote patient monitoring records. Such data is instrumental in mapping patient journeys across various healthcare settings, providing comprehensive insights into clinical outcomes, treatment and resource utilisation.

This longitudinal information is crucial for evaluating interventions like Integrated Care Pathways (ICPs) and their impact on both the quality of care and overall costs. For instance, a systematic review highlighted that predictive models using EHR data can effectively forecast hospital readmissions, thereby aiding in the allocation of healthcare resources and the development of targeted interventions (Mahmoudi et al. 2020). Additionally, research indicates that EHR-based clinical decision support systems enhance the management of chronic diseases by improving provider adherence to guidelines and facilitating better monitoring of disease indicators (Hazazi 2021).

> "The adoption of Value-Based Healthcare (VBHC) in Europe is progressing slowly, and there are valid reasons for this hesitancy."

Difference-in-Differences

Difference-in-Differences (Diff-in-Diff) is a comparative method used to evaluate changes in outcomes over time for two groups: one that has been exposed to the intervention (eg patients enrolled in a diabetes ICP) and one that has not been exposed (eg patients receiving standard care) (Wang 2024). By examining the difference in outcome changes between the two groups, Diff-in-Diff helps isolate the effect of the intervention while also accounting for broader trends affecting both groups.

For example, consider a diabetes ICP designed to improve the management of Type 2 Diabetes through structured interventions like regular monitoring, patient education and enhanced care coordination. A published review of ICPs in diabetes care (Grant et al. 2014) highlighted their positive impact on clinical outcomes, such as improved glycaemic control, and operational

outcomes, including reductions in hospital admissions. Importantly, reviewing this paper with an economic lens suggests that a Diff-in-Diff model could be readily applied to evaluate the value of diabetes ICPs. This model would measure changes in key outcomes before and after pathway implementation across comparable patient groups. For instance, hospitalisation rates could be used as the primary outcome of interest, comparing a cohort of patients enrolled in the diabetes ICP to a comparable cohort receiving standard care.

By analysing trends before and after implementation, Diff-in-Diff estimates the extent to which changes in hospitalisation rates in the treated group deviate from those in the control group. If hospitalisation rates for both groups were declining at a similar rate before the ICP, a steeper decline in the ICP group post-implementation can be attributed to the pathway itself.

> "Econometric approaches offer a unique advantage in determining value because they (…) quantify the degree of deviation in outcomes attributable to a particular treatment or pathway."

A key requirement for the validity of Diff-in-Diff is the assumption of parallel trends (Kahn-Lang et al. 2020): in the absence of ICP, both groups must have experienced similar changes in hospitalisation rates over time. This assumption ensures that any divergence in post-implementation outcomes can be attributed to the ICP rather than external factors. Temporal factors like seasonal variations or broader healthcare system changes are also adjusted for, making this a robust tool for evaluating coordinated care models.

Synthetic Control Method

The Synthetic Control Method (SCM) is a novel econometric approach that allows for the evaluation of a causal impact when a natural control group is not available (Abadie 2021) (Krajewski et al. 2024). SCM constructs a "synthetic" control group by creating a weighted combination of untreated units (e.g., patients, hospitals or regions) that closely matches the treated unit's pre-intervention characteristics and outcomes (Bonander et al. 2021).

SCM is particularly powerful in settings where traditional comparison methods may not be robust due to the absence of an identifiable comparable control group. It also can be linked to the concept of digital twins in healthcare through its use of weighted untreated groups to create highly individualised and dynamic controls, although the two concepts are not identical.

For example, consider the implementation of a stroke ICP in a single centre. This pathway is designed to improve functional independence through faster thrombolysis, standardised rehabilitation protocols and enhanced follow-up care (Sulch et al. 2000). In situations where there is no natural control group of patients not exposed to the pathway but otherwise comparable, SCM can create a synthetic control group by combining data from untreated patients across multiple centres.

Using weights, SCM ensures that the synthetic control group mirrors the treated group in terms of baseline characteristics such as age, gender, stroke severity, comorbidities and pre-intervention functional independence scores. For instance, if the hospital implementing the stroke ICP had a pre-intervention functional independence rate of 50%, the synthetic control is constructed to replicate this baseline while incorporating other relevant predictors of outcomes.

After the intervention, in this case, the ICP, SCM compares the treated group's observed outcomes to those of the synthetic control group. A significant improvement in functional independence for the treated group, compared to the synthetic control, would indicate the effectiveness of the pathway. By creating a weighted synthetic control group, SCM effectively serves as a practical application of digital twin technology, generating a counterfactual that is tailored to the specific characteristics of the treated group.

In the case of the stroke ICP, SCM could provide insights into the pathway's impact on functional independence, hospital readmissions and time-to-thrombolysis. However, the challenge lies in identifying outcome measures that are truly meaningful to stakeholders, especially payers. From a payer's perspective, outcomes must not only reflect clinical improvements but also demonstrate clear links to value. This includes showing reductions in overall healthcare

costs, improved resource utilisation or longer-term cost avoidance through enhanced recovery.

Outcome Measures in VBHC: Accounting for Clinical Outcomes

Emphasising healthcare utilisation as a primary outcome reflects the efficiency of resource use and its broader societal impact. Metrics such as hospital readmissions, emergency department visits and length of stay are valuable for assessing how interventions alleviate strain on healthcare systems. For instance, reductions in hospitalisations following a stroke Integrated Care Pathway (ICP) not only ease system capacity but also generate economic benefits, enabling improved access to care for other patients and reducing associated costs.

However, while healthcare utilisation metrics offer valuable insights, they must be integrated alongside clinical outcomes to provide a comprehensive assessment of value (Damman et al. 2020). To achieve this, predefined targets for patient-reported outcome measures (PROMs) can ensure that clinical benefits remain central to the analysis. Additionally, econometric modelling can be used to quantify how reductions in healthcare utilisation align with improvements in clinical outcomes.

In the second stage of the analysis, it is important to ensure that patient-centred outcomes remain integral to the evaluation. This can be achieved by adjusting the VBHC model, which primarily focuses on cost reductions linked to healthcare utilisation, to account for patient-reported outcome measures. This adjustment can be achieved by incorporating PROMs as additional covariates in a multivariate regression model. This approach allows for the simultaneous evaluation of cost reductions and their relationship to clinical or patient-relevant outcomes, ensuring a comprehensive assessment of value. Ultimately, this structured framework will link efficiency gains to meaningful benefits for both patients and the healthcare system.

Conclusion

Econometric modelling, particularly Integrated Care Pathways (ICPs), has proven useful to evaluate Value-Based Healthcare (VBHC). By leveraging methods such as Difference-in-Differences (Diff-in-Diff) and Synthetic Control Method (SCM), we have demonstrated how these models provide robust frameworks for establishing causal relationships between interventions and outcomes. This approach addresses the limitations of traditional methods like Health Technology Assessment (HTA).

> "Without a more comprehensive approach, significant advancements in areas such as diagnostics, coordination and system efficiency may fail to receive the recognition they deserve."

While outcome measurement remains a critical consideration in VBHC, particularly in balancing healthcare utilisation with clinical outcomes, the primary focus here is on illustrating how econometric models can be employed to evaluate the system-wide value created by coordinated care pathways. This methodological approach offers a pathway for assessing not only clinical effectiveness but also broader operational and societal benefits. By doing so, it enables stakeholders to make evidence-based decisions about the scalability and sustainability of VBHC initiatives.

Conflict of Interest

None

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Future Hospital

Looking for the Next Unicorn or the Uber of Healthcare? Why the Quick-Fix Formula Is a Bandage, Not the Cure

Disruptive innovation in healthcare demands solving systemic problems rather than chasing quick fixes or becoming the “next Apple.” With healthcare’s complexity, including multistakeholder challenges and interconnected systems, impactful disruption requires integration and alignment. True innovators start by diagnosing root issues, iterating on solutions and scaling thoughtfully. The goal is not isolated advances but transformative improvements addressing cost, access and quality comprehensively.

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key points

- Focus on solving systemic healthcare issues like cost, access and quality, not isolated fixes.
- Address the fragmented healthcare system by aligning patients, providers, payers and pharma.
- Ensure innovations integrate seamlessly into healthcare to avoid disrupting interconnected systems.
- Innovate iteratively: diagnose issues, test solutions and scale while embracing lessons from “failure”.
- Lead boldly with sustainable efforts that align with healthcare’s complex, multistakeholder needs.

The desire to be the next Apple or Uber of healthcare is irresistible. Everyone wants to be the leader who disrupts the system and leaves a legacy. But in chasing unicorns, we often forget the realities of the healthcare landscape: a fragmented, overwhelmed system with symptoms far beyond what a single innovation—or a quick-fix formula—can address.

Before we define what it takes to lead disruptive innovation, let’s start by diagnosing the patient—our healthcare system.

Symptoms of a Struggling System

- **Healthcare spending** worldwide accounts for 10% of global GDP and has been rising steadily, but the financial burden doesn’t match the quality of care. Globally, 1.5 billion people lack access to essential services, with over 16 million people in the EU alone facing unmet healthcare needs.
- **Burnout** among healthcare workers is a global crisis. A 2021 WHO survey found 60% of health workers suffering from significant mental health

strain, with similar figures seen across the EU. With increasing turnover and workforce shortages, especially in frontline care roles, we need urgent action to ensure the sustainability and mental well-being of the healthcare workforce.

- **Access to healthcare** remains a global issue. The gap between available resources and healthcare needs is widening, and without innovative solutions, millions will remain underserved.
- **Chronic diseases** like cardiovascular diseases, diabetes and respiratory diseases are responsible for 70% of global deaths, according to the WHO. Despite this, just 3% of global health spending is allocated to prevention.

The Risks of the Disruption Obsession

Chasing the unicorn dream can also have unintended consequences:

- **Burnout and Unrealistic Expectations.** Startups and established players alike often run themselves into the ground chasing the next big thing, ignoring the toll it takes on people.
- **Market Fragmentation.** The race to disrupt often isolates efforts rather than uniting them, creating fractured solutions that fail to address the system's interconnected needs.

> "Disruption in healthcare should be less about being the next Apple or Uber and more about redefining how we work together across the entire system."

- **Medical errors,** which, according to global studies, harm one in 10 patients, with poor communication being a major contributor. This lack of coordination leads to avoidable harm, creating additional strain on an already burdened system.
- **Fragmentation paralysing progress:** from competing priorities across stakeholders (payers, providers, patients, pharma) to regional disparities, healthcare's multistakeholder nature can stifle innovation.

The Desire—and Illusion—of Disruption

The desire to become a disruptive innovation leader comes with two dangerous misconceptions:

- **Chasing Disruption Over Value.** Many equate disruption with flashy breakthroughs. However, true disruption in healthcare means solving problems that matter—like improving access, quality and cost—rather than creating solutions that shine but fail to scale.
- **Neglecting Incremental Improvements.** The obsession with being a unicorn often overshadows the power of small, meaningful changes. Yet, in a system as complex as healthcare, incremental improvements can cascade into transformational impact.

From Disruption to Systemic Change: What Kind of Unicorn Are We Looking For?

So, what kind of unicorn or disruptive innovation would actually address the multifaceted healthcare crisis?

Why Fixing One Won't Fix All

In fact, singular innovations—no matter how groundbreaking—can sometimes feel like a bandage on a haemorrhage. They may offer temporary relief or improved efficiency in one part of the system but fail to address the underlying, interconnected issues causing the dysfunction. The challenge is that healthcare isn't just about fixing one part of the system. Even if tomorrow we could find a cure for cancer or restructure insurance models to make healthcare more affordable, those changes alone wouldn't heal the systemic wounds.

Why? Because healthcare is a multiorgan system—every innovation in one part has ripple effects across the rest. For example, an insurance reform might reduce costs for patients, but without addressing workforce burnout or communication breakdowns between stakeholders, it won't improve care delivery or outcomes. Similarly, a cancer vaccine might save lives, but if healthcare systems remain overloaded and access is still inequitable, many people might not benefit from it.

This is why disruptive innovation in healthcare isn't about finding a quick, isolated fix but about creating

a collaborative, system-wide solution that addresses the root causes of inefficiency, inequity and burnout. Disruption in healthcare should be less about being the next Apple or Uber and more about redefining how we work together across the entire system.

Why Quick Fixes Fail

Think of healthcare as a critically ill patient. Attempting to disrupt it without a clear understanding of the problem is like rushing into a multiorgan transplant without a proper diagnosis. Worse, the system's "body" may reject the innovation altogether if it doesn't integrate seamlessly with the existing ecosystem.

This is where the real challenge lies: we don't even agree on the patient's diagnosis. Is the priority improving outcomes? Reducing costs? Expanding access? For some, it's all three, while others are focused on entirely different goals. In addition, the countless treatment pathways pursued independently by various stakeholders make the system's fragmentation clear.

What Would True Disruption Look Like?

Here's the uncomfortable truth: disruptive innovation isn't about being the next Apple or Uber of healthcare. It's about:

- **Falling in Love with the Problem.** The best innovators don't start with a shiny solution. They start with a deep understanding of the problem they want to solve. In healthcare, that means addressing the root causes of access, quality and cost issues.
- **Bold Collaboration.** Disruption in healthcare is more likely to succeed when it brings stakeholders together rather than isolating them. Imagine pharma, medtech, providers and insurers truly aligning around a shared vision.
- **Resilience Through Failure and Iteration.** The path to disruption is messy. It requires the courage to fail fast, learn and iterate. The real "unicorns" are those who embrace failure as a step forward.

> "The race to disrupt often isolates efforts rather than uniting them, creating fractured solutions."

- **Balancing Disruption and Incremental Change:** Sometimes, the most disruptive thing you can do is to start small—scaling incrementally while keeping the broader system in mind.

Before we chase the unicorn dream: what is the problem we are trying to solve? Define it so clearly that even if your solution fails, when we do not reach the moon as planned, we'll land among the stars. Let us keep in mind that healthcare is a multiorgan system. A bold innovation in one area will inevitably ripple into others. The key to sustainable disruption is recognising this interconnectedness and designing solutions that strengthen the whole, not just the parts.

The real boldness isn't in claiming the unicorn title or emulating the Apples of the world. It's in creating a healthier, more resilient system.

> "The real boldness isn't in claiming the unicorn title or emulating the Apples of the world. It's in creating a healthier, more resilient system."

In your view, what's your boldest step toward transforming healthcare?

Checklist for Approaching Disruptive Innovation in Healthcare

1. **Define the Problem Clearly.** Ensure a deep understanding of the challenge, considering healthcare's interwoven dimensions of access, cost and quality.
2. **Focus on Value Over Disruption.** Prioritise solving real problems rather than pursuing disruption for its own sake.
3. **Collaborate Across Stakeholders.** Engage providers, payers, patients and innovators to co-create solutions and align incentives.
4. **Prepare for Iteration and Failure.** Adopt a mindset of learning through trials, emphasising resilience and adaptability.
5. **Address Workforce Well-being.** Recognise and mitigate burnout among healthcare professionals to sustain innovation efforts.
6. **Anticipate System-Wide Impact.** Evaluate how innovations in one area could affect other parts of the healthcare ecosystem.
7. **Balance Incremental and Bold Solutions.** Leverage small, impactful improvements alongside larger transformative projects.
8. **Commit to Sustainability.** Ensure innovations are scalable, equitable and capable of long-term integration into existing systems.

Conflict of Interest

None.

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HealthManagement

Promoting Management and Leadership

WHAT'S COMING NEXT?

COVER STORY:

Cost Management & Green Sustainability

This issue will explore strategies for cost-effective healthcare delivery while maintaining sustainability and high-quality care. Key topics include optimising resource allocation, integrating green technologies, enhancing operational efficiency and innovative systems and financial models that reduce waste and improve patient outcomes, ensuring long-term sustainability in healthcare systems.

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