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VOLUME 22 • ISSUE 3 • € 22

ISSN = 1377-7629

AI: Opportunities, Capabilities and Limits

THE JOURNAL 2022

9 771377 756005 07

Editorial

AI: Opportunities, Capabilities and Limits

Prof Lluís Donoso Bach
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HealthManagement.org Editor-in-Chief, Imaging

There is no doubt that Artificial Intelligence (AI) can transform how we deliver care. It can increase clinician productivity and improve efficiency and enable existing healthcare systems to provide care to more people than before. AI can also improve data analysis and utilisation, facilitate better decision-making and promote early diagnosis and treatment. In addition, the application of AI in healthcare can assist clinicians with their daily tasks, thus helping them handle their workload better, spend more time with patients and prevent stress and burnout.

In this issue, our contributors discuss the opportunities, capabilities, benefits, application, challenges and limitations associated with implementing **Artificial Intelligence** in healthcare. They explore how the benefits of AI can be realised and some important gaps that technology and digitalisation can address in healthcare.

Henrique Martins and co-authors talk about the Hospitals-on-FHIR initiative that aims to boost interoperability maturity in organisations by fostering a progressive and collaborative approach to gearing up to the European Health Data Space ethos of creating value for patients through data sharing.

Rafael Vidal-Perez talks about the application of AI in cardiac imaging and echocardiography and highlights the need to be prepared for automation in cardiology. Konstantinos Petsios and co-authors provide an overview of digitalisation at Onassis Cardiac Surgery Center in Greece and the application of AI to take advantage of the current realistic opportunities and future perspectives offered by modern technology.

Sai Pavan Kumar Veeranki and co-authors discuss the need to shift to a new paradigm where the focus is on knowledge sharing rather than data sharing and how this exchange of knowledge can advance AI in healthcare. Thomas Kau discusses the current state of AI in diagnostic imaging and how its clinical value can be improved through well-curated data, external validation of algorithms, and user-friendly workflow integration.

Eleonora Barcali and co-authors provide an overview of current research in radiomics and AI at the Department of Radiology of the University of Florence and focus on the need for personalised medicine and the transition from qualitative to quantitative imaging. Ronald Schilling discusses the potential of AI and how it can improve both knowledge and patient outcomes provided we change our mindset to doing things right instead of focusing only on doing the right things.

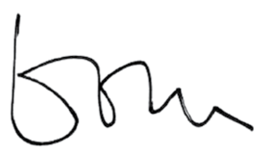
Simon Wilson talks about network modernisation and how it will be key for healthcare organisations as they continue introducing Internet of Things devices to their operations and work towards digital transformation. Ashley MacNaughton and Deepa Shukla discuss digital twin technologies and the use of AI and data science to revolutionise the provision, delivery and sustainability of healthcare.

In two exclusive interviews with HealthManagement.org, Elmar Kotter and †Werner Leodolter discuss the benefits and application of clinical decision support in healthcare and its implementation and integration in radiology.

David Krahe and co-authors provide an overview of the process of digitisation in the medical device industry and important questions that organisations should ask to best prepare for the digital disruption ahead. Jonathan Lee discusses the rising threat of cyberattacks as healthcare organisations become increasingly connected through technology and the importance of evaluating security practices and stances taken within any third-party organisation involved.

We hope you will enjoy this issue. As always, your feedback is welcome.

Happy Reading!



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Subscription Rates (6 Issues/Year)
One year: Euro 106 + 5% VAT, if applicable
Two years: Euro 184 + 5% VAT, if applicable

Production & Printing
Total circulation 50,000
ISSN = 1377-7629a

Verified Circulation
According to the standards of International Business Press Audits.

HealthManagement.org
is independently audited by TopPro Audit

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Connected Patients in Light of Big Data

Massive amounts of patient data are collected while providing care. How is patient privacy protected? How can this data be secure? How and when can patients access their data? What issues affect the regional and international transfer of data?

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AI: Opportunities Capabilities & Limits

Hospitals-on-FHIR: Preparing Hospitals for European Health Data Space

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Giorgio Cangioli | Technical Lead | HL7 Europe | Italy
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Hospitals and other healthcare organisations are where health data is predominantly created. If the European Health Data Space (EHDS) is to become a reality for citizens, both via supporting primary use as well as secondary use of health data, data located in these organisations needs to be able to be shared. Experts, industry, and EU-funded projects are converging on the HL7 FHIR as a route to interoperable healthcare and a central tenet of the European Electronic Health Record and its Exchange Format. The Hospitals-on-FHIR is an initiative that aims to boost interoperability maturity in organisations by fostering a progressive and collaborative approach to gearing up to the EHDS ethos of creating value to patients through data sharing.

Key Points

- The European Health Data Space (EHDS) needs data that flow through interoperable channels all the way from inside hospitals to the regional, national and EU levels.
- Organisations need to be ready for safe, secure and interoperable data exchange to support increasingly relevant Personal Health Data Spaces as individuals also claim and desire to access their health data in a rekindled health data activism movement.
- Interoperability in healthcare has never been more needed as integrated care is required for quality, sustainability, and resilience. Maturity in interoperability relates to the level with which hospitals, and other healthcare organisations, make use of well-known and internationally accepted standards.
- The Hospitals-on-FHIR (HoF) initiative, started by HL7 Europe, aims to create a community of learning in data sharing and proposes a 10-step maturity model to realise the KIWI (Knowledgeable, Intelligence, Wise and Interoperable) principles, and can bridge with the HIMSS EMRAM® maturity levels.
- The HoF maturity model illustrates milestones in the path towards interoperability that apply to hospitals and health care organisations that wish to share and exchange health data.

Introduction

The growing trend and importance of citizen-generated health data, in the construction of Personal Health Data Spaces (Moen et al. 2022) can foster better health promotion or contribute to real world evidence collection. However, hospitals and other healthcare providers are still, for the most part, hesitant and worried when health data is generated from healthcare encounters, captured, and indeed stored in often old legacy information systems, as they struggle to migrate to new interoperable EHRs solutions.

The rise of the data economy brings changes in the role of hospitals and other large healthcare organisations in their capacity and their internal dynamics related to how they can support digital health services from personal, to national and even European levels. Healthcare providers and their managers need to see themselves as knowledge organisations but need to be more than that. They need to be Knowledgeable, Intelligent, Wise and Interoperable (KIWI) (Martins 2021).

The ability of hospitals to connect and share knowledge, their interoperability maturity, has to do with their use of the HL7 FHIR standards and associated specifications. The Hospitals-on-FHIR initiative, started by HL7 Europe, proposes a 10-step maturity model that builds upon the KIWI maturity principles.

Hospital and healthcare managers need to be increasingly aware of the importance of interoperability and capable of triggering the right investments to advance their hospitals capacity to share health data. Joining hospitals-on-FHIR network and progressing in HoF maturity levels will allow their organisations to become KIWI instances of efficient, knowledgeable and resilient, future proof healthcare organisations.

The continued need for healthcare interoperability

The need for interoperable health and care services has never been greater and so greatly appreciated as chronic diseases increase with the COVID-19 pandemic resulting now in thousands of long-term cases of either long-COVID or post-COVID patients requiring continuous respiratory or rehabilitation care. As citizens move along their health journey, life-long conditions require them to have more control and usage of their health data, and to benefit from articulated care networks spanning cross-borders of both nationality and public-private divides.

The seamless navigation of a health system by an individual, and the capacity to receive integrated holistic care rests heavily on the degree to which healthcare providers, particularly hospitals, can use and exchange health data in real time. This requires that information systems in use can utilise modern and advanced connections that follow interoperability rules. International standards, like HL7 FHIR, have helped industry and implementer teams in healthcare institutions to advance with some degrees of integration, particularly inside the realm of each hospital or healthcare organisation. The challenge is now to advance further safe and secure sharing between organisations in and between many of the EU countries and indeed beyond to non-EU countries. Also, to create the conditions to link health data holder organisations to a growing paraphernalia of new digital health solutions - often mobile and occasionally associated with digital therapeutics – being offered by a flourishing industry driven to satisfy citizens and patients as the new clients in the growing digital health market. The member states and the EU are also envisioning more access to health data, for policy, system management and public health. This desire, the value and its justification have increased in a pandemic crisis era. The recent proposal for a Regulation on the European Health Data Space is the hallmark of this trend.

Hospital and healthcare managers need to be aware of the importance of interoperability and capable of triggering the right investments to advance their capacity to share health data

Personal health data spaces

If each one of us is to have access and the capacity to use and control all of his or her health data de facto, then that data needs to be accessible in a sophisticated manner. A data lake of paper printouts, PDF files, or some visually accessible digital format through a patient portal without the possibility to search, use, and reuse are no longer sufficient. It is to be in a plastic, almost fluid, manner. Certainly mobile, mouldable, and manageable (3Ms) according to mobility needs (over distance and time), edit desires (corrections, comments and cocreation) and digital health literacy requirements, respectively are at the top of the list. These 3M Personal Health Data Spaces (PHDS) are likely to materialise first in mobile apps fully integrated to hospitals and any other healthcare points along the health journey, and later to dematerialise into more ubiquitous computing solutions, as these integrate into different IoT-enabled medical and common devices as well as into the smart health working and living environments of the near future. Many healthcare providers are already offering their users/clients mobile access to increasing amounts of health data and do so using HL7 protocols, and increasingly HL7 FHIR due to its simplicity and links to web protocols such as REST.

European Health Data Space

The European Health Data Space will need health data. It is pointless without it. Large amounts of good quality health data. Ideally clinically relevant health data good for research analysis. Clinically relevant health data has been produced during healthcare encounters in healthcare providing institutions and stored in numerous Electronic Health Record (EHR) systems using different terminologies and database structures. Thus, the data needs of the European health data space can only be satisfied by creating interoperable digital bridges between the past and the future. Between locally installed EHRs or departmental information systems in healthcare organisations and the envisioned federated European health data space, regional or national databases can serve as midpoint standard data aggregators.

Understanding the EHDS as a big data project for secondary use can be misleading. It equally encompasses what is increasingly called primary use of health data reflecting the capacity to use a digital health service to support the provision of care. Through Myhealth@EU services, the EHDS will continue to support the expansion of cross-border sharing of ePrescriptions and Patient Summaries, enlarging and refining the scope. Laboratory data, imaging reports, or hospital discharge letters as the new domains of the European Electronic Health Record exchange format (EHRxF) (www.x-ehealth.eu) are to be shared in the EU space as citizens may request healthcare services to access home-located health data when traveling and when requesting a second option. Such scenarios are complementing PHDS covering personal health care between healthcare encounters and call for the same data to be made available and is seamlessly integrated. Again, HL7 FHIR standards and implementation profiles are the key to this coherent health data ecosystem and critical to patients and citizens experience with digital health services based on reliable health data and information for their empowered decision making about their health and care needs.

The EHDS regulation proposal, somehow anticipates this need when it foresees the establishment of national EHRs certification/appraisal systems. There is a clear recognition that the IT industry needs to supply healthcare with advanced solutions, but also that regulators need to intervene. From an EU level perspective, advancements in the European EHRxF will hopefully create a referential. Nationally, adoption and verification of conformance will need to be promoted. Finally, at each hospital or healthcare provider, if high quality interoperable solutions are not installed and the organisations are not capable of using REST APIs (seen as clear reference to HL7 FHIR implementation needs) and other technical gateways for seamless flows of health data, then that data will not be able to flow out, to patients and their PHDS, or to national and European health data spaces.

What is Hospitals-On-FHIR (HoF)?

Hospitals-on-FHIR is an HL7 Europe triggered initiative that aims to deliver on the transformation of health and care and the needs of European citizens, by understanding the needs of hospitals and supporting their interoperability journey towards comprehensive HL7 FHIR implementations, including the EHDS, with grassroots sharing of experience, collaboration, and synergies.

To achieve this objective HoF provides a maturity model, the neutral grounds for a community of practice and the encouragement and knowledge through different experience sharing events.

> **The European Health Data Space will need health data. It is pointless without it**

The idea of HoF was first presented in 2021 in this publication in a brief article on Fast Healthcare Interoperability Resources (FHIR), as hospitals and their interconnections were seen as a critical asset and the next step for European health data interoperability (Martins and Cangioli 2021). The Hospitals-on-FHIR launch event took place on March 31, 2022 online. Although it was planned as a small family event, it attracted more than 140 participants from hospitals, research organisation, industry, and academia. The European Commission was represented and shared its key interoperability initiatives, to illustrate the importance of grassroot community initiatives like Hospitals-on-FHIR. At the same time, the website www.hospitalsonFHIR.eu went live inviting hospitals and HL7 FHIR experts to join. A number of initiatives planned for the rest of 2022, aim to spread the world and set the groundwork of the HoF Virtual Community of Practice.

Why HoF?

For a long time, interoperability standards have been a purely technical affair engaging health professionals, business analysts, and software engineers. Implementations were local and the budget involved rational and limited. This is no longer the case.

With the advent of the data economy and the digital transformation of health and care, hospitals and healthcare organisations in general rely on digital health services, connectivity, and reliable data. Sharing experience and supporting each other within and across jurisdictions, hospitals can align their implementation strategy and accelerate developments, potentially at reasonable costs and realistic timelines. Moreover, HoF uses HL7 FHIR to discuss interoperability plans and associated maturity to the C-suite, making the adoption of HL7 FHIR, very much like EHDS as strategic priority.

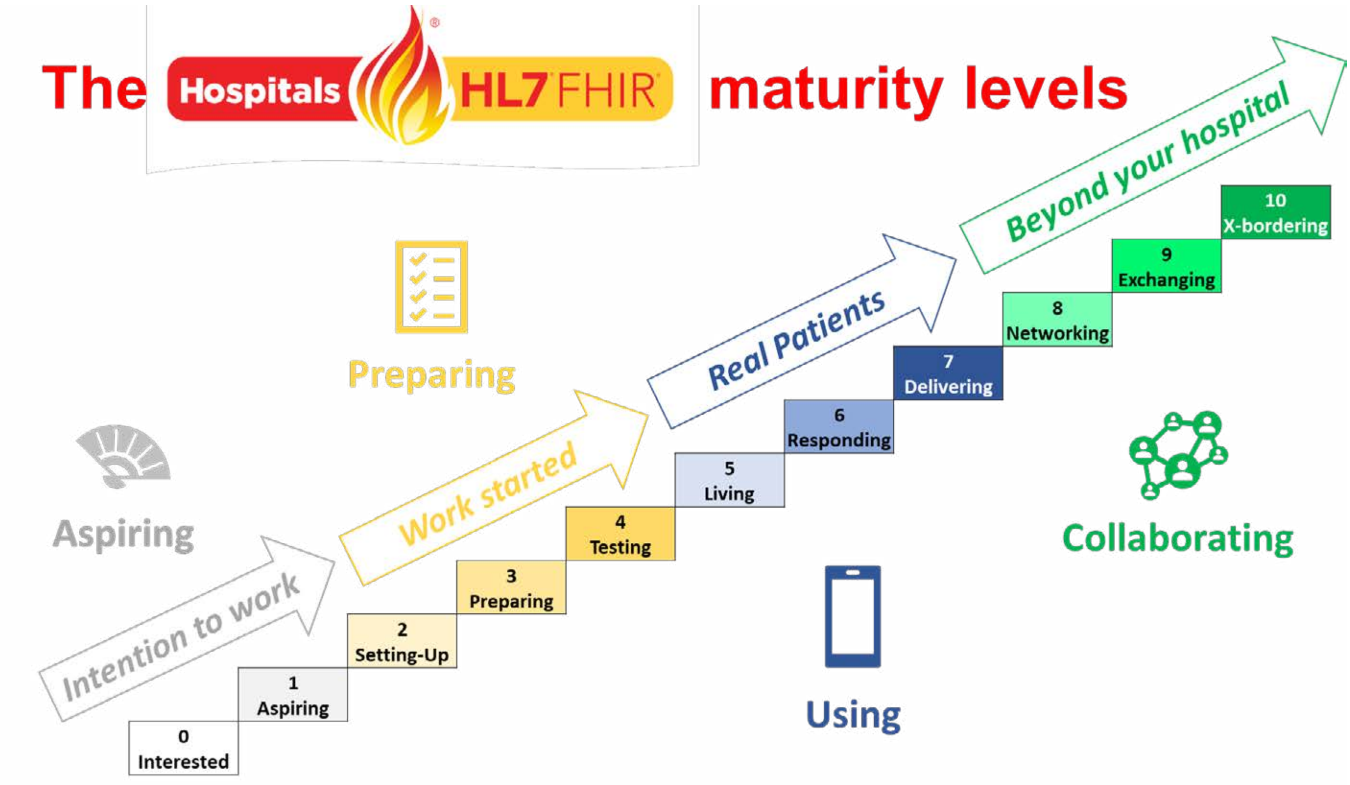

Figure 1: The Hospitals-on-FHIR maturity model in summary

Value proposition

Hospitals-on-FHIR places hospitals on the European map, expressing their intent to explore the adoption of HL7 FHIR and accelerate their progress towards safe, secure and effective participation in the EHDS. It also allows hospitals to assess their status, their maturity level, overall and in regard to specific domains, applications areas or use cases, linked to the European EHRxF.

HoF also is valuable for patients and for national and Europe level efforts to benefit from better digital health. The four levels value proposition can be summarised in a F.H.I.R mnemonics:

- **F**or patients who need to access, use, curate their health data and see it being used and shared for their benefit.
- **H**ospitals and other healthcare provider organisations need to share experiences, techy enthusiasm and do it together.
- **I**nteroperability and integration at national level depend on organisations opening their technical doors.
- **R**egions like Europe and even extending out, need to collect, secondary use and explore the value of health data.

How Can Hospitals Prepare for the Future and the EHDS?

Adoption the KIWI principles as part of the mission of the organisation, helps develop their capacity to become interoperable with other organisations, offering comprehensive services to their patients/clients, and getting ready to use health data to support continuous improvement, resilience, and cutting edge health research programmes. For example, consider the support of seamlessly data integrated patient care journeys, across borders, providing data for exchange, via MyHealth@EU, in the context of the EHDS. These can be bilateral cross-border regional meaningful collaborations (i.e. stimulated by Interreg challenges) or support to care provision – what is commonly known are primary use of health data. It could also help to provide data for research and policy making, into national or European data spaces, where it can be analysed in big data efforts – commonly referred as secondary use of health data. For hospitals and other healthcare organisations to do this, as HL7 FHIR can serve as an accelerator, and a multiplier for organisations ready to collaborate, knowing and sharing with peers along the same interoperability readiness journey.

HoF Maturity Model

The HoF Maturity Model (HoF-MM) serves as a means for hospitals and other healthcare providing organisations to measure their capabilities in offering interoperability services through HL7 FHIR and communicate with other hospitals and relevant stakeholders. Therefore, the HoF-MM model is a means to reinforce interoperability and accelerate the potential for continuous improvement, resilience, and mutual support.

The HoF-MM is not just a measure of the technical capacity of implementing HL7 FHIR (micro-)services, but taking in account also non-technical aspects that are essential for the success of such types of interoperable networks, it advances collaboration, sharing of experiences, and mutual learning. It establishes a non-technical language, that drives the capacity of building a community of adopters, create relationships with other organisations, share best practices, provide mentorship, and engage in joint projects. Moreover, it acknowledges the crucial role of decision makers in the C-suite, to understand the long-term implication of adopting HL7 FHIR for the participation of their hospitals in the EHDS. In fact, without a recognition of the role of HL7 FHIR by these decision makers, it is unlikely that all the supporting actions required to step-up in the HoF-MM levels will be realised.

The HoF-MM is a top-down model constituted by 10 levels, grouped in four grades. The model provides a common framework that can be adapted to different jurisdictions or context of use, keeping however a consistency among the levels across possible different adoptions. The model in itself does not concern with the domain, use case, or medical specialty. These are left to specific layers in the HoF Map (Figure 1).

The HoF maturity grades roughly classify in four categories or phases that indicate how advanced the organisation is in the process of putting HL7 FHIR to work:

- **Aspiring:** the organisation expressed its interest in using HL7 FHIR and connects with the HoF network.
- **Preparing:** the organisation has started the process to be "on-FHIR"
- **Using:** the organisation is internally using HL7 FHIR for real services: it is "on-FHIR".
- **Collaborating:** the organisation has established external collaborations. This may include the sharing of HL7 FHIR data beyond its boundary.

Excluding aspiring, each phase includes three levels. The **Aspiring** category is the entry level for a hospital to be included in the HoF map: Level 0 indicates that a first connection between the organisation and the HoF network occurred; while the first real level (level 1) indicates that an aware decision to be part of HoF has been made.

The **Preparing** grade ranges from the initial self-assessment and planning to realise HL7 FHIR based services (level 2) to the testing activities before going live (level 4).

With the **Using** grade your organisation is "on-FHIR". This may imply that you are "just" using HL7 FHIR (level 5) or that some of your services comply with some relevant selected Implementation Guides (level 7).

Aspiring		
0	**Interested to be On-FHIR**	The hospital agreed/expressed an **interest to participate** in Hospitals-On-FHIR.
1	**Aspiring to be On-FHIR**	The hospital **has filled** in the participation and consent **form** - basic information necessary.

Preparing		
2	**Setting-Up to be On-FHIR**	The hospital has performed a **self-assessment** on conditions to establish and operate HL7 FHIR-based services.
3	**Preparing to be On-FHIR**	The hospital is **preparing** to technically have functional HL7 FHIR-based services.
4	**Testing to be On-FHIR**	The hospital is engaging in internal and/or external **testing** also with external (e.g., HL7 affiliate/HL7 Europe) support.

Using		
5	**Living On-FHIR**	The hospital is **piloting** or has **gone LIVE** and has at least one HL7 FHIR-based service that is regularly used (minimum once/day).
6	**Responding On-FHIR**	The hospital **formalised the capabilities** offered by its HL7 FHIR-based services. This is technically done by means of HL7 FHIR capability statement(s) and providing access to them.
7	**Delivering On-FHIR**	The hospital **implements** at least one of the relevant selected HL7 FHIR-based services. That is, your HL7 FHIR-based service **conforms** to **selected Implementation Guides** (e.g., EEHRxF Lab, IPS).

Finally, the **Collaborating** category: your organisation is so mature in adopting HL7 FHIR that it can cross the hospital boundaries and start networking with other hospitals (level 8) or even be ready for exchanging data cross-border (level 10).

Collaborating		
8	**Networking On-FHIR**	The hospital is **networking** with other hospitals about offered HL7 FHIR-based services. This includes also mentoring activities.
9	**Exchanging On-FHIR**	The Hospital is using HL7 FHIR-based services to **exchange** health data with entities (e.g. hospitals, citizens, regions..) **inside the country**.
10	**X-bordering On-FHIR**	The Hospital is using HL7 FHIR-based services to **exchange** health data with other entities (e.g., hospitals , citizens,) **cross-border**. a) Europe (e.g., European EHRxF) b) Global (e.g., IPS)

HoF community of practice as a social innovation resource
x-eHealth, the support and coordination action funded by European Commission to support the development of the European EHRxF, analysed the role of the Communities of Practice as a mechanism to advance adoption of the interoperability standards and specifications it develops. Building on the preceding work on Patient Summaries in the Trillium II project and international-patient-summary.net, guidelines were produced for communities that wish to start their interoperability journey, considering interoperability standards as infrastructure for innovation.

According to Etienne Wenger (2015) communities of practice (CoPs) "are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". Compared to formal workgroups, informal networks and project teams, CoPs are driven by people that share a common interest for what they do and the need to do it better, therefore they interact regularly, collaborate and develop a sense of commitment.

There are three elements which when combined comprise a CoP and only by fostering them in parallel we can nurture the community (Wenger and Snyder 2000):

- The domain of knowledge: it is the area of shared interest and thereby of collective knowledge and combined experience and competence that defines the identity of the CoP and promotes commitment.
- The community: it is the members of the CoP, a group of persons or organisations who strongly care about the domain of knowledge to be willing to interact regularly, engage in shared activities and discussions, help each other, exchange ideas and expertise, advance mutual learning and eventually better their practice.
- The practice: a shared body of knowledge, experiences, and techniques among the members of the community. It is important to emphasise here that the community members are practitioners in a specific field, not merely people with shared interests, and they join to produce an inventory of resources (that could be anything from developing tools and documentation, to seeking experience, to provision of solutions to frequently encountered problems, etc.).

x-eHealth in itself aims to connect communities of practice that aim to further interoperability for specific domains or patient needs e.g. childhood cancer survivors. Diego Kaminker, Deputy Chief Implementation Officer at HL7 International elaborated on this concept (Figure 2).

Building on this body of work, guidance is provided by the x-eHealth support action in Deliverable 8.1 for communities of practice that wish to work together and learn from each other. In particular, these are some of the ways a hospital or health organisation can further adoption of the European EHRxF:

- Becoming a reference site for shared awareness and knowledge of the community.
- Enriching the knowledge base, creating datasets, improving tools.
- Enabling and empowering the connection between different partners and networks, engaging and educating all interested stakeholders.
- Promoting the use of best practices and ensuring that adequate attention is given to the x-eHealth project results.
- Facilitating discussions, gathering feedback from implementation efforts and case studies, sharing success stories but also identifying challenges.
- Supporting Proof of Concept developments of the European EHRxF.
- Participating in events such as hackathons, datathons, connectathons, projectathons, etc.

Conclusion: The EHDS and the HoF Learning and Piloting Space

Upon adoption of the EDHS, possibly in 2023, there will be a time for implementation. While between the Cross-Border Directive (2011) and the first ePrescriptions were exchanged between two countries using a EU infrastructure (late 2018) almost 8 years elapsed, COVID-19 has shown that when there

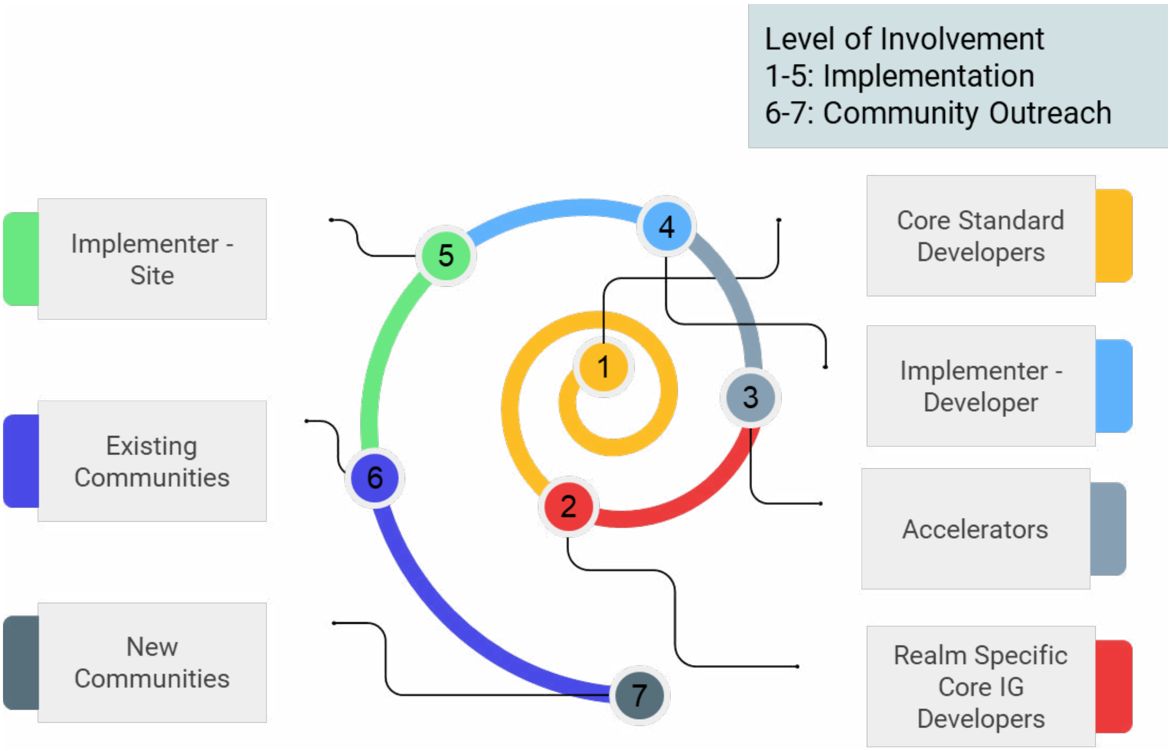

Figure 2: HL7 Communities: The path from 'Informal New Community' to 'Core Standard Developer' Why a spiral? Near the core: few persons, more 'abstract' / standard oriented work (Kaminker 2020).

is a will, some things in digital health can move faster.

Legacy systems, large needs for investment and upgrading in hospital IT services, and the existence of significant semantic challenges mean the road to seeing seamless data flows from each hospitals/HCP in Europe to the EHDS is a long journey. The HoF network can be a learning and piloting space, for increasingly higher levels of data integration and data usage by each individual patient/citizen and the whole of our Union and beyond.

Conflict of Interest

None. ■

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Artificial Intelligence and Echocardiography: Are We Ready for Automation?

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Artificial intelligence has many potential applications in the field of cardiac imaging and echocardiography is not an exception. There are clear examples in different aspects like cardiac chamber quantification, assistance on the interpretation of stress echocardiography or the evaluation of valvular heart disease. We need to be prepared for automation in echocardiography as well as in other fields of cardiology.

Key Points

- The use of computers to assist with radiologic image interpretation tasks is here to stay.
- The inclusion of artificial intelligence tools in cardiac imaging into daily decision-making will improve care delivery.
- Automation in echocardiography is not really a new concept and has evolved forward.
- Assessment and quantification of left ventricular size and function is a pivotal aspect of echocardiography.
- There are numerous limitations to the use of automated tracing; however, further updates to this technology are ongoing to enhance reproducibility and the user experience.

Decision Making in Cardiac Imaging

It is probable that the inclusion of artificial intelligence (AI) tools in cardiac imaging into daily decision-making will improve care delivery. But it is also necessary that cardiologists must retain the last step in the control of the system, keep an eye on the decisions and have the authority to change algorithms in cases that AI gets wrong.

In this evolving field, AI applications in cardiology show, for example, that simple tools like electrocardiography (ECG) could bring a lot of potential information converting the ECG into a powerful instrument for prediction (Vidal-Perez 2020).

In the radiology field, the potential influence of AI on the future progress of this medical specialty is obvious. The use of computers to assist with radiologic image interpretation tasks is here to stay, for example, in cardiothoracic imaging, the most widely used subset in medical imaging is machine learning (ML). A lot of scientific research has focused on the use of ML for pattern recognition to detect and potentially diagnose several pathologies (Moore 2020).

AI and ML models are quickly being applied to the analysis of cardiac computed tomography (CT) as it is an independent tool of a manual approach as echocardiography is. Within echocardiography, the quality of imaging obtained is critical, however for cardiac magnetic resonance or cardiac CT, the quality of the imaging obtained is not a real problem as it is not obtained manually. This combination of ML and cardiac CT (Hyett Bray 2022) is also bringing a lot of advancements such as:

- Non-invasive CT-fractional flow reserve (CT-FFR) can accurately be estimated using ML algorithms and has the potential to reduce the requirement for invasive angiography.

- Coronary artery calcification and non-calcified coronary lesions can now be automatically and accurately calculated.
- Epicardial adipose tissue can also be automatically, accurately, and rapidly quantified.
- Effective ML algorithms have been developed to streamline and optimise the safety of aortic annular measurements to facilitate pre-transcatheter aortic valve replacement valve selection.
- In the field of electrophysiology, the left atrium (LA) can be segmented and resultant LA volumes have contributed to accurate predictions of post-ablation recurrence of atrial fibrillation.

AI can impact patient care at multiple stages of their imaging experience and assist in efficient and effective scheduling, imaging performance, worklist prioritisation, image interpretation, and quality assurance

Nevertheless, AI algorithm development is now directed toward workflow management. AI can impact patient care at multiple stages of their imaging experience and assist in efficient and effective scheduling, imaging performance, worklist prioritisation, image interpretation, and quality assurance (Moore 2020).

Automation in Echocardiography

Automation in echocardiography is not really a new concept and has evolved forward by the works of pioneers such as Chu and colleagues (Chu 1978). In these old studies they used a Fourier analysis technique to process information from the M-mode tracing of the anterior mitral leaflet to detect normal and abnormal cardiac states such as mitral valve prolapse (MVP), rheumatic mitral stenosis, and hypertrophic cardiomyopathy. Using a classifier system, the algorithm was able to identify MVP with accuracy providing optimism for automation in echocardiography (Chu 1979).

Assessment and quantification of left ventricular size and function is a pivotal aspect of echocardiography. Significant variability exists in technique and methods for tracing biplane disc summation to quantify left ventricular volumes and ejection fraction (Gandhi 2018). Prior to conventional ML and deep learning (DL), deformable models showed great promise for border detection, segmentation, shape representation, and motion tracking (McInerney 1996). Automation for measurements using current AI technology has been shown to increase the reproducibility of measurements, bridge the gap between expert and novice readers, and increase efficiency and workflow in echocardiography laboratories. Automated software created by multiple vendors has been found to be reproducible, feasible, and accurate for 2D and 3D echocardiographic measurements (Gandhi 2018).

The next step forward is the automated echocardiographic detection of severe coronary artery disease using AI. The point of this innovation is to validate an AI system to automate stress echocardiography analysis and support clinician interpretation. This has been demonstrated with automated image processing pipeline that was developed to extract novel geometric and kinematic features from stress echocardiograms collected as part of a large, UK-based prospective, multicentre, multivendor study. An ensemble ML classifier was trained, employing the extracted features, to identify patients with severe coronary artery disease on invasive coronary angiography. An acceptable classification accuracy for identification of patients with severe coronary artery disease in the training data set was achieved on cross-fold validation based on 31 unique geometric and kinematic features, with a specificity of 92.7% and a sensitivity of 84.4%. This accuracy was maintained in the independent validation data set from the U.S. This approach of providing automated classifications to clinicians when reading stress echocardiograms could improve accuracy, inter-reader agreement, and reader confidence in the near future (Upton 2022).

The last step in echocardiography, recently published, is the automated analysis of doppler echocardiographic videos as a screening tool for valvular heart diseases (VHDs). The authors of this study (Yang 2022) developed a 3-stage DL framework for automatic screening of echocardiographic videos for mitral stenosis (MS), mitral regurgitation (MR), aortic stenosis (AS), and aortic regurgitation (AR) that classifies echocardiographic views, detects the presence of VHDs, and, when present, quantifies key metrics related to VHD severities. The algorithm was trained (n= 1335), validated (n=311), and tested (n = 434) using retrospectively selected studies from five hospitals. A prospectively collected set of 1374 consecutive echocardiograms served as a real-world test data set. Disease classification accuracy was high, with areas under the curve of 0.99 (95% CI: 0.97-0.99) for MS; 0.88 (95% CI: 0.86-0.90) for MR; 0.97 (95% CI: 0.95-0.99) for AS; and 0.90 (95% CI: 0.88-0.92) for AR in the prospective test data set (Yang 2022).

Are We Ready for Automation?

There are numerous limitations to the use of automated tracing; however, further updates to this technology are ongoing to enhance reproducibility and the user experience. Most studies assessed patients in sinus rhythm with limited knowledge of the use of automation among patients with significant conduction disease, arrhythmia, and paced rhythm. Poor and fair-quality images were found to increase erroneous border tracings by the computer, and in several patients, the automated software did not work. This will be a limitation moving forward in the development of this software. Contour adjustments seem to increase accuracy of automated analysis with greater correlation to cardiac MRI; however, this increases analysis time and reduces workflow efficiency. Lastly, automation correlated well with cardiac MRI volumes as traditional 2D measurements have been suggested to underestimate chamber volumes (Gandhi 2018).

Will AI replace echocardiographers? Not anytime soon. AI results must be interpreted in the context of other available echocardiographic and stress testing information. However, AI stands to increase the efficiency and reproducibility of echocardiography; cardiologists must strive to understand AI and be prepared to document its effectiveness. AI in stress echocardiography should not be regarded a threat but rather a remarkable opportunity to further enhance the value of an already extremely useful test (Pellikka 2022).

The question is, if we have so many promising results, why are we not implementing them in clinical practice? Don't we have a moral obligation to use everything in our hands to provide better patient care? Do we not believe the validity of these results? Or are we just afraid that our jobs are at stake if AI starts to take over some of the tasks that currently we do? In the end, history has shown that it doesn't really matter what we think. We can disagree with or even revolt against these technological advancements, but in the end, they will come—simply because in the long term, it is better for everyone (Kolossvár 2022).

AI in stress echocardiography should not be regarded a threat but rather a remarkable opportunity to further enhance the value of an already extremely useful test

Another concern is what to do when man and machine disagree. The importance of outstanding validation of the algorithms must, therefore, be underscored. Clinical judgment by the physician is essential, with a dose of humility as well, to ensure that AI would be used to support and not replace clinical decision-making. Certainly, explainability (the ability to explain how the algorithm came up with its output) can be limited in unsupervised ML, such as with the specialised techniques involved in DL. However, the future remains bright for AI applications in healthcare, as the potential to enhance our practice in the field of medicine is impressive.

Conclusion

We need to be prepared for automation in echocardiography as we will need it in other fields of cardiology. The future will be bright because the best outcome will probably be found when combining the wisdom and experience of the physicians with AI in a human-AI partnership for success. Therefore, don´t be afraid of the rise in automation.

Conflict of Interest

None.

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Artificial Intelligence in Radiology: Realities, Challenges and Perspectives from a Tertiary Cardiac Centre in Greece

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An overview of the digitalisation at Onassis Cardiac Surgery Center in Greece and the application of artificial intelligence (AI) to take advantage of the current realistic opportunities along with future perspectives offered by modern technology.

Key Points

- The use of AI in radiology has led to innovative applications throughout the entire radiology pipeline, from improved scanner performance to automatic disease detection and diagnosis.
- AI will provide healthcare professionals powerful data-driven tools that will meet the increasing need for accurate and rapid diagnostic imaging with the use of prognostic risk scores.
- The contribution of AI to the interpretation of medical images can be considered a given for contemporary clinical practice with increasingly implemented applications in the near future.
- Onassis Cardiac Surgery Center, a tertiary hospital providing specialised cardiac care, is under a transitional period during which the centre is developing full digitisation and investing in the targeted introduction of innovation and artificial intelligence.
- Onassis Cardiac Surgery Center, in collaboration with a private company (3D Life) and the Centre for Research and Technology Hellas (CERTH) engaged the Project 3D4Kardia that offers an innovative approach for an optimal pre-interventional personalised assessment in patients with congenital and acquired heart diseases.

There is enough scientific evidence that Artificial Intelligence (AI) will fundamentally transform diagnostic imaging. The use of intelligent algorithms for segment formation is now based on machine deep learning leading to more concrete, standardised and personalised imaging, propelling medical image analysis field at a rapid pace (Hosny et al. 2018; Yang et al. 2022). The use of AI in radiology has led to innovative applications throughout the entire radiology pipeline, from improved scanner performance to automatic disease detection and diagnosis (Decuyper et al. 2021; Slart et al. 2021). AI will provide healthcare professionals powerful data-driven tools that will meet the increasing need for accurate and rapid diagnostic imaging with the use of prognostic risk scores. The use of AI algorithms will reshape clinical workflows, decrease or even prevent diagnostic errors, increase productivity and decrease costs leading to a personalised outcome-oriented clinical decision-making (Lee et al. 2019; Lin et al. 2020; Lee and Yoon 2021).

The contribution of AI to the interpretation of medical images can be considered a given for contemporary clinical practice with increasingly implemented applications in the near future (Tang 2019). A recent technology review concluded that *"AI methods are now becoming an ubiquitous tool in any medical image analysis workflow and pave the way for the clinical implementation of AI-based solutions"* (Barragán-Montero et al. 2021).

AI algorithms will reshape clinical workflows, prevent diagnostic errors, increase productivity and decrease costs leading to personalised outcome-oriented clinical decision-making

Onassis Cardiac Surgery Center is a tertiary hospital providing specialised cardiac care to patients of all ages with heart disease. The current era is under a transitional period during which the centre is developing full digitisation of its services and investing in the targeted introduction of innovation and artificial intelligence in order to excel its services for the benefit of cardiac patients in Greece.

This article focuses on the origin of this investment in order to take advantage of the current realistic opportunities along with the future perspectives offered by modern technology despite the unique challenges and barriers. Digital transformation is a change management process that increases value for patients, the hospital and the healthcare system.

At a time when integration of technological innovation is considered a primary objective for many industries, many AI algorithms have already proven their benefits in healthcare. A projected next step would be helping everyday practice with intelligent software in order to significantly add value for the entire discipline, while at the same time improving the physician's experience and preventing burnouts. Numerous case studies verify the tangible advantages brought about by AI. Numerous other applications are in development and can be expected in coming years providing added value in patients' care (Dey et al. 2019). For example, in cardiovascular imaging, AI algorithms are used to quantify prognostic imaging biomarkers, to predict cardiovascular risk from images and to integrate data from many different sources in order to provide individualised risk prediction (Lin et al. 2021). Likewise, AI applications for different imaging modalities have also proven their value. According to a three-month clinical implementation phase in a U.S. healthcare network, head CTs can be evaluated in seconds using an intelligent algorithm to detect unknown intracranial bleeding and prioritise the scans for rapid interpretation, which could literally save lives (Arbabshirani et al. 2017). This list could go on with other AI applications that are either at a practical development stage, or under imminent approval for clinical use by health regulatory authorities across the world.

Onassis Cardiac Surgery Center, in collaboration with a private company (3D Life) and the Centre for Research and Technology Hellas (CERTH) engaged the Project 3D4Kardia that offers an innovative approach for an optimal pre-interventional personalised assessment in patients for the whole range and categories of congenital and acquired heart diseases. It enables cutting-edge clinical research, 3D digital modelling, 3D printing and virtual reality technologies resulting in improvements in clinical outcomes, patient experience, clinician performance and cost reduction. Based on our preliminary analysis there is evidence that the pre-interventional assessment based on the combination of 3D-modelling and 3D-printing improves clinical outcome and performance in all moderate and high-risk interventions of structural and congenital heart diseases and contributes to the following improvements:

- Reduction of surgical/interventional time
- Reduced rate of complications
- More accurate and individualised selection of implants
- Reduction of cost
- Faster recovery after surgery/intervention
- Improved quality of life
- Better care experience

At the practical level it provides an optimal preoperative evaluation of patients and an improved training experience for our medical teams through the development of a virtual reality platform offering better semantic visualisation of each pathogenesis and details personalised to the patient, based on real clinical cases. The project has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH–CREATE–INNOVATE (project code:T2EDK-04012).

All the above facts do not mean that there are no challenges to be overcome. The first challenge we have to deal with is the increasing demand for diagnostic imaging in combination with the almost stable number of radiology specialists. This leads to greater demands for work efficiency and productivity. In our case the interpretation of heart and thorax imaging is demanding and the use of algorithms is beneficial. Moreover, the image resolution is continuously improving and the product is not just pictures but rather data.

In the case of radiology data, the volume of pictures is tripled every year and accurate interpretation without the use of computerised digital processing is quite demanding and time consuming. Use of imaging biomarkers and radiomics under automated procedures and extensive datasets seem to be the future (Hwang et al. 2019; Decuyper et al. 2021; Lin et al. 2020). The identification of novel biomarkers and applications of deep machine learning algorithms to cardiovascular imaging techniques will further improve diagnosis and prognostication for patients with cardiovascular diseases.

Recently the European Association of Nuclear Medicine (EANM) and the European Association of Cardiovascular Imaging (EACVI) published a position paper to provide an overview regarding modern machine learning-based artificial intelligence, to highlight current applications and to enhance strategies that support its clinical application in the field of cardiovascular imaging using nuclear cardiology (hybrid) and CT techniques (Slart et al. 2021).

Moreover, radiologists need to obtain new skills in order to facilitate deep learning. This means that they have to invest in long training cycles for a better understanding of big data usage and complex hardware specifications understanding (Yang et al. 2022). Therefore it is a challenge to decide the use of the existing algorithms because they usually only perform single tasks. This poses a dilemma for radiologists; either they will restrict the use of AI to specific cases, or they will try to integrate various algorithms developed from different vendors into their IT systems. The latter could raise issues as far as both practicability and compatibility are concerned. Hence, to fully take advantage of the benefits of AI applications new forms of comprehensive solutions for clinical routine should be developed (Kotter and Ranschaert 2021). Finally, there are also a variety of ethical implications around the use of AI in healthcare. As Davenport and Kalakota (2019) commented *"the use of AI to make or assist clinical decisions raise issues of accountability, transparency, permission and privacy".*

An additional challenge is the reduction or even prevention of diagnostic errors. Previous studies reveal that there is a mean of 4% error in radiology diagnoses, a rate that varies depending on the procedure and the available time (Sokolovskaya et al. 2015; Waite et al. 2017; Kotter and Ranschaert 2021). Algorithms that enable data-based image analysis with artificial intelligence and machine learning methods seem to be the optimal choice for the near future.

It is well known that the use of machine learning in medical imaging is not new. Nevertheless the current algorithms are more powerful than traditional applications. Notably, image data availability is an important hurdle for implementation of AI in the clinical setting. Willemink et al. (2020) proposed federated learning, interactive reporting, and synoptic reporting as approaches to address data availability in the future (Willemink et al. 2020; van Ginneken 2017). The use of artificial neural network for deep machine learning is promising in developing high complexity models even in non-linear contexts (Lee et al. 2019; Sarker 2021). Implementation of AI in clinical practice undoubtedly will result in many ethical, medical, occupational and technological changes in healthcare.

To this effect, various strategies are emerging. Many software providers form consortiums with an eye to coordinating their AI applications. At the same time, big companies of the industry are already working to design right from the start integrated AI assistance systems so that they can provide multifunctional support. Onassis Cardiac Surgery Center invested in state of the art technologies for outstanding image quality that combine AI in medical imaging, resulting in higher automation, productivity and standardisation. The use of a recognition algorithm in combination with a 3D diagnostic software automatically detects anatomical structures, simplifies workflows in diagnostic imaging and decreases diagnostic errors (Hosny et al. 2018).

In conclusion, let's not forget that AI is a technology based on learning, in the sense that it is an innate characteristic of intelligent algorithms to learn by processing large amounts of data and then accordingly adjust and optimise their internal parameters. As Slomka et al. (2017) concluded *"the upcoming developments will not replace the role of physicians but will provide them with highly accurate tools to detect disease, stratify risk in an easy-to-understand manner and optimise*

Radiologists need to obtain new skills in order to facilitate deep learning... they have to invest in long training cycles for a better understanding of big data usage

patient-specific treatment and further tests".

It is only natural then, that regular updates of the applications are still necessary. This obviously means that already operating application with tangible results can only get better in the future. Cloud-based infrastructures along with user feedback will help algorithms to be adapted at a faster pace, and new applications to be integrated into existing AI systems. It seems that it will not be long before we can really talk about comprehensive, AI-powered whole-body imaging. Finally, healthcare managers should enhance transformation of AI implementation - from speeding up workflows to improved diagnostics and cost-effective outcomes - making patient care more effective and efficient.

Conflict of Interest

None. ■

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Artificial Intelligence – Impact, Challenges and Opportunities

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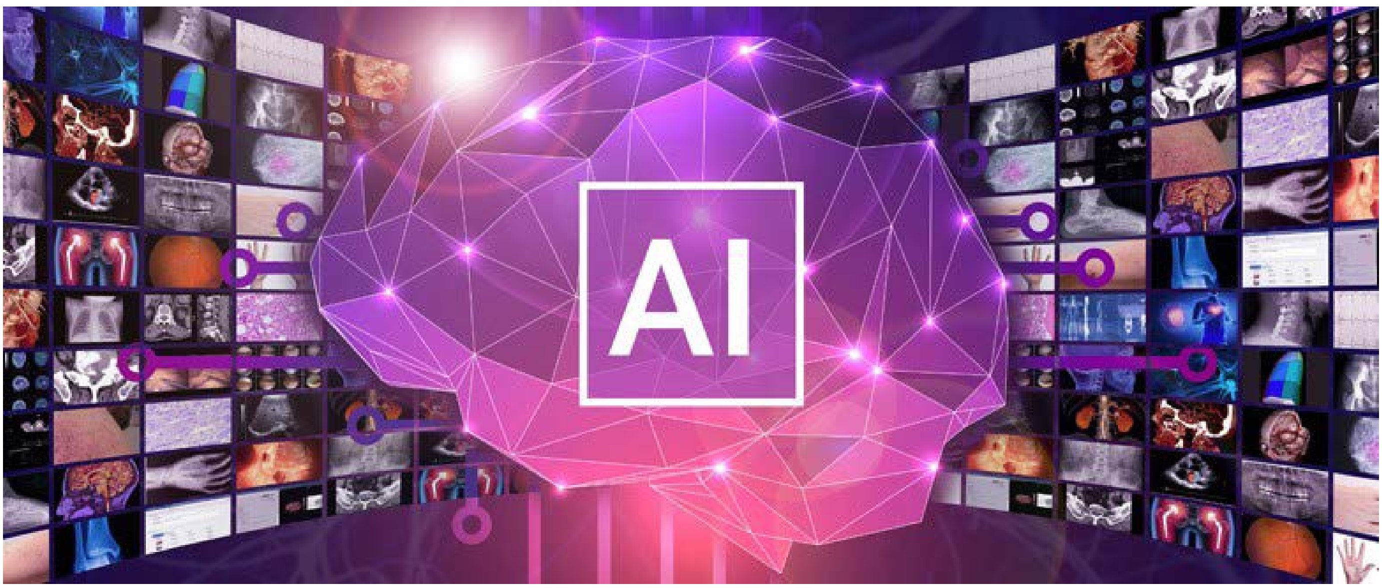
Dr Anjum Ahmed is the Chief Medical Officer at Agfa HealthCare. He has played an essential role in steering the company's innovation strategy for Enterprise Imaging and Artificial Intelligence. Dr Ahmed has over 23 years of global experience in solutions innovation, governance, change management and digital transformation. Before joining Agfa HealthCare, he spent 12 years implementing clinical and imaging IT solutions for a top-tier global vendor. He has published white papers in leading societies, including HIMSS Europe, and ESR, on timely topics such as value-based care and evidence-based use of AI. HealthManagement.org spoke to Dr Ahmed about Artificial Intelligence (AI) and its impact, challenges and opportunities in healthcare.



How have you seen AI change from hype to reality over the last few years?

In recent years, there has been a lot of hype around whether Artificial Intelligence (AI) is real or something in the distant future. There are multiple applications of AI, ranging from deep learning and machine learning to natural language processing. Over the last few years, several AI start-ups have developed these applications. There has also been a lot of hype that AI will replace radiologists or physicians. But the fact is that AI cannot be used in its own silo. It has to work with clinicians to augment their knowledge. A good majority of diagnosticians, globally, are advocating for embedding AI not only for clinical use, but also trying to understand its impact on education and training.

Did the pandemic impact the development and deployment of AI in radiology?

During the pandemic, there was a need for systems automation, speed and efficiency, and enhancement of clinical workflows. This brought more attention to AI. There were also issues related to fast access to clinically relevant patient information with limited capacity and with clinicians working from home. There were growing requests regarding automation and enabling triage for exams with specific or critical findings. All these are key workflow facets that facilitated the implementation of AI-related applications into clinical practice. Hence, the pandemic has had a remarkable influence on how innovations and technologies could be implemented in practical terms. It has also impacted how regulatory bodies, whether in Europe or the U.S. or Canada, started assessing the practical application of these technologies and their intended use in clinical practice.

You have been accompanying a lot of large health institutions in the implementation and adoption of AI in medical imaging. What problems are these institutions usually trying to solve?

The first thing that should be addressed is understanding that AI is not a product or a clinical application. It is a technology that can help healthcare organisations achieve an end goal.

Back in 2016/2017, when the hype around AI started, Agfa HealthCare partnered with a large private healthcare organisation to look at some common challenges related to chest screening. When it comes to diagnostic images, plain films of chest x-rays constitute more than 40 to 50% of the workflow; in some cases, even over 80% if it's a primary care screening setting. This organisation had 90% of their workflow allocated to screening and x-rays. That posed a challenge for them in terms of resources. In addition, there were also challenges related to productivity, staffing and burnout.

We collaborated with the healthcare organisation to develop x-ray-related AI technologies that would solve some of these challenges. We soon realised that AI, if developed in a silo, will remain in its silo, and will keep doing things on its own without influencing the outcomes. Hence, the first step is to define what clinical outcomes need to be improved. Once that is defined, one can set certain key performance indicators or metrics.

For our customers, the main challenge with AI deployment is implementing and embedding it into clinical use. The RUBEE™ framework developed by Agfa HealthCare revolves around five core pillars of the AI strategy, ranging from workflow orchestration, triage, advanced visualisation, automation, and precision reporting by capturing the AI generated intelligence. These five specific workflow aspects are what customers need to help address.

AI is not replacing radiologists. Instead, it allows them to focus on the clinical side of the analysis, which is much more meaningful

How did the work you were conducting improve clinical confidence?

AI is a new technology, and there are still discussions around trust and standards to evaluate the results that it can generate. Radiologists play a crucial role in providing diagnostic intelligence to referring physicians. If referring physicians receive evidence-based information, they can make more informed decisions. One approach we took in the early phases of testing was to validate the results from AI with the radiologist so that they could see the performance of these AI algorithms compared to the radiologist.

An important aspect of AI is machine automation. AI applications can improve the performance, efficiency and speed of certain tasks that humans would take more time to evaluate. The time that is saved improves efficiency and allows radiologists to look at findings and provide diagnostic intelligence. This is one aspect that can help improve the adoption of AI because it can help radiologists perform faster and be more efficient. AI is not replacing radiologists. It allows them to focus on the clinical side of the analysis, which is much more meaningful.

The other challenge is to improve confidence and the adoption rate. This can be done by providing peer-reviewed scientific data and publications. The better the data, the better the algorithm performance. Another way to convince radiologists is to enable them to see the clinical applications and action of their own data and population samples. This gives the clinical user confidence in how AI behaves in a case they may have already evaluated.

Do you encounter any clinical use cases in particularly high demand for AI?

Over the last few years, some of the top use cases that have evolved where AI is being implemented, tested and validated are around cancer screening programmes. There are also use cases revolving around plain films or x-rays because x-rays constitute a large volume of diagnostic imaging done across public health, institutes, or hospitals.

Another use case that is evolving is the detection of intracranial haemorrhages or workflows related to stroke because speed, time and efficiency are of key relevance in early detection and saving patient lives. There are also emerging use cases related to detecting fractures of the bones or bone age and other musculoskeletal findings like osteoarthritis-related conditions.

The important thing is to look at the clinical areas that the healthcare providers are focused on and embed AI workflow into their current ecosystem. It's all about bringing the clinical relevance of AI into practice.

There are certain solutions in the market that allow radiologists to use AI on a need basis. This is called pay-per-use. The challenge with pay-per-use is that it does not provide automation and real-time assessment. The approach Agfa HealthCare has is in real-time, embedded into the workflow. AI works in the background, and radiologists can already see the results that are processed. That's where you see the benefits for clinicians in real-time.

AI comes with a price tag. What aspects should be considered when hospitals build their business case?

AI is a new innovation. Many scientific publications demonstrate the sensitivity and specificity of AI, but this is based on retrospective data. There is some prospective data where certain studies indicate how it can perform as well as radiologists and how radiologists using AI can improve their productivity. But what does it mean? How do you translate it into numbers? The first thing to look at is speed and efficiency. How fast would the results be available compared to what is being done today? It is important to translate this into minutes – to show how much time is saved.

The other aspect is clinical programmes. It is important to know what clinical programmes healthcare providers are trying to improve. If the challenge is related to missing certain findings, it has to be addressed. If AI can pick findings that would otherwise be missed, that could impact patients' life expectancy and survival rates. The other indirect cost-related aspect of this is the clinical side. The earlier you pick up a particular challenge, the less cost is incurred on performing procedures and subsequent treatments.

The third aspect that certain hospitals look for is evidence. Some cases require more evidence to facilitate the right decision. If AI can provide that evidence, radiologists can help avoid unnecessary procedures and put the patient into the care paradigm earlier.

Another important aspect that customers want to address is faster reporting turnaround times to allow more patients into the screening programme.

What are the three winning arguments to convince customers about AI?

The primary argument favouring implementing AI is that it should be part of the workflow. If it is not part of the workflow, it will only assess and automate findings and results. These results must be accessible to the radiologist to demonstrate that AI is working for them in the background.

The second aspect is displaying results and reporting. There are several applications out there, and they have their own methodology in terms of how they display data. With RUBEE™, we embed and visualise AI results seamlessly in the existing workflow.

The third aspect is time. The goal of AI is to help radiologists save time by making clinical information easily available and providing automated comparisons to have all the information they need without running around to find a scan.

If we present all the above to a clinical user, it's a no-brainer that AI can be implemented and used successfully.

How do you help hospitals reap the benefits of AI - not only the deployment of AI but true augmented intelligence?

Augmented intelligence is the intersection of machine learning and advanced applications where clinical knowledge and medical data converge on a common platform. That's where the enterprise imaging strategy comes in.

One key benefit that the IT organisation and hospitals acquire with the enterprise imaging strategy is consolidation – to break the silos of the imaging workflows and build a common platform. There are multiple AI application developers out there. But that should not mean organisations have to acquire a new AI technology or worry about integration every time. Agfa HealthCare's RUBEE™ framework, developed as part of the Enterprise Imaging strategy, addresses this problem. RUBEE™ comes with a series of carefully curated AI packages that include multiple applications to analyse and display results to the end-user. Clinical users should not have to worry about

The approach we have enables Augmented Intelligence, embedded into the workflow. AI works in the background, and radiologists see the results that are processed by AI in real-time

integrating AI results or applications and automation.

In this issue, we discuss the opportunities, capabilities, and limitations of AI. With this in mind, where do you see AI today?

AI is as good as the data it has been trained on. It will have benefits if it is correlated with the clinical intelligence that resides in the systems already. There are multiple applications to consider when implementing AI. The challenge for the clinical decision-makers is to choose. We have addressed this with the RUBEE™ framework by curating clinical packages of relevant AI applications.

There is also the technology aspect and the importance of engaging the vendor. When hospitals decide on a particular AI technology, the Enterprise Imaging solution provider should be engaged earlier. It should not be an afterthought.

The third aspect relates to the clinical informatics residing in the EHR. AI can bring automation, but the missing link is clinical intelligence. With machine learning and natural language processing algorithms, this information can be automated and presented to radiologists.

Overall, AI will continue to play an important role in healthcare. As long as the implementation and integration process is handled smoothly, it will help clinicians make evidence-based decisions faster and more efficiently. ■

Learning From Each Other: An Artificial Intelligence Perspective in Healthcare

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An overview of how exchange of knowledge can advance Artificial Intelligence (AI) in healthcare with total data privacy.

Key Points

- Artificial Intelligence is playing an important role in taking better decisions across multiple sectors and the healthcare sector is not an exception.
- Rule of thumb: The larger the datasets the better the accuracy of machine learning methods.
- Healthcare data sharing is difficult because of some obvious reasons such as GDPR.
- New paradigm - learn from each other through sharing knowledge instead of sharing data.
- Methods such as federated learning, swarm learning and transfer learning enable us to exchange knowledge across institutions with total data privacy.
- The healthcare sector shall create a space to develop such generalised machine learning models in order to provide personalised, precise medicine and healthcare.

Digitalisation of healthcare data and the beginning of digital transformation reshape individual organisations in many aspects such as optimising healthcare processes, providing better healthcare, changing values, attitudes, and strategies and of course taking better decisions. Introduction of national wide Electronic Health Records (EHR) not only enables exchange of patients' healthcare data in between healthcare stakeholders but also enables interoperability of collected data. The metaphor of the subconscious as a model for rethinking healthcare (Leodolter 2015) can help promote partly autonomous healthcare providers to coordinate themselves like a self-controlling system. This includes the way to work with patients' healthcare information to provide personalised medicine and healthcare.

Parallel to medicine and healthcare, which are two paramount aspects of each healthcare provider within strict boundaries, the time has come to gain insights across the whole industry. We can do more as we humans learn from each other. Likewise, the larger the network of healthcare providers, the more we can learn from each other. We need a transformation to make use of AI in healthcare effectively - a new paradigm to gain insights from multiple healthcare providers with total data privacy: Exchange the knowledge gained from each individual institutional data through machine-learning methods/models within the network of healthcare providers instead of sharing the data is the idea (Li et al. 2020).

Hospitals are in the process of standardising the exchange of information following the data privacy regulations with their limitations. In the last decade, we have seen the concepts of Artificial Intelligence (AI) emerging into our daily lives helping us in taking better decisions. They are also more and more becoming part of this "subconscious minds" of organisations. The healthcare field is not an exception. The results of AI are promising in application of data driven machine-learning methods in predicting certain clinical events with good accuracy thus improving prevention and care.

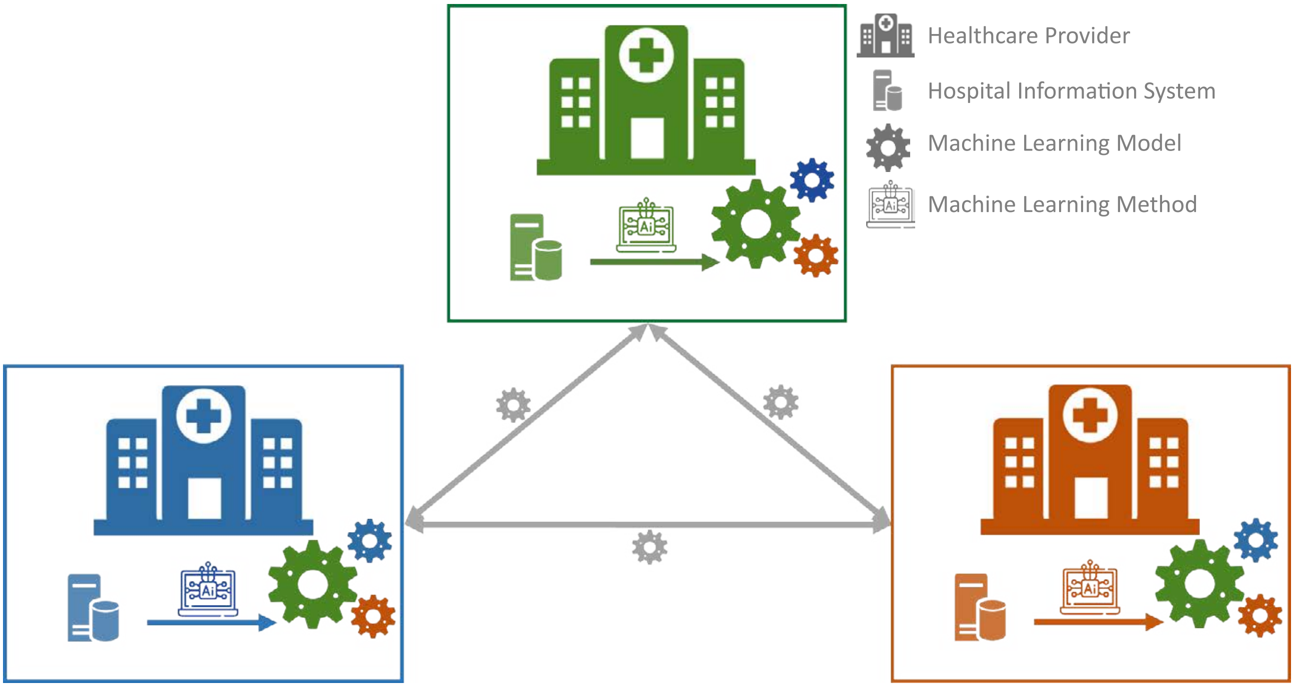

Figure 1: Not the data, rather only ML-Models or their parameters will be exchanged

The classical machine learning methods require data accumulation at a single location. Each healthcare provider usually hosts the data of her patients and uses the data primarily to provide medicine, healthcare and documentation. In a secondary use of the data, each healthcare provider's patients' data can act as a data lake to apply machine-learning methods. These methods acquire knowledge along with certain institutional data attributions in the form of models. Although various machine-learning models have been developed using EHR data recently, there is a need for external validation of these models in order to develop generalised models that discriminate reasonably across various multi-institutional cohorts. However, such studies are often difficult to perform due to data sharing limitations. Even when the data is anonymised for sharing, the anonymity can be compromised.

Techniques such as federated learning, swarm learning, and transfer learning among few others are emerging with favourable results in exchanging the knowledge - in other words: exchanging and merging machine-learning models instead of data. Although there are slight differences in afore mentioned methods, the general idea is to keep the data safe and do the learning in total data privacy.

Federated learning is described as the aggregation of models that have been developed at individual healthcare providers (Brisimi et al. 2018). Swarm learning, model parameters are communicated within the network of healthcare providers during the learning process. Learning can be either sequential or parallel with prior consensus (Warnat-Herresthal et al. 2021). Both federated learning and swarm learning deals with a single clinical event whereas transfer learning (Torrey and Shavlik n.d.) deals with the big picture, where the models are trained with large sets of data to acquire knowledge at a higher level and then learn at individual healthcare providers for specific use case.

The European Union artificial intelligence regulations released in April 2021 are encouraging institutions to use AI responsibly. With these developments, we envision that the institutions create space for the innovation to progress knowledge exchange. There is a potential in gaining generalised insights of various epidemiological conditions throughout the complete healthcare industry in order to provide personalised, precise medicine and healthcare.

Conflict of Interest

None. ■

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The Current State of AI in Diagnostic Imaging and How to Improve its Clinical Value

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More well-curated data, external validation of algorithms, and user-friendly workflow integration will help translate the potential of AI into clinical routine.

Key Points

- Representative datasets and external validation are key issues for AI algorithms to become more accurate and generalisable.
- Machine learning is not only used for automation; it will also help expand the vocabulary of patterns that lead to treatment decisions or find new relationships.
- Although individual tasks are taken over by AI, computers will augment human decision-making rather than replace imaging professionals.

Although an ever-increasing number of publications suggests that artificial intelligence (AI) could provide value in numerous medical imaging applications, there seems to be a considerable gap in moving from proof-of-concept to production. Once a software solution has made it to commercialisation, it still needs to prove its robustness and deliver its benefits within a well-established clinical workflow. To date, only a limited number of AI solutions provide evidence of meeting the ultimate goal of any healthcare technology, which is to improve patient outcomes. By posing four provocative questions, this article suggests how to enhance the value of AI for radiology and other diagnostic specialities.

Are Commercial AI Solutions Accurate and Generalisable?

Performance consistency is increasingly becoming the focus of scientific research. In their recent exhaustive review, Brendan Kelly and co-workers found a propensity for bias and a lack of generalisability for many published algorithms (Kelly et al. 2022). Across all studies included, the median performance for the most utilised metrics was a Dice score of 0.89, an area under the curve (AUC) of 0.90, and an accuracy of 89.4. Average performance in those studies allowing for direct comparison decreased by 6% at external validation, ranging from an increase of 4% to a decrease of 44%. The requirement for external validation of AI solutions even after approval by regulatory authorities corresponds to published evidence including our own experience derived from a neuro-computed tomography (CT) study (Kitamura et al. 2021; Kau et al. 2022).

If a decision support software produces a limited number of erroneous alerts which experienced physicians can easily resolve, it may still hold promise for triage and notification (Figure 1). Statistics are critical in assessing AI performance. Therefore, it should be no surprise that metrics are used to the advantage of the respective product, at least in marketing brochures. The AUC provides a single aggregated measure. However, Elad Walach, CEO of Aidoc, once explained that it is confusing to physicians and may be overemphasised (Walach 2019). The negative predictive value of a decision support software should be really high, while a relatively low positive predictive value could still be satisfying for detecting rarer diseases. Ideally, disease prevalence in a training data set should correspond to the real-world clinical scenario. Apart from the size of a convolutional neural network, diverse and meticulously labelled data sets and better disease models are key issues for AI algorithms to become more accurate.

Do Current AI Developments Reflect Clinical Needs?

Much of the recent excitement surrounding AI in diagnostic imaging gravitates toward algorithms developed for interpretative tasks. In fact, AI promises to have an impact on

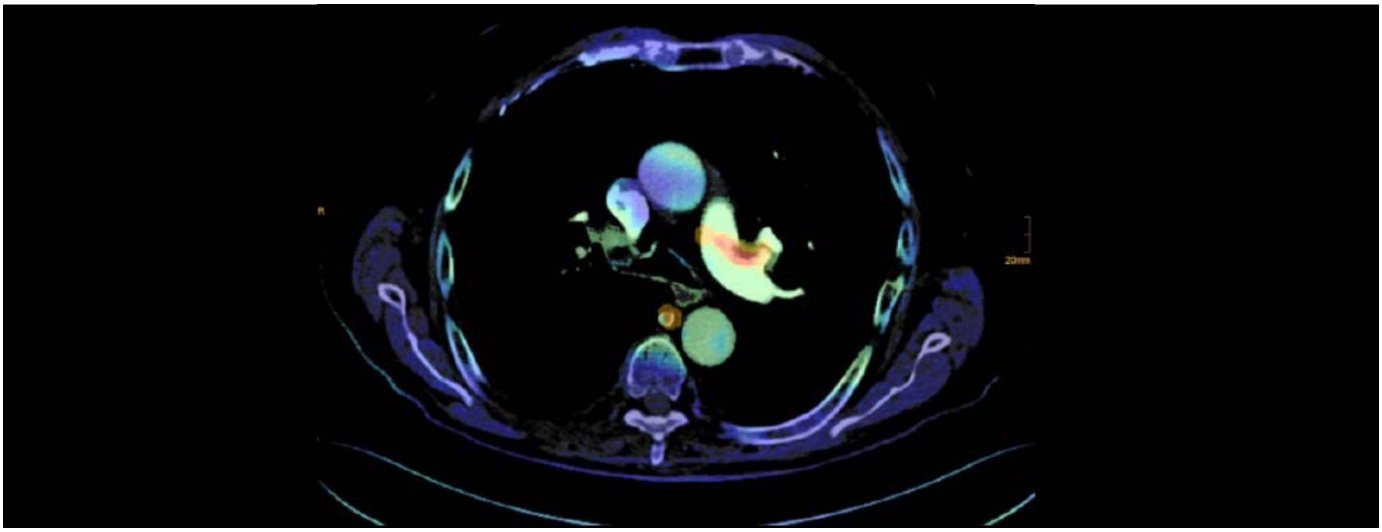

Figure 1: Contrast-enhanced thoracic CT analysed by a commercial triage and notification software that flags and communicates pulmonary embolism. While correctly marking an embolus in the left pulmonary artery *(red, anteriorly)*, it erroneously also highlights the azygos vein *(red, posteriorly)*.

medical diagnostics along its entire value chain (Richardson et al. 2021). That ranges from using deep learning towards dose optimisation to case prioritisation and from automated segmentation tasks to pattern recognition. To develop an additive value in clinical routine, isolated solutions must be integrated into an efficient workflow. With different degrees of maturity, marketing framework, and media attention, we see AI developments focussing on patient safety, image quality, reduction of reading time, or decision support. A promising research area, yet slowly translating into practice, is the characterisation of "radiomic" features, which are not discernible by visual inspection (Bera et al. 2022). Such MRI fingerprints have been shown to be predictive of treatment response in specific diseases, which may even lead to the re-classification of certain pathologies. Not without reason, AI is considered a key tool on the road to personalised precision medicine.

It is doubtful for various reasons, not least regarding data-sharing and economy, whether an undisputed wish of healthcare professionals will soon be taken into focus, namely the development of decision support algorithms for rare diseases. Think, for example, of pattern recognition in acquired and, moreover, congenital metabolic brain disease. Its aetiopathogenetic diversity with sometimes similar imaging patterns, gradual as well as inhomogeneous expression, and infrequent appearance of single types make this neuroradiologic topic a traditional challenge for differential diagnostics. In current commercial software, there is a clear tendency towards solutions for frequent diseases or imaging requests, respectively.

Is There a Risk That AI Will Deskill or Even Replace Radiologists Instead of Complementing Them?

In many countries around the globe, as the demand continues to increase, the emerging support offered by disruptive technologies meets a current supply crisis in diagnostic imaging services. It is expected that algorithms will overtake some of the core tasks of radiologists. Whenever the issue is narrowed down to the question of whether humans or machines produce better results, we should not forget that AI systems work with high levels of standardisation and without being vulnerable to fatigue or cognitive biases – while being prone to other sources of bias. At the moment, however, we are dealing almost exclusively with single task solutions which, if sufficiently accurate, take on individual tasks such as the detection of pulmonary embolism. By producing timely alerts, they steer the radiologist's eye in the right direction. On the other hand, we are currently far from AI software covering the entire differential diagnostic spectrum, especially in complex clinical scenarios. Needless to say, several expectations are linked to the patient/doctor relationship of trust, ranging from contextual experience via personal responsibility to medical advice. The level of additional diagnostic accuracy, consistency, and, ultimately, patient outcomes will likely depend on the careful coordination of machine and human capabilities.

Breast imaging is a very promising use case for AI as it is expected to impact several of the aforementioned aspects. As for screening mammography, recent evidence (McKinney et al. 2020) suggests that AI algorithms may soon be able to replace the second reader for unequivocal cases, saving resources to a limited extent. However, there is a lack of compelling evidence from large prospective studies based on models fusing AI and human expert vision (Lehman et al. 2021).

Generally, in the foreseeable future, computers will augment human decision-making instead of replacing imaging professionals. While triggering a need for education in basic principles of machine learning methods, the introduction of AI software also includes the risk of deskilling among diagnostic imaging specialists, as put up for discussion by Michael Fuchsjäger in the course of last year's AICI Forum (Leodolter 2021). In order to be able to check the plausibility of software outputs, future radiologists, pathologists, and other diagnostic specialists will still need classic knowledge and skills. Furthermore, they are expected to keep a holistic approach in the increasingly overlapping field of medical diagnostics. Finally, augmented teaching tools will expand medical training in a meaningful way.

What are the Challenges for AI to Provide Value in Clinical Routine?

Translating the potential demonstrated in AI research into a measurable clinical benefit requires healthcare stakeholders to be aware of all the expectations, challenges and pitfalls that can accompany the development and deployment of AI systems in a diagnostic imaging environment. In his recent article on "Separating hope from hype" in AI for radiology, Jared Dunnmon stressed the importance of meaningful performance measurement for a consistently defined and clinically relevant task (Dunnmon 2021). To deliver repeatable and reproducible results, datasets used for evaluation must represent the characteristics of a population on which an algorithm is intended to be applied, including sufficient granularity to capture relevant variations. This leads to the perception of AI algorithms as a "black box". The higher the rate of false-positive and even more so false-negative results, the greater is the demand for interpretability. Further research is warranted on explainable AI, although explainability is not an exclusive parameter of trustworthiness and certainly not a good indicator of accuracy.

Another hurdle for translation into clinical care is the lack of large, diverse, and well-curated data sets for independent training and testing of algorithms. Such requirements challenge the legal and ethical framework towards enabling secure data-sharing for the public good and, in patient care, cloud-computing versus on-premise solutions. Once deployed in a radiological workflow, AI software is expected to perform consistently over the full range of possible imaging patterns and present results timely on user-friendly interfaces. For the time being, healthcare professionals are still "sipping from the glass", just having a try with a few algorithms here and there. In the near future, the industry will likely provide something like a marketplace or app store for imaging specialists to choose from a preselected number of AI tools which may be always on or work on click (Saboury et al. 2021).

AI systems work with high levels of standardisation and without being vulnerable to fatigue or cognitive biases – while being prone to other sources of bias

It is beyond the scope of this article to elaborate on economic concerns for healthcare providers such as budgeting and reimbursement of AI supply. What is becoming more and more apparent, though, are heavily hardware-centric budget plans confronted with a dynamically growing software market.

In conclusion, AI holds the potential to provide value by improving patient access to expert service, extracting information and new knowledge from imaging data, increasing diagnostic certainty, saving time, and ideally improving clinical outcomes. In order to get disruptive changes realised beyond the hype, several stakeholders should keep fusing their ideas and viewpoints on all available levels. One of those opportunities will be the 4th AICI Forum taking place in Graz, Austria, this autumn.

Conflict of Interest

None. ■

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Artificial Intelligence and Radiomics at the University of Florence

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This paper provides an overview of current research at the Department of Radiology of the University of Florence. It concerns radiomics along with Artificial Intelligence (AI) applied to various medical fields. The need for personalised medicine and the transition from qualitative to quantitative imaging are at the heart of the projects described in this text. The purpose of this paper is to extend the collaborations of the group and find innovative ideas.

Key Points

- The application of AI in medicine has led to greater automation in several fields.
- Radiomics together with AI is useful in diagnostic imaging.
- The transition from qualitative to quantitative imaging could improve the diagnostic and therapeutic approach in several diseases.

Radiomics

Radiomics is a new discipline that allows to extract and analyse a large number of quantitative features taken from medical images acquired with standard techniques (Schapicchio et al. 2021). Once the characteristics of the radiological images are identified and selected, they are stored and then analysed for clinically valid results (Guiot et al. 2022). The term "radiomics" was first introduced in 2012. The birth of this discipline is linked to the need for more personalised medical diagnostics for patients.

Artificial Intelligence (AI), in turn, is a mix of advanced computational algorithms that, once trained, acquire the pattern of data given as input and become able to make predictions about new datasets (Chen et al. 2021; Koçak et al. 2019).

These two disciplines can be used together to manage larger datasets more comprehensively than traditional statistical approaches. The common goal is to extract and analyse as much hidden and meaningful quantitative data as possible to use as a decision support tool (Koçak et al. 2019).

In radiomics there are two different approaches that exploit AI: hand-crafted radiomics and deep radiomics (Figure 1). The

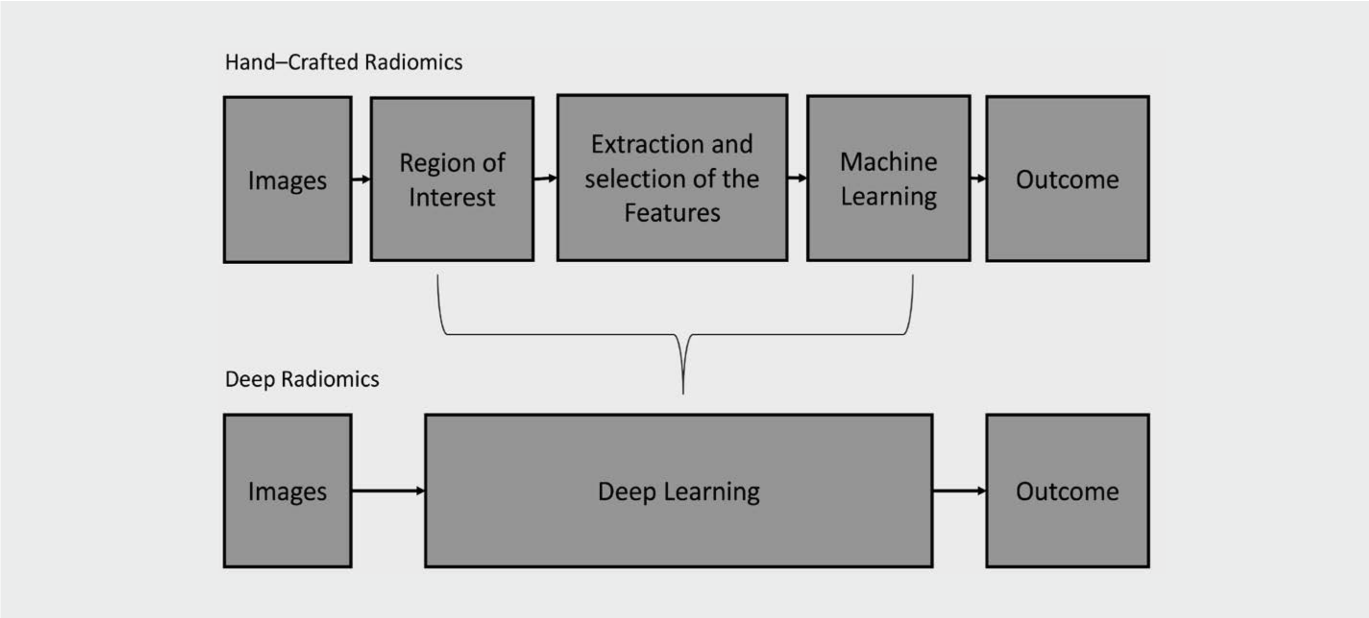

Figure 1: Diagram of the process steps of Hand-Crafted Radiomics (top) and Deep Radiomics (bottom)

first uses Machine Learning (ML), a subcategory of AI, while the second exploits deep learning (DL), a subcategory of ML, from which it takes its name. The difference between these two is that in hand-crafted radiomics human intervention is required, while in deep radiomics the computer provides the result without any human intervention.

The growing interest in the use of these combined disciplines, AI and radiomics, is evident considering the histogram of the publications over the years obtained by searching "Artificial Intelligence" and "Radiomics" on PubMed (Figure 2).

Ongoing Projects of the UNIFI

A multidisciplinary research group was recently created at the Department of Radiology of the University of Florence (UNIFI). It includes Stefano Colagrande (full Professor and chief), two radiologists, Cosimo Nardi (MD, PhD) and Linda Calistri (MD, PhD), one biomedical engineer, Eleonora Barcali (PhD student) and one rheumatologist, Martina Orlandi (MD, PhD). It also has the support of Professor Leonardo Bocchi, PhD, of the Department of Information Engineering of the UNIFI.

The team thus formed is currently focusing on AI and radiomics in diagnostic imaging. Starting from the literature study on the use of these innovative technologies, the group has conceived four main projects discussed in the following subparagraphs.

A further collaboration, that will not be dealt with in this paper, is being established with Anna Julie Peired (PhD), from the Nephrology unit of the UNIFI, and will focus on developing new methods to assess renal function in paediatric patients using Intravoxel Incoherent Motion (IVIM) parameters from Diffusion Weighted Imaging (DWI) on MR.

COVID-19

The first project discussed is the one from the HORIZON 2020 consortium financed by Innovative Medicines Initiative 2 and titled DRAGON (The RapiD and SecuRe AI enhAnced DiaGnosis, Precision Medicine and Patient EmpOwerment Centered Decision Support System for Coronavirus PaNdemics). This one, whose principal investigator at UNIFI is C. Nardi, concerns the use of AI applied to the COVID-19 emergency. It deals with the development of an ML system to make diagnosis in time and, in the future, be able to better manage upcoming epidemics.

In addition, it aims to predict the evolution of diseases caused by this pathology that are known as long-COVID. The role of the group in this case is focused on the provision of clinical data and CT scans. This project was the first approach of the team to AI applied to diagnostic imaging and the source of inspiration to develop the subsequent projects in other medical fields .

Lung Parenchyma

A second project will investigate the role of MR in the evaluation of the lung parenchyma comparing imaging data provided by CT images with those provided by MR. In particular, it will focus on interstitial lung diseases, especially those secondary to connective tissue disorder. The real challenge is to distinguish mainly inflammatory features from fibrotic damage, in order to select the most appropriate therapy for the patient (immunosuppressant or antifibrotics). In this context, radiomics along with AI could also play a key role in quantifying the percentage of reversible inflamed lesions.

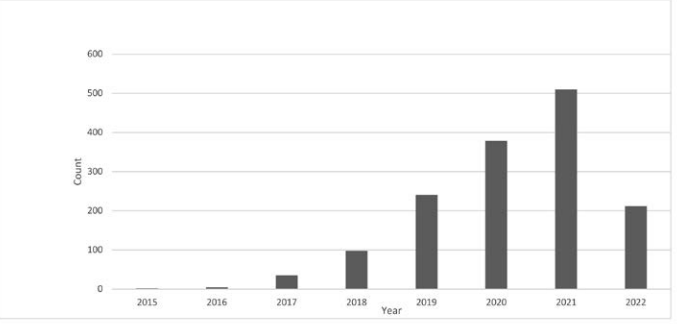

Figure 2: Histogram of evolution of the trend of publications of "Artificial Intelligence and Radiomics" from 2015 to the present. Source: PubMed (top) and Deep Radiomics (bottom).

Liver Parenchyma and Function

The third project is currently being evaluated, having been presented to a national programme called PRIN (Projects of Relevant National Interest) 2022, that promotes and funds public research at the national level. The principal investigator is L. Calistri. The project title is "A multifaceted quantitative approach by MRI to stratify liver derangement and dysfunction in chronic liver disease (CLD): a prospective multicentre study by texture analysis, IVIM evaluation and T1 relaxometry" and involves three other Italian universities.

It has three purposes:

- Perform a stratification of different levels of CLD based on the Native T1 value and the T1 Reduction Rate of the hepatic parenchyma after gadoxetic acid disodium (EOB-Gd) administration and the IVIM parameters from DWI on MR.
- Obtain a "quantitative functional liver imaging score" (qFlis) based on the parameters expressed in the previous point to predict CLD outcomes.
- Evaluate CLD grades using liver texture analysis on T1-weighted images to predict patient outcome in comparison to qFlis.

This latter aspect can be achieved by using radiomics to detect changes in individual voxels and their organisation on T1-weighted images to investigate the level of parenchymal imbalance.

In summary, the goal is to calculate a score from the parameters IVIM, T1 Reduction Rate and Texture to semi-quantitatively assess the grade of CLD and predict its outcomes.

Bone Strength

The bone strength, fracture resistance under stress, is strictly related to both mineral density (BMD), and macro/micro geometrical characters. Generally, volumetric BMD can be evaluated quantitively by using Hounsfield Unit calibration of Multi Slice CT (MSCT) images, while for microstructure, the micro-CT is currently the gold standard.

The fourth project of the group aims to evaluate the strength of the bone from cone beam CT (CBCT) images. It relies on the support of EIDO Lab, the joint laboratory founded by the UNIFI together with Imaginalis S.R.L. The purpose is to investigate a new way to make accurate strength assessments from CBCT images using small bones of the extremities, full of trabeculae. The goal is to exploit the AI systems used in radiomics to find a correlation between the trabeculae, their spatial arrangement and their thickness with the strength of the entire structure. The analysis will begin by comparing voxel by voxel the images obtained by MSCT with those obtained by micro-CT and CBCT to find a correlation between them and any change.

Conclusions and Future Developments

The projects described are still in their infancy, but the goal of the group is clear: to contribute to the transition of imaging from qualitative to quantitative and from morphological to functional in the AI era. One of the toughest challenges is to create larger datasets to exploit AI potential at its maximum. The idea of sharing ongoing activities is to create new collaborations and find innovative proposals to form an international multidisciplinary network with a common purpose.

Conflict of Interest

None. ■

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Integrated Cancer Care and Intelligent Imaging

Ben Newton I GM Oncology I GE Healthcare I UK

Early diagnosis of cancer can lead to better patient care and better outcomes. In particular, the use of intelligent imaging technology along the patient's journey, from screening to diagnosis to treatment, monitoring and follow-up, is essential. HealthManagement.org spoke to Dr Ben Newton, General Manager, Oncology at GE Healthcare, to discuss his views on integrated cancer care, the optimum use of imaging data and clinical information, the importance of early diagnosis and the need to close the gap in cancer care.

Key Points

- Cancer is one of the leading causes of death worldwide.
- Cancer care is complex, and interruptions and delays can significantly impact patient outcomes.
- Fragmentation in terms of access or fragmentation at different levels of care or fragmentation of clinical practice must be overcome by integrating care.
- Technology can support clinicians and patients throughout the patient's cancer journey, whether it's at the stage of screening and diagnosis, determining the right treatment strategy or monitoring patient progress.
- The key is to close the gap in cancer care through early detection and more timely and advanced treatment strategies.

Integrated Cancer Care – Overview and Benefits

Cancer is one of the leading causes of death worldwide. It has an impact on life expectancy and the cost of care. Cancer care is an extremely complex process, and any interruptions and delays can change the course of care and have a significant impact on patient outcomes. It is critical to reduce the time between the appearance of symptoms, diagnosis and initiation of treatment.

The issue of uncoordinated care, sub-optimal management, fragmentation of information and the discontinuous application of interventions may be overcome by using a multidisciplinary team (MDT). An MDT can come together and integrate those datasets in defining the disease, stratifying the patient into a particular type of disease, or understanding (from a differential diagnosis) the exact nature of the problem. These teams consist of radiologists, surgeons, nurses and pathologists coordinating care as a multidisciplinary team, bringing all the strands of evidence together to determine what the symptoms mean. Also, using multidisciplinary teams helps develop ownership at every level and allows clinicians and radiologists to give their input as they are the ones who are delivering care. Bringing together all these colleagues and promoting co-creation and collaboration can only benefit the patient in the long run.

Integrated care can help reduce the gaps in the cancer care pathway and bring patients and caregivers closer together

The goal of integrated cancer care is to propel new thinking, transform care pathways, and better utilise imaging data technology. One of the biggest challenges in cancer care is the lack of consistency. There are nearly 20 million new cancer cases annually, and patients are distributed across the globe. Different health systems have different practice methods, and diagnosis and treatment vary by location. Along the patient care pathway, patients can get different tests done in different locations. They may also interact with several different caregivers along this journey. In addition, patients in rural areas may not have access to the same quality of care or treatment technology. Finally, there are always issues of coordination among the different care providers. Hence, this fragmentation - whether its fragmentation in terms of access or fragmentation at different levels of care or fragmentation of clinical practice - must be overcome through the integration of care and through an overall improvement in screening programmes, faster access to diagnostic tests, use of cutting edge treatments and technologies and personalised treatments. Integrated care can help reduce the gaps in the cancer care pathway and bring patients and caregivers closer together.

Optimising Imaging Data and Clinical Information

A great deal of information is generated at different points in the patient care pathway. Maximising the use of data – imaging data, digital pathology data etc. – can help clinicians draw better insight and make more effective treatment decisions due to improved access to this information. The goal is to enhance the use of the massive amount of clinical information that is available to drive better decision-making and facilitate consistency within the cancer care pathway. Ultimately, the biggest benefit of integrated cancer would be to deliver care to the patient as early as possible and improve their access to treatment.

Data-driven cancer care is the future. More effective utilisation of electronic health records and radiology information systems, imaging and other medical data can help to simplify cancer care and reduce fragmentation and variation.

Integrated Care and Technology

The goal of integrated care can become possible through the use of technology. Technology can pave the way to allow clinicians to deliver earlier diagnosis and use more accurate treatment strategies. This can go a long way in improving the health outcomes of cancer patients. Hence, advanced technology and intelligent tools can be used to connect different imaging networks, enable early cancer detection, improve access to treatment, and promote high-quality, personalised care. Technology can support clinicians and patients throughout the patient's cancer journey, whether it's at the stage of screening and diagnosis, determining the right treatment strategy or monitoring patient progress. It can support and integrate cancer patient data from multiple sources into a single resource that clinicians can use to make optimal clinical decisions. Digital technology can be used to pull information into a centralised framework to display the pathology, the imaging, the medical records and the genomic information that is becoming even more critical to defining the right kind of treatment.

The Importance of Early Diagnosis

Early diagnosis and treatment are crucial to improving the survival rate of cancer patients, and innovative technology and improved patient care models can help facilitate faster diagnosis, as well as more precise treatments.

To help improve patient outcomes, cancer care needs to be less siloed and more efficient. Education, awareness, and specificity around testing and screening for multiple risk factors associated with disease and putting those risk factors together with presentation-based information are important for early diagnosis. Once a patient gets into the system, integrated cancer care strategies can help drive and support the triage of patients in the right diagnostic pathway and facilitate definitive diagnosis.

Cancer care is a journey and this journey needs personalised solutions from diagnosis through every stage of treatment - efforts must be made to use the right tools for the right patient at the right time.

Closing the Gap Through Earlier Detection

Moving into precision medicine and using advanced diagnostic tools can improve cancer diagnosis and survival. The future of cancer care is not just developing and introducing new equipment - it is about providing better patient care and using improved solutions and advanced technology designed to improve patient outcomes.

It is important to identify the patients that need care and follow-up after the initial screening process. It is equally important to improve the diagnosis of all types of cancer. Triaging patients from screening into diagnosis more efficiently can transform cancer outcomes. The use of Artificial Intelligence (AI), machine learning (ML) and other advanced software engineering techniques can support the goal of personalised and precision cancer care and help integrate clinical, imaging and genomic data from multiple sources into a single interface. Ultimately, integrated cancer care is designed to try to diagnose every cancer patient and provide these patients with the treatment they need as early as possible so that they can have a better chance of survival. Numerous patients do not have access to asymptomatic cancer screening. They only seek treatment or attention when symptoms appear, but these delays can have a significant impact on their chances of survival. Some patients with false positives are subject to invasive procedures that they may not need at all. This is not only harmful and stressful for the patient, but it also takes up valuable healthcare resources. The challenge is to get patients who are truly positive into treatment quickly and efficiently. This can transform cancer care and improve outcomes while the strain of late diagnosis can be devastating for patients and healthcare systems.

> **Triaging patients from screening into diagnosis more efficiently can transform cancer outcome**

Conclusion

Early diagnosis of cancer can lead to better patient care and better outcomes. Over the years, there have been many important developments in the diagnosis and treatment of cancer through the use of imaging technology along the patient's journey - from screening to diagnosis to treatment, monitoring and follow-up. To help continue to drive improved patient outcomes, integrated cancer care that includes the use of cutting edge treatments and technologies, as well as improvement in screening programmes, faster access to diagnostic tests, and personalised treatments is critical to helping reduce the gaps in cancer care. ■

The Knowledge Model and Enabling Artificial Intelligence

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The purpose of this paper is to provide a growth path to AI development. It is based on principles learned from launching CT, MRI, Neuro Vascular, and PACS.

Key Points

- Create a model (The Knowledge Model) that will build with additional concepts as they develop, resulting in synergistic thinking (Causal Knowledge by Judea Pearl – one of the Fathers of Artificial Intelligence).
- Select a leading factor (Intuition) that will be tested for its leadership as the process continues. Crucial for medicine.
- Select a leading process (Clinical/Technical Tie) that is well proven. Created by Dr Alex Margulis, UCSF Chair when CT was being established.
- Manage technologies (2D/2.5D/3D/Holography etc.)
- Build synergies (e.g. radiology/surgery) to expand interoperability.

An Opportunity – Colonoscopy in True3D Space

Let's begin with an example of colonoscopy using interactive mixed reality (IMR). Think about a hologram where the user can "swim" through the object (True 3D). The goal is to increase patient outcomes when compared to optical colonoscopy (present standard) and virtual colonoscopy (with visualisation limited to 2D views). Optical colonoscopy misses about 40% of flat lesion cancers (cancers that are on the inner wall of the colon and are therefore very challenging to visualise.) 2D virtual colonoscopy misses between 20-80% of flat lesion cancers. True 3D colonoscopy has a flat lesion detection close to 100% (UCSF/Clinical Trial) (Table 1) (Yee 2016).

2D Views vs True 3D Visualisation

Let's examine how experts in the field of medical imaging describe 2D views vs True 3D visualisation for brain and spine imaging and the impact on intuition. Meaningful data and insights are embedded within medical images. Often insights are undetectable via routine visual analysis with 2D/2.5D view (2.5D views represent a 2D view of a 3D volume object.) Valuable information is being overlooked and the optimum level of intuition is not realised with 2D views. It is important to understand that images are more than pictures - they are data (Gillies et al. 2016).

When a physician examines a CT, they're piecing together multiple 2D perspectives—or 3D perspectives on a 2D screen—to imagine a patient's 3D anatomy. That mental leap means they're forced to make assumptions about what the patient's colon truly looks like—which can slow down workflow and open the door to overlooking critical clinical information. True 3D uses existing medical image datasets to give physicians an interactive, three-dimensional solution that may make reading medical images more intuitive, help physicians reach a diagnosis, and assist in complex surgical planning applications.

For brain, 3D is the answer. "It is no longer adequate to analyse complex brain and skull-base tumours with 2D views..... the future of neuroradiology is in advanced techniques such as virtual reality and augmented reality, which produce a dynamic, interactive 3D view of the patient's imaging" (Kumar 2018).

For spine, again 3D is the answer. Scoliosis is a 3D problem. IMR could be utilised for the surgeon to accurately position the placement of rods to achieve the best efficacy for treatment – e.g. addressing the twist in the spine. IMR technology takes treatment from "best guess" to "I know intuitively I am correct." IMR is used by spine, gastro and pulmonary experts to confirm the ideal solution (Ross and Burnett 2018).

Cheryl Petersilge, former CMO at the Cleveland Clinic, stated that, "One of the critical shifts that we as radiologists, or in the radiology industry, need to think about, is shifting our focus

	Optical Colonoscopy	2D Virtual Colonoscopy	True3D Colonoscopy
Image Type	Video 	CT 	CT 
Detection	Can miss up to 40% of cancers in right side of colon (most are flat lesions)	Flat lesions between 20-80%	Flat lesions approximates 100%* UCSF trial
Interpretation Time	45 – 90 minutes	30 – 40 minutes	5 – 10 minutes*UCSF trial
Preparation	Laxative + Anesthesia	Laxative and non laxative preparation – No Anesthesia	Laxative and non laxative preparation – No Anesthesia
Cost	$2,500 U.S. Average	$500 - $750 U.S. Average with reimbursement	$500 - $750 U.S. Average with reimbursement

Table 1: Virtual colonoscopy – Increasing clinical efficacy and workflow = increased patient outcomes

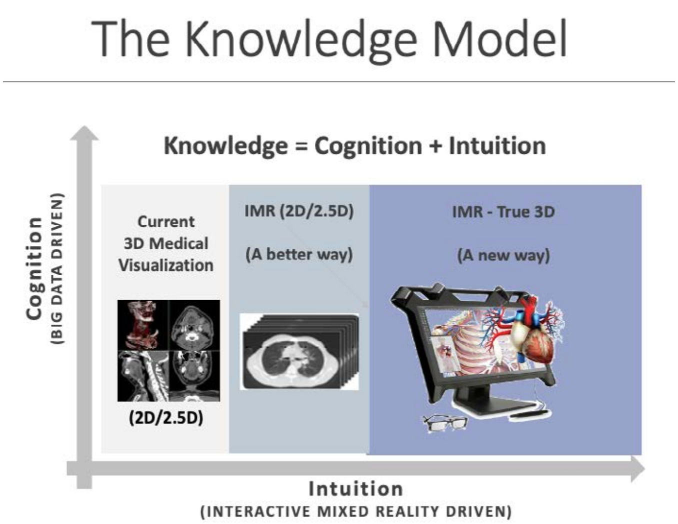
to the outcomes at the enterprise level, and use our radiology environment and enterprise imaging as tools (e.g. imaging in open 3D space), to affect the enterprise outcomes" (Petersilge 2019).

The Knowledge Model and Enabling AI

Let's look at some definitions that will be helpful in analysing the Knowledge Model and enabling Artificial Intelligence (AI). Knowledge is composed of cognition (vertical axis of the model) and intuition (horizontal axis of the model) (Figure 1).

Knowledge drives clinical efficacy (CE) + workflow (WF) = patient outcomes (PO). Intuition is more powerful than cognition and uses human intelligence (HI). Intuition (HI) drives "Doing the Right Things." Cognition uses Machine Intelligence (MI); Big Data; AI; etc. Cognition drives "Doing Things Right." Protocols (clinical/technical tie) is driven by HI. The Intuition Engine provides the required structure to minimise cognitive bias and maximise the intuitive process.

AI provides significant potential for improving both knowledge and patient outcomes. To achieve these powerful results,



there are several steps that are proposed for users to follow:

1. The Clinical/Technical Tie – having Clinical and Technical team members working closely to ensure "Doing The Right Things" (DRT) by use of Human Intelligence.
2. Step (1) will lead to "Protocol Development" that delineates paths to follow for "Doing Things Right" (DTR).
3. DTR will result in sections of the protocol that allow for creation of AI steps – e.g. partitioning a long object into sections, or detection of abnormal tissue shapes, or characterising the specific tissue as cancerous.

The Key Ingredient – The Protocol

1. The Clinical/Technical Tie – Physician/Scientist – deep understanding using human intelligence.
2. Thinking "outside the box" – driven by intuition.
3. Dreaming in open 3D space, "creating a new box."
4. For True 3D Virtual Colonoscopy – dividing the colon into linear sections, studying one section at a time to find polyps = a new way of thinking.

These results can't be created by studying an infinite array of 2D/2.5D images. They have been created by human intelligence at work in an environment established by True 3D-Open 3D space imaging.

Let's focus on the AI steps being selected. They would not exist in analysing the colon without true 3D imaging. That is, without the protocol that was selected.

Protocol Example – Left Atrial Appendage

Patients with atrial fibrillation can be seriously harmed by clots coming out of the left atrial appendage (LAA). An implant device can block the opening to the LAA. The goal is to accurately size the implant for breadth and depth of placement and guide it into the ostium.

The solution is to get to the face of the ostium and measure for implant size. With interactive mixed reality, it takes approximately 1.5 minutes to reach the target and click. With 2D/2.5D, it takes 20 minutes.

For virtual colonoscopy, intuition is the key for developing

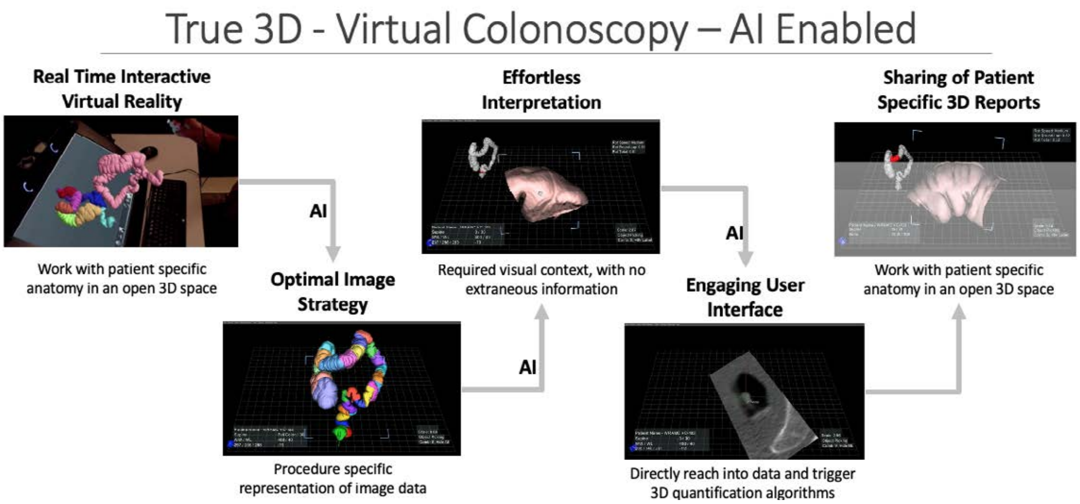


Figure 2: Enabling AI in True 3D Colonoscopy
Case #1 – Optimal Image Strategy - AI can replace the radiologist in sectioning the colon to create the optimal image strategy.
Case #2 – Effortless Interpretation – AI can rapidly determine the probability that the polyp in question is a true polyp vs extraneous material, etc.
Case #3 – Engaging User Interface – AI has the capability to determine the probability of the polyp in question is cancerous.
Summary – the protocol to divide the colon into sections, test each section, etc., enables AI to perform tasks that it can effectively do.

the protocol process. For the LAA, intuition plays a key role in levelling the playing field in dealing with patients of various sizes and shapes. Interactive mixed reality provides the intuitive capability.

The Big Win - The Intersection of Big Data and IMR

IMR drives the intuitive element of knowledge while Big Data drives the cognitive element of knowledge thus reducing cognitive bias. The potential for a big win would be:

1. IMR – initial protocol for increasing patient outcomes (Doing the Right Things)
2. Big Data - using 1. provides best practices to optimise the IMR Protocol (Doing Things Right)

The Future Path

Big Data/ML are not sentient beings. They are not able to perceive and feel things. AI must be embedded into the complex workflows of healthcare to significantly create value. This is exactly the perspective that was followed in this paper. The intuitive aspect of imaging allows doctors and scientists to work together, in open 3D space to create protocols focused on patient outcomes, i.e. DOING THE RIGHT THINGS. The cognitive aspect of imaging then provides for optimising the protocol and patient outcomes, i.e. DOING THINGS RIGHT. The Knowledge Model, characterising the cognitive/intuitive activity represents the overall interaction. It is becoming evident that when protocols are jointly developed (e.g. radiology and surgery), interoperability and enterprise are complete with improved patient outcomes.

Dr Lenny Berliner, Interventional Radiologist sums it up well when he says, "Interactive Mixed Reality provides a direct path to intuition. The viewing of 2D/2.5D views actually creates an impediment to intuition".

Conflict of Interest

There are no conflicts with regard to any of the material provided.

Acknowledgment

Sergio Aguirre, EchoPixel Chairman and CEO for creating the future, Dr Frandics Chan, Stanford University Radiology as key clinical developer, Dr Judy Yee, Chair Montefiore Hospital for providing clinical guidance for the colonoscopy programme at UCSF, Alex Seelenberger for being an outstanding entrepreneur by being the first investor and Dr Thomas Fogarty for his insight and guidance and support. ■

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Network Modernisation: The Key to the Future of Healthcare

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In the post-COVID era, network modernisation will be key for healthcare organisations as they continue to introduce Internet of Things devices to their operations- in fact, it must underpin every institution's roadmap towards digital transformation.

Key Points

- Outdated networks can act as roadblocks and trying to adapt them to modern demand can be more trouble than it's worth.
- Technology can help simplify workflows and alleviate administrative burdens, allowing for staff to redeploy their precious time and focus on patient care.
- With staff, patients and visitors constantly moving in and out of hospital networks often with multiple devices, security risks have never posed such a threat.

There's no denying that COVID-19 had an irreversible impact across every industry, perhaps most notably the healthcare sector. Two years ago, healthcare providers and facilities had to make huge changes to adjust to the influx of COVID patients. Many of these changes involved digitisation, as between the initial uncertainty of COVID transmission and on-and-off lockdowns, digital services went from optional to mandatory overnight.

From telemedicine to patient portals, new technologies are still being deployed today to help the system fight back against the backlog of patients needing care, as well as deliver the improved and more seamless service that patients now expect. This has meant that Internet of Things (IoT) device usage is on the rise across the healthcare sector. In fact, Deloitte predicts that the IoMT market will grow in Europe from $12 billion to $44 billion by 2025.

As healthcare organisations continue to introduce IoT devices to their operations, their digital success stories depend on one fundamental component – a reliable network. Resilient and secure connectivity must underpin every institution's digital roadmap, upholding and progressing the convergence of information technology (IT), patient care and operational efficiencies. So, just how do they achieve this?

Step 1: Upgrading the Network

The legacy networks that IT teams in the healthcare sector are pushed to work with were designed during a pre-COVID time when applications were static. These outdated networks not only create their own roadblocks but trying to adapt them to support today's demands can also result in huge operational issues. An IT team tasked with adapting their network to support a surge in users, devices and new applications across various locations would be faced with having to manually process every request if the network hasn't been modernised.

Fast forward to 2022 and the aforementioned shift towards personalised healthcare and increased dependence on mobile devices and applications means that this manual process is simply no longer sustainable. In order to support the surge of IoT devices, and unlock the opportunities they bring around autonomous, predictive, and analytical capabilities, healthcare organisations need to automate and to do that they firstly upgrade and modernise their networks.

Here, organisations should consider a cloud-centric network architecture, as whether it is consumed in the cloud or on-premises. This will provide organisations with much-needed agility for future scale and connectivity.

On top of this, networks based on traditional virtual local area network (VLAN) architectures will struggle to accommodate the differing and granular security policies required by huge amounts of IoT devices, so modernising the local area network (LAN) to be policy-driven and wide-area network (WAN) solutions with software-defined wide area networks (SD-WAN) should be seen as the next step for healthcare organisations. Offering greater efficiency and cost savings, hospitals and clinics can also opt for an approach that doesn't involve the wholesale replacement of their current infrastructures, but rather look for options that coexist with current architectures. Here, healthcare organisations can introduce network overlays such as ethernet VPN/virtual extensible LANs (EVPN/VXLAN) on existing infrastructure to support the new applications and use cases.

As healthcare organisations continue to introduce IoT devices to their operations, their digital success stories depend on one fundamental component – a reliable network

Step 2: Leveraging Automation

With a modern network in place and now set up for scale and connectivity, health organisations must then look towards leveraging the benefits of automation.

As all these IoT devices churn out large quantities of health information, automation merged with other smart technologies such as machine learning can help turn data into actionable insights that healthcare organisations can use to deliver better outcomes.

Here, simplified workflows can also help alleviate administrative burdens and redeploy precious time so that staff can focus on patient care. From apps that help patients manage their care themselves, to online symptom checkers and e-triage artificial intelligence (AI) tools, virtual agents that can carry out tasks in hospitals, or a bionic pancreas to help patients with diabetes, adding AI to your technology arsenal can greatly enhance patient care. Of these AI applications, some help improve healthcare operations by optimising scheduling or bed management, others aid population health by predicting the risk of hospital admission or helping detect specific cancers early enabling intervention that can lead to better survival rates, and others even help optimise healthcare R&D and pharmacovigilance. All of this can go a long way to help hospitals make better use of their resources in an age where they're more stretched than ever. But it takes a strong and secure network to support this.

Step 3: Security

While a modern network and the IoT devices and AI solutions it can support have the potential to transform healthcare in practise, the growing use of connected devices also poses increased risk for healthcare organisations. In a hospital setting where staff, patients and visitors are always on the go, multiple new devices are constantly joining and leaving the network. Now, securing the network is more important than ever.

The key to a secure network is visibility. This means that everything, from sensors to visitors' phones, needs to be individually identified, secured, and monitored. By 'fingerprinting' every device this way, vulnerabilities can be spotted and addressed faster, ideally before it is exploited. This level of nuance is also particularly vital in healthcare. In life-or-death environments, critical-care devices that need to run continuously can't be treated the same way as those which can be disconnected if needed. Instead, Zero Trust architectures ensure that all devices and users trying to access the network are identified and authenticated, before providing the least amount of access required through a predefined security policy.

Conclusion

The digital transformation of our healthcare system is being driven by the benefits of a truly IoT-device connected environment. However, in order to unlock the promises of this future, it is fundamental that organisations have a network in place to support this. By deploying a modern and secure network and leveraging automation, healthcare organisations can drive operational efficiencies, redeploy employee time, and ultimately enhance patient care.

Conflict of Interest

None. ■

Digital Twin Technologies - Shortening Waiting Lists and Reducing Inefficiencies

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Deepa Shukla I Healthcare Expert I PA Consulting I UK

Digital twin technologies and the use of artificial intelligence and data science to revolutionise the provision, delivery and sustainability of healthcare.

Key Points

- The NHS needs to look to different approaches to achieve sustainable, high-quality healthcare that meets both patient need and expectations.
- Using a combination of retrospective, real-time and prospective analytics in day-to-day decision making is the key to unlocking sustainable solutions which improve healthcare outcomes.
- Digital twin technologies use AI and data science to accurately forecast what could happen in the future using a virtual replica of a hospital environment.
- Developing, implementing, and embracing these technologies will unlock the transformation that healthcare needs to deliver sustainable high quality cost-effective healthcare.

The challenges to providing healthcare at this period in history are numerous - workforce shortages, the longest waiting list in NHS history and increasingly complex conditions are just some of the obstacles that hospitals face today. Tried and tested productivity and efficiency programmes are struggling to meet demand, and it is clear that the NHS needs to look to different approaches to achieve sustainable, high-quality healthcare that meets both patient need and expectations.

An Effective Response Needs Intuitive, Live and Insightful Predictive Analytics

In order for NHS Trusts or ICSs to respond to the challenges ahead, it is critical that the NHS and contributing partners, organisations, collaboratives, networks, neighbourhoods, places and systems, develop their use of data to embrace the full breadth of analytical capability. Using a combination of retrospective, real-time and prospective analytics in day-to-day decision making is the key to unlocking sustainable solutions which improve healthcare outcomes while maximising financial and operational efficiency.

Whilst NHS use of retrospective and real-time data is increasingly widespread, analytics that looks forward and predicts the future is in its embryonic stage with limited investment and largely locally led implementation. And where it is used is often only during times of immediate crisis. Examples being major incidents or when ambulances are queuing outside ED and nursing teams are asked to predict what patients are due to go home in the next 24-48 hours. Not only is this data time consuming to collect and synthesise, it goes out of date almost immediately and doesn't elicit sustainable solutions.

Transforming Decision Making

Imagine being able to accurately predict what bed capacity you are likely to need to a level of detail that enables you to identify potential over occupancy of inpatient beds several weeks in advance of it happening. Then imagine doing so with such detail that you can adjust your nursing ratios to accommodate for example, an increase in elderly admissions requiring interventions from the fragility team. Or having analytics that identifies patients who are likely to be complex discharges before they have even arrived at hospital. These insights would redefine healthcare models of service provision, giving local health providers advance notice and, therefore, time to work proactively together to create and agree a discharge pathway that meets the needs of the patient, their families and the clinical teams.

Digital twin technologies use AI and data science to accurately forecast what could happen in the future using a virtual replica of a hospital environment, pulling data from multiple IT systems to simulate likely patient pathways and outcomes. Developing, implementing, and embracing these technologies will unlock the transformation that healthcare needs to deliver sustainable high quality cost-effective healthcare – and will have huge benefits across a number of areas, including:

By using forward-looking metrics as opposed to retrospective metrics, hospital teams can work together to identify opportunities for improving overall productivity

Workforce optimisation: Workforce shortages across core clinical professions make it increasingly difficult to recruit, motivate and retain staff – and develop/train them to meet the requirements of 21st century healthcare. Therefore, efficient use of resources is critical. Consider the planning of elective surgery. Aligning the structure and skill mix of theatre teams to match the case-mix is a simple but effective way to positively improve productivity to benefit both the service provider and the patient. Data that provides information in advance of the theatre list as to whether staffing is optimum would inform teams on whether, for example, an anaesthetist is required or whether an additional theatre nurse is required to support due to case complexity.

Bed optimisation: At Nottingham University Hospitals NHS Trust, we use data collected routinely on hospital IT systems to predict length of stay for all patients at the point of their admission, accurately forecasting bed usage weeks in advance. Predicting both the number of hospital beds due to be used and the utilisation of those beds directly drives proactive use of these expensive resources, gives the patient a better experience and, ultimately, a better outcome. For example, teams booking patients to theatre lists can do so with increased confidence that the operation will not be cancelled due to non-clinical reasons, as currently 20,000 operations are cancelled year on year for reasons such as bed capacity. Medical teams can then work proactively with community and social care to ensure that, once the patient is ready for discharge, any care package is optimised and ready to start immediately. By using forward-looking metrics such as how many beds do we need to use, as opposed to retrospective metrics, meaning how many beds did we use, hospital teams can work together to identify opportunities for improving overall productivity.

Pathway optimisation: Being able to forecast the likely treatment pathway for a patient such as their need for radiology, pathology or pharmacy input would be invaluable in reducing waiting times and effective utilisation of resources. Not only would this revolutionise the management of capacity and demand across the NHS, it would also improve the patients' experience by giving visibility of what scans or appointments they may potentially have and increase their ability to 'own' their care pathway.

Outcome optimisation: Most importantly, maximising the potential of technologies to accurately predict and forecast will improve the quality of care, speed of intervention and overall outcome for patients. Predicting length of stay will transform discharging practices, leading to fewer "failed discharges" and a reduction in hospital re-admissions. Elective patient pathways can be condensed, reducing time spent organising appointments and maximising the time spent by key clinical teams and departments on direct patient care. As patient care and treatment increases in complexity, the decisions about the optimal care pathway will be enhanced through accurate and evidence digital tools that help guide, prioritise and inform evidence-based decisions. That would be truly patient-centric treatment that is individualised, efficient and effective.

Digital Twin Technology Offers Opportunities to Unlock Real-Time Sustainable Efficiencies

Hospitals are increasingly complicated, interconnected and variable. Operating at close to maximum capacity most of the time whilst trying to balance increasing demand and funding gaps means that having access to a variety of analytical tools is less of a luxury and more of a necessity. Across the NHS, knowing what is going to happen before it actually happens is going to be a vital component in providing safe, efficient and effective healthcare. Technologies such as digital twins are going to revolutionise the provision, delivery and sustainability of healthcare – not just in the NHS, but worldwide.

Conflict of Interest

None. ■

"One Ring to Rule Them All" in AI – Affidea's Experience

Alessandro Roncacci I Senior Vice-President I Chief Medical Officer I Affidea

An overview of Affidea's experience on the road to AI implementation and the need to understand the complexity of integrating multiple AI solutions safely, offering clear benefits to patients and radiologists.

Artificial Intelligence in Healthcare

Artificial Intelligence (AI) in radiology is growing at a fast pace. A 2020 study from the American College of Radiology on radiologist uptake of AI shows that clinical adoption of AI has increased dramatically over the last five years, with 30% of radiologists indicating that they use AI in some capacity – up from none five years ago.

This is showing, once more, that it is true that "radiologists who use AI will replace radiologists who don't", as Curtis Langlotz, Stanford Hospital and Clinics, said three years ago. At Affidea, we strongly believe in this. The most successful cases we've implemented so far prove that AI is augmenting the radiologists' intelligence and optimising their practices, not just by saving time but by enhancing their precision in diagnosis and potentially preventing what could have been an easy miss, increasing patient safety in some cases and driving operational efficiencies.

Affidea – Driving the AI Disruption With One Ring to Rule Them All

It was key for us to disrupt the utilisation of AI in daily practice, finding a unified and secured platform that can give us access to a catalogue of expert AI applications directly integrated into the workflow and PACS/RIS infrastructure.

Starting in July this year, in Affidea Portugal, we are implementing the Incepto platform that gives our doctors access to a portfolio of AI solutions that we are piloting under one single secured platform, directly integrated with our PACS/RIS infrastructure, without changing any equipment or without having to integrate every AI software separately. The platform is currently piloted in 14 centres, where our radiologists can work daily with the support of five different AI solutions based on local needs and best-in-class available sub-specialties, involving our clinical, operational and IT teams and in collaboration with Incepto specialists from the same fields.

All these solutions that we are implementing in our clinical routine and digital infrastructure come with great benefits for patients and doctors:

- improved patient care through AI-aided detection, measurement and diagnostics confidence;
- operational optimisation through shorter acquisition times, triage and prioritisation;
- reassurance for the medical staff.

Our goal is to accelerate the process of integration of AI solutions in our workflow, to make all our radiologists familiar with this innovative approach and then to roll it out across other Affidea countries where we are ready thanks to previous experiences.

Affidea's Journey to Date in AI Implementation

Over the past three years at Affidea, we have started several pilots to assess the clinical, operational use and commercial opportunity associated with AI-enabled technologies in diagnostic imaging. Our objectives were:

- to verify how some AI solutions focused on neuro, lung, breast, prostate, and oncological examinations or on driving operational efficiencies in MRI can qualitatively support the reporting activity of our radiologists in specific disciplinary areas;
- to understand how these can contribute to increasing the safety of our patients who undergo diagnostic tests;
- to verify how AI can optimise the operational processes in our daily workflow.

We have been heavily investing in digital infrastructure and IT capabilities to give our centres the necessary capabilities to test safely different AI solutions. We are currently working with over six AI vendors and piloting 10 AI solutions in 10 countries.

Affidea's Methodology

At Affidea, we have an ideal environment in terms of geographical presence, multinational clinical expertise, best technology with over 1450 pieces of equipment across 15 different healthcare markets and a team of subspecialty experts.

When we pilot an AI solution, we base our decision on a structured nine-stage framework for the evaluation and commercialisation of AI solutions, including:

- selection criteria for AI solutions, countries and centres.
- legal review, including medical device class and data protection impact assessment.
- technical architecture review, including digital infrastructure and AI solution integration.
- clinical and technical assessment.
- training of healthcare professionals.
- identification of key performance indicators.
- workflow redesigning to assess the benefits of the AI solution.
- commercialisation process.
- preparation of stakeholders' information and communication strategy.

The more we advance on the road to AI implementation, the more we need to think about the complexity of integrating multiple AI solutions in a safe and compliant way, offering clear benefits to our patients and radiologists in every country. Making it simple is not easy, but at Affidea, we have all the competencies, experience and resources to successfully lead this journey, always with clinical excellence, safety and precision at the core. ■

Decision Support

Integrating Decision Support and AI in Radiology

Elmar Kotter | Vice Chair and Director of Imaging Informatics | Department of Radiology | University of Freiburg | Freiburg, Germany | President | EuSoMII | Editorial Board Member, HealthManagement.org

Prof Elmar Kotter is the Vice-Chair and Director of Imaging Informatics & Quality and Risk Management at the Department of Radiology of Freiburg University Medical Center, Germany. He is also Chair of the eHealth and Informatics Subcommittee of the European Society of Radiology (ESR) and President of the European Society of Medical Imaging Informatics (EuSoMII). Prof Kotter is dedicated to patients, co-workers and process improvement in radiology. HealthManagement.org spoke to Prof Kotter about using clinical decision support in healthcare and integrating decision support systems and artificial intelligence in radiology.

How would you define clinical decision support and its use in radiology?

In a broad sense, clinical decision support is the use of information technology to help clinicians make better decisions and improve the diagnostic and therapeutic process. In radiology, the primary use of decision support systems is to support diagnostic decision-making. There has been an exponential growth of information in radiology, but this is not accompanied by an equivalent increase in the number of radiologists. Therefore, radiologists have to deal with a growing amount of increasingly complex information, making decision-making more and more complex. This is where decision support systems come in, as they can help radiologists handle this huge amount of information and better analyse this information that is getting more complex year after year.

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What fundamental characteristics should decision support systems have for greater application in radiological practice?

The main characteristic required is that the reliability of decision support systems is proven. This is an important issue as many Artificial Intelligence (AI) systems on the market do not have proven reliability. Integrating those decision support systems into the daily workflow of radiologists is also important. A remote decision support system not integrated into the workflow is not useful for radiologists. In addition, the recommendations that the decision support systems make need to be transparent so that the radiologists understand how the system produced the decision or the recommendation.

What are the most important factors considered by a radiologist when evaluating clinical decision support tools?

There are different ways to analyse decision support systems. One would be the scientific way, by evaluating the system and checking for accuracy. The other aspect is their use in the daily workflow. Radiologists must feel comfortable with the system and must be convinced that the system is helping. It is often a matter of perception. For example, a radiologist will always feel happier if they are the ones detecting a fracture rather than the AI system doing it. Hence, it is important for radiologists to feel comfortable with the clinical decision system they intend to use.

Computer-aided detection (CAD) systems have already been in use within the radiological practice. What is the distinction between CAD systems and decision support systems?

CAD systems, which are not based on AI systems, have been in use for almost 20-25 years, have been working quite well, and are considered very reliable. However, decision support system have much more to offer than only computer-aided detection. Decision support systems can help understand and manage complex information and data. Think about longitudinal information, the evolution of the tumour burden for a given patient, or a patient pathway where there is a need to make decisions on therapeutic measures, analyse where the patient stands on this pathway, and comparing this to the pathways where other patients have been. All these are complex activities that require integrating a lot of information. This is where decision support systems stand out and can be more effective.

What are the main benefits for radiologists when using a clinical decision support system?

First, it can act as a safety net for radiologists in terms of simple detection. It can enhance the work of radiologists by helping them not to miss lesions in the images they evaluate. There is also the efficient handling of complex information that can help radiologists make better decisions.

Radiologists have to get used to the idea of AI and decision support systems and how these tools can help them in their daily work

Decision support may have some trust issues. What are the primary criteria for doctors to be able to trust and adopt such tools?

It is very important for AI solutions to have reliability. This reliability can be achieved through scientific evaluation, application, and practice. It is also important to effectively integrate these tools within the radiology workflow. But if there is one key element, it is trust, and this trust is built over time. It is not possible to trust AI or a particular system by simply using it and trusting it from the first day. It will happen gradually. Radiologists have to get used to the idea of AI and decision support systems and how these tools can help them in their daily work. They also have to get used to the particular decision support systems or AI systems used in their workplace.

The future of healthcare will be an intelligent mix of human computers and technology. What major trends do you foresee?

It's difficult to identify one major trend. There are many applications of decision support systems in radiology when you think about the whole workflow in radiology. This can range from scheduling, optimisation of examination protocols, the diagnostic applications of AI etc. I think the trend will be having many of these systems assisting radiologists, technologists, and the administrative people in radiology departments to do their work more efficiently and more reliably.

There has been a great deal of hype about AI in healthcare. Is there any key metric to successfully implementing AI in radiology?

The one metric would be reimbursement for AI. There is no

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doubt that AI systems work quite well and can help radiologists in their clinical routine. But in Germany and many other European countries, there is no additional payment for using AI. It is important to understand that AI systems are not for free. You have to pay for them. It can be very difficult to convince the administration to invest in these AI systems. They will immediately question if such an investment would reduce the need for radiologists or administrative personnel. But this is not the goal. The goal is to enhance the work of radiologists with the use of AI. Hence, if there is one key element, it is the reimbursing of the use of AI in some way.

How does AI support radiology workflow? Is there an improvement in efficiency, patient outcomes or patient safety?

There are many applications that could enhance patient safety. Think about secure identification of patients. The new CT systems today have a camera on the ceiling to help with patient positioning. In the future, these cameras could be used to identify the patient - to ensure that the patient on the table is the right patient. This is a simple example of enhancing security. AI can also help optimise protocols to lower the dose for a specific patient. This could be done by considering the previous examination of a given patient to optimise the dose for their next examination. Hence, there are many examples where AI can enhance security, help lower doses, and enhance the workflow.

Are there any limitations or risks in using AI in radiology? And if yes, how should these be addressed?

The discussions about the ethics of AI are very broad. There could be risks of bias and discrimination, and inequality in healthcare. On the other hand, AI has the potential to individualise healthcare and make better care accessible for a larger portion of the world population. Also, AI can play an important role in developing countries, where, for example, there are not enough radiologists, and other medical disciplines are practicing radiology. In these situations, AI can be very helpful. Therefore, it is important to discuss the risks and reach a consensus within the radiologist and general population about how these risks should be handled. But we must be aware of the possibilities that AI has to enhance healthcare.

How would you address concerns that AI could one day replace radiologists?

There is no reason to be afraid that AI will replace radiologists. But this needs to be discussed. People are afraid because they don't know enough about AI. I believe that AI will not replace but augment radiologists. As Curtis Langlotz, a radiologist at Stanford, once said, "AI won't replace radiologists, but radiologists who use AI will replace radiologists who don't." Think about the time before PACS. When I learned radiology, half of my time was spent finding the films with the examinations and hanging them onto light boxes. There is no need to do that today because of PACS. These days, the way residents learn radiology is much more intensive since they are free from these tasks. Back in those days, switching to PACS was a huge step forward, and something similar will happen with AI. Fast forward 20 years, and we would wonder how we spent our time looking at those images to detect nodules or other lesions without having AI assistance to do it.

What does the future of radiology look like in terms of digital transformation?

The future looks really bright for radiology. Radiology is one of the most digitised medical disciplines, and radiologists are already at the forefront of digital transformation. It is important to be active and visible in this transformation. Only then can we have a chance to be at the centre of patient care in the future. I believe that the future of healthcare will be about how we handle data. In this regard, the discipline of radiology already has a huge advantage compared to others.

Is there anything else you would like to add?

There is a lot of discussion about AI in radiology and healthcare today. During the 1990s, there were many concerns whether it was possible to report a CT or a chest x-ray from a monitor instead of film. Then we saw the introduction of modern CT scanners that could produce examinations with 400, 500, and 600 images per examination. That stopped the discussion very quickly because it was impossible to handle this amount of images on film hard copies. It was the tipping point for the introduction of monitor reporting and PACS systems. In the near future, there will be a similar tipping point for the introduction of AI in healthcare, where we realise that it would be simply impossible to continue to practice healthcare and radiology without the use of AI systems. ■

Watch the full interview here.

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Teamplay Digital Health Platform for Performance Management in Radiology

An overview of teamplay applications for performance management in radiology and how they offer a clear overview of performance data and facilitate radiology directors or clinical administrators to make fast and well-informed decisions.

Key Points

- The teamplay digital health platform enables digital transformation by facilitating easy access to solutions for operational, clinical and shared decision support.
- The teamplay performance management applications allow radiology directors to access, monitor and compare their institution's key performance indicators in a single dashboard accessible from anywhere, anytime.
- The teamplay digital health platform combines two different deployment models - cloud and on-edge deployment to enable integrated solutions according to specific use cases and requirements.
- With the teamplay digital health platform, radiology operations can be optimised by accessing and analysing data more effectively, understanding the workflow, optimising operations by taking direct measures and creating a culture of continuous improvement.

The healthcare environment for radiology directors can be extremely challenging. Not only do they have to stay compliant with nationally defined reference levels for applied radiation, but they are also expected to increase efficiency, produce results and provide a data privacy-compliant way to share and manage medical images. In addition, protocol management can be a time and resource-consuming effort. In simple words, radiology teams have to achieve better outcomes and results with less investment and resources. One way to overcome this change is through digitalisation. Siemens Healthineers' teamplay performance management applications allow radiologists to better utilise patient data, improve workflow and optimise daily operations.

Benefits of Teamplay Applications

With teamplay performance management applications, clinicians can access objective data insights to make well-informed and prompt decisions and improve radiology operations. Streamlining operations in a radiology department is not limited to scanning more patients. It is also important to optimise processes and deliver high-quality care while complying with national regulations.

Some of the key benefits of teamplay applications for radiology directors include:

- Ability to monitor quantities like imaging throughput, dose levels, utilisation of staff, rooms, and department resources down to each device and procedure.
- Simplify reporting and gain insights into where workflows need adjustments.
- Link with other teamplay users and their data for comparable benchmarks and effortlessly exchange images and reports.
- Easily connect with other healthcare professionals, hospitals, and institutions through teamplay's rich cloud-based network.
- Access metrics from your own imaging fleet and a shared pool of imaging data.
- Connect and collaborate in a trusted environment with high data privacy and security standards to improve patient outcomes and quality of care.

Teamplay Performance Management Applications

The teamplay performance management applications allow radiology directors to access, monitor and compare their institution's key performance indicators in a single dashboard accessible from anywhere, anytime. Some of these indicators include:

teamplay Dose – Simplify radiation dose management

The application helps identify areas of improvement and administer best-practice exams. All insights in teamplay Dose are based on data extracted from the radiation data of scanners.

teamplay Usage – Increase efficiency and expedite imaging fleet utilisation

Explore workflow-specific data on patients and exams and/or focus on the efficiency and performance of individual devices, identifying optimisation potential to do more with less.

teamplay Images – Share and discuss images in a secure environment

With teamplay Images, images can be shared in a secure environment and additional collaboration features help engage with other peers.

teamplay Protocols – Speed up protocol management by remote access

Speed up protocol management by editing protocols remotely and distributing these protocols to the image fleet.

Teamplay Digital Health Platform – Enabling Your Digital Transformation

The teamplay digital health platform is an enabler for digital transformation in radiology. 6500 institutions in more than 75 countries are already benefitting from this platform by using a broad range of applications developed by Siemens Healthineers and third parties. The teamplay digital health platform enables digital transformation by facilitating easy access to solutions for operational, clinical and shared decision support:

Powerful marketplace

Access to innovations and solutions in digital health and AI from Siemens Healthineers and curated partners. These solutions can help radiology departments transform a complex multisite, multivendor imaging environment into an integrated imaging service line with a patient-centric focus throughout the entire workflow.

Digitally enabled collaboration

Sharing and collaborating with peers and patients via standardised interfaces between institutions and care settings.

Scalable deployment models

Innovative and flexible software deployment combining cloud and on-edge to serve your individual needs with a broad portfolio of transformative and AI-powered applications. The deployment models are based on the client's infrastructural demand and preferences and offer flexibility and scalability with future-readiness. The applications can be accessed easily via the digital marketplace that provides state-of-the-art SaaS (software-as-a-service) business models and scalable computing power.

Seamless interoperability

One vendor-, system-, device-neutral digital health platform for cross-departmental and cross-institutional interoperability in a secure and regulatory-compliant environment. It allows easy connection of devices and systems, aggregates data from various sources and provides advanced analytics that results in actionable insights. With the teamplay healthcare digital platform, big data can be converted into smart data and can be used to increase the effectiveness of clinical routines through improved patient outcomes and reduced cost.

Strong platform partner

Secured environment to consume, deploy or operate digital solutions globally by leveraging Siemens Healthineers' ever-expanding infrastructure and services with over 32,000 connected systems, 6500 institutions in 75 countries and more than 30 million patient records accessible cross institutionally through seven major data centres worldwide.

Data Where It Needs To Be

Digital solutions require an innovative and flexible software deployment. Siemens Healthineers' teamplay digital health platform offers this flexibility by combining two different deployment models - cloud and on-edge deployment to enable integrated solutions according to specific use cases and requirements. Leveraging the benefits of both deployment models is called hybrid computing which is enabled by edge technology. With hybrid computing, you can:

- Manage local and global data as per preferences and regulatory requirements and ensure continuous operations.
- Benefit from instant data processing and storage on the local edge device and aggregate and balance load in the cloud when needed.
- Benefit from fully managed operations remotely from cloud: up-to-date software and algorithms, state-of-the-art security and high availability of apps.

Conclusion

Overall, Siemens Healthineers' teamplay digital health platform enables radiology departments to connect different imaging modalities and generate, collect, analyse and access patient data through a range of powerful applications. The teamplay performance management applications provide greater transparency in the workflow and help radiologists increase their productivity and better balance their department's resources. With centralised protocol management, clinicians can deliver a higher quality of care and ensure standardisation. With better data analysis, clinicians can perform in-depth analytics with intuitive dashboards. In addition, the teamplay performance management applications help radiology teams understand cost inefficiencies within their workflow and can implement changes accordingly to optimise operations. In other words, radiology operations can be optimised by accessing and analysing data more effectively, understanding the workflow, optimising operations by taking direct measures and creating a culture of continuous improvement. ■

Clinical Decision Support – Benefits and Application in Healthcare

†Werner Leodolter I CIO I KAGes I Professor of Applied Business Management I University of Graz I Austria I Editor-in-Chief IT, HealthManagement.org

†Werner Leodolter was the CIO of KAGes. He was a Professor of Applied Business Management in Healthcare at the University of Graz and a lecturer at the Medical University of Graz and Graz University of Technology. Prof Leodolter was also the author of two books, "The Subconscious of Organizations - New Technologies - Rethinking Organizations" and "Digital Transformation Shaping the Subconscious Minds of Organizations – Innovative Organizations and Hybrid Intelligence". He was the co-founder of the company, The Consulting Decision Support Systems. HealthManagement.org spoke to Prof Leodolter about clinical decision support and how it can help improve the delivery of care.

How would you define clinical decision support, and what tools fall under its umbrella?

Clinical decision support refers to a system where the computer assists the doctor or the nurse in using available data by providing relevant information, giving warnings, and detecting, categorising and quantifying suspicious areas in images from radiology, pathology, dermatology, gastroenterology etc. In other words, there is a broad field of application for clinical decision support.

What are the most important factors that healthcare providers and staff consider when evaluating clinical decision support tools?

Clinical decision support tools should bring benefits to the patients in terms of patient security. At the same time, they should benefit medical staff by increasing efficiency, saving time for retrieving information, and improving the decision-making process. On the other hand, it is also important to consider the risks for an organisation when computer assisted decisions go wrong, for example, when malign lesions and cancer are not detected. Therefore, it is important to consider the pros and cons when evaluating clinical decision support tools and determining what these tools are to be used for within a healthcare organisation.

What benefits can healthcare facilities and healthcare providers derive from clinical decision support?

Some of the most important benefits are saving time finding relevant data and their interpretation and freeing time for interaction with patients thus motivating their staff. The quality of healthcare services can be improved with better diagnosis and more prevention.

What are the primary criteria for doctors to be able to trust and adopt decision support tools?

The algorithms have to be validated where appropriate and certified as medical devices. Wherever possible, they have to be explainable for the user, for example, by providing the clinical parameters of the patient indicating the predicted risk for the patient and thus supporting the clinical reasoning of the doctor or the nurse. From my point of view, explainable AI is a prerequisite to increasing trust by healthcare staff. If the staff does not trust in clinical decision support AI, they won't use it because, in the end, they are responsible for the decisions that are made.

The future of healthcare will be an intelligent mix of human and computers/technology. What major trends do you foresee?

A time will come when it will not be state-of-the-art anymore to make no risk profiling based on available data or to get no second opinion of the computer when assessing pathology images etc. A time will come when interpretation of genomic analyses will become standard supporting diagnostics due to falling costs for sequencing. Clinicians require assistance in decision-making. Therefore, AI will become part of everyday business. It's not there yet, but the time is not too far.

How do you think this collaboration can be optimised, and how can healthcare efficiently benefit from the cooperation between humans and technology?
We will have to shape and establish some sort of hybrid intelligence with good collaboration between human and artificial intelligence - with the human staying in the driver's seat and the AI assisting. Thus we have to deliberately shape the subconscious mind of the respective healthcare organisation and provide high quality decision making and patient safety by providing excellent processes, controls and checks in this new hybrid world.

The pandemic revealed significant weaknesses in healthcare systems worldwide. Do you think clinical decision support tools can help increase operational effectiveness in healthcare?
There is a good chance of it. Risks for severe illness after a COVID infection or even necessity for an ICU-bed will be more predictable and those at risk can be closely monitored at home and provided with special medication. The transfer to the hospital will thus be well controlled and reduced to really necessary transfers. The same idea is also applicable to other diseases. With the new possibilities of home telemonitoring, lab-on-a-chip etc., there are now multiple opportunities to combine telemedicine/telemonitoring with AI and clinical decision support tools.

How do you think clinical data can be better utilised?
Currently, there are some obstacles here, especially in Germany and Austria, because there is a high sensitivity concerning data privacy and the way GDPR is interpreted. However, in Northern Europe, countries have found good solutions to enable the secondary use of clinical data. For example, Finland, Estonia and Denmark are far ahead of Germany or Austria in this respect. They demonstrate that reasonable secondary use of healthcare data can be organised in compliance with GDPR.

Do you think there are threats or risks associated with AI if our dependence on it increases?
There are significant threats. Imagine a young doctor who always says yes to proposed decisions for 10 years without practicing extensive clinical reasoning – maybe due to workload. Will he be a good doctor in situations without clinical decision support due to cybercrime, blackout etc.? Will he have enough self-confidence? I think not. AI and decision support tools provide an opportunity to free clinician time for the patient. But when implementing these technologies, healthcare organisations must focus on giving clinicians enough time for clinical reasoning. Decision support tools should be used to give information to the doctor, but when a doctor thinks a particular prediction is wrong, the doctor's decision should be the one that takes priority. If there are any biases in the system, they cannot be used. Hence, AI-based support tools should not be used without continuous monitoring.

Clinicians require assistance in decision-making. Therefore, AI will become part of everyday business

Decision support systems come with a price tag. Do you think it's worth investing in these new systems?
That depends on the price tag and the use case. What is the scenario in which it is being used? It is important to validate and check how it fits an organisation's decision and clinical pathways. It is important to look at the big picture. If the goal is to improve the quality of imaging, an organisation may have to consider big scanners. But if the goal is to enable remote assessment of images, an organisation can evaluate the resources it already has. It might not be too difficult to take digitally available images and run them through AI, maybe in the cloud. Hence, the price tag is not only the price tag of the provider but also the price tag of the implementation as a whole. It is also important to consider the benefit to clinicians and to the patients. I am convinced that these tools will be affordable in the future. And as I said before, a time will come when it won't be state-of-the-art anymore not to use this.

Is there anything else that you would like to add?
Prediction is feasible not only with algorithms based on very big data or by collecting patient data from many sources - probably in conflict with GDPR. Good data curation and federated learning can provide excellent predictive results with not so big data. There are a lot of possibilities with AI and decision support tools, and very dynamic development is ahead of us. ■

Watch the full interview here

Governance & Leadership

How Digitisation is Transforming the MedTech Talent Landscape

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Wolfgang Bauriedel I Technology Sector I Russell Reynolds Associates I Boston, USA
Sarah Flören I Russell Reynolds Associates I New York, USA

An overview of the process of digitisation in the medical device industry and important questions that organisations should ask to best prepare for the digital disruption ahead.

Key Points

- Digitisation is in full swing for the medical device industry and will continue to disrupt the sector throughout the 2020s.
- This has created a need for board directors and leadership teams that are equipped to tackle not just the new technology and innovation, but also changes in business models, types of talent and company culture.
- Organisations need to revisit their talent management strategy.
- Individuals will not be able to drive the digital transformation alone – it needs to be an organisation-wide push with dedication and enthusiasm driven from the top by the board and C-suite.

Accelerated by the COVID-19 crisis, digitisation is in full swing for the medical device industry and will continue to disrupt the sector throughout the 2020s. As Jim Hollingshead, President, Sleep & Respiratory Care Business at ResMed stated in an interview with Russell Reynolds Associates (RRA), “We went from being a medical device-only company to being a medical device plus software plus analytics company”.

This has created a need for board directors and leadership teams that are equipped to tackle not just the new technology and innovation, but also changes in business models, types of talent and company culture. In order to be successful, organisations must identify tech-savvy leaders that can navigate this rapidly transforming environment with its new competitors, stakeholders and possibilities around connected care (Figure 1).

Attracting as well as retaining strong technology talent has proven to be difficult. In an interview with RRA, Sue Siegel, Board Member at Align, Illumina and Nevro described it as an “incredible rush to compete with the tech world to hire some of the most technically-savvy talent: engineers, data scientists, AI/ML experts, to mention a few. The scramble to find that type of talent is real.” Organisations need to revisit their talent management strategy, which includes demonstrating a commitment to digital transformation both internally and externally, placing a greater value on external technology talent and establishing fitting recognition and career opportunities for current and new tech-savvy leaders.

For an organisation to reach its digital ambitions in a timely matter, it cannot only focus on attracting talent that will support the organisation’s organic growth and transformation. A hybrid strategy that includes organic growth using in-house incubators and cultivation of digital and entrepreneurial talent, inorganic growth through targeted mergers and acquisitions, and an effective ecosystem of partners will be required to reach the organisation’s full potential.

The ability for a company to successfully lead through the ongoing digital transformation will be dependent on the calibre of the leadership team in charge. This calls for a level

Capability	Traditional model	Connected health model
Business model	Hardware products	Platform-driven engagement
Business factors	B2B	Hybrid B2B/B2C (patient, payor, provider)
Revenue stream	Asset-based	Data and insight-centric
Strategic focus	Protecting the core	Embedding into ecosystem
Speed to market	Traditional MedTech (months to years)	Accelerated products (months to years) and fast digital services (days to weeks)
Technology focus	Software servers	Cloud and customer
Healthcare focus/patient interface	Via provider intermediaries	Direct to patients/providers Behaviour-changing engagement

Figure 1: The migration of the MedTech enterprise. Source: Russel Reynolds Associates

of awareness around the digital capabilities the current organisation has. It will require leaders to challenge the broader organisation around the culture it is creating as well as the gaps that need to be addressed in terms of digital expertise. Chet Kolley, Group VP, Healthcare and Life Sciences Business at GlobalLogic shared with us: “It's really become a prominent part of the company strategy: the way they go to market, the way they differentiate themselves, the way they build relationships directly with the people whom they consider their stakeholders with whatever business that they do”. Individuals will not be able to drive the digital transformation alone – it needs to be an organisation-wide push with dedication and enthusiasm driven from the top by the board and C-suite.

To best do so, RRA compiled a list of questions the board and C-suite should be asking themselves in order to best prepare the organisation for the digital disruption that is ahead:

- Do we have a digitally-savvy leadership team to support our digital agenda?
- Do we have capabilities at the C-suite level and within the board to steer the enterprise through the next industry transition into new business models?
- If not, how do we get those capabilities?
- How do we organise ourselves around our digital agenda?
- How do we scale our many digital initiatives or ‘1000 flowers blooming’?
- How do we leverage the groundswell in our organisation?
- Do we need more digitally-savvy board directors?
- Do we need a chief digital/technology officer?
- How do we become a magnet for digital talent?
- Are our next generation of leaders ‘digitally conversant’?
- How do we take advantage of the fact that the next generation of leaders have grown up in a completely digital world?
- Do we have the feedback loops and a mindset in place to ensure the organisation doesn't ‘tune out’ (and force out) new hires who get it?
- To what extent are we hardwiring comfort with ambiguity into ongoing leadership development programmes?

As digital leadership is increasingly becoming an urgent C-suite priority, successful leadership teams will be those able to ask the difficult questions regarding their own capabilities and actively seek out and grow the ‘digital native’ perspective in their organisations.

Conflict of Interest

None. ■

Application of Artificial Intelligence in Healthcare

Sourabh Pagaria I Executive Vice President & Managing Director, Southern Europe I Siemens Healthineers

Artificial Intelligence is believed to lead the process of digitalisation and transformation in healthcare. How can healthcare organisations prepare for this change? What opportunities does AI offer for the healthcare sector? Which AI-based radiology tools are expected to make a difference? HealthManagement.org spoke to Sourabh Pagaria, Executive Vice President & Managing Director of the Southern European business of Siemens Healthineers to get some insight on these important questions.

What, in your opinion, is the true value of digitalisation in healthcare?

The role of digitalisation as a game-changer in the healthcare world was clear since the outbreak of COVID-19. It is the key enabler in providing high-value patient care. But in the course of these two years, we have also understood that digitalising healthcare in a sustainable way goes beyond adopting new tools and technologies. It requires a cultural change and a re-alignment of organisations around data-driven digitally-enabled processes and care models. Simply digitalising current processes and procedures is not enough. With this said, in my opinion, the true value of digitalisation can be broken down into the following elements: increasing efficiency, expanding access to care, improving clinical outcomes and accelerating innovation cycles. For instance, home-based telemedicine or teleconsultation can reduce care costs in several chronic conditions. Teleradiology can give remote locations and standalone imaging clinics access to teaching hospital quality care, and allow clinicians to collaborate and share information productively in virtual spaces. Digitalisation can help connect caregivers and patients for better coordination and knowledge sharing while strengthening integrated care across the health systems.

What specific opportunities do you see with respect to the application of medical AI technology in healthcare?

In the future of healthcare, Artificial Intelligence (AI) will be indispensable for translating the growing volumes of data into decision-relevant knowledge. In general, digitalisation, data and artificial intelligence are key for scaling the application of technical advances as AI-enabled tools identify meaningful relationships in raw data, extract relevant insights, and apply those lessons to new patient cases. For example, during the COVID-19 outbreak, it was essential to identify as quickly as possible if a specific patient was suffering from COVID-19 pneumonia or if the pneumonia had a different cause. This is what the rapid AI-based algorithm Siemens Healthineers developed does by automatically quantifying air space opacities associated with COVID-19 pneumonia. To sum up, whenever analyses are too difficult, time-consuming, or inefficient to perform alone, AI provides valuable assistance to clinical professionals, allowing them to stay focused on their patients and better use their own expertise. AI can help bridge the gap between the demands of ever-increasing, extremely complex data and the number of radiologists to simplify data interpretation through sophisticated AI algorithms, thereby improving the diagnostic process. Moreover, AI-powered clinical decision support systems could help free up precious physician and specialist time which could then be used by them to provide more emphatic and personalised care to the patients as comprehensively and productively as possible.

AI is expected to lead the process of transformation in healthcare. What good practices do healthcare organisations need to adopt to better prepare for this?

Healthcare organisations should shift towards building a digital enterprise with a clear commitment to managing data as a strategic asset. Healthy systems have to integrate data from multiple sources on secure and easily accessible data platforms.

In our view, there are four steps to be taken to create smart data management:

1. Set data strategy and establish governance
2. Capture data securely and automatically
3. Validate data via automated clean–up
4. Connect data via secure, accessible platforms and EHRs

These four steps will result in reliable and secure data that, together with advanced modelling and AI, empowers data-driven decisions within a health system – be it in the clinical, operational space, or directly helping consumers make the right decision in their care.

sources (e.g., pathology, lab, genetics, imaging) to best navigate and stratify patients for their personalised therapy. We cannot predict the future, but we can prepare for a future that is increasingly unpredictable with the tools we already have. For example, AI algorithms enable automated detection

With AI-assisted image analysis and triaging algorithms improving by the day, radiology, as we traditionally know it, will have a very different and pivotal role to play in the future

of anatomical structures, intelligent image registration and reformatting. Abnormalities and segment anatomies are automatically highlighted, and results are compared to reference values in order to increase precision and speed up the workflow. These efficiency gains will become increasingly important given the growing demand for diagnostic imaging and rising cost pressure.

For effective application of AI in healthcare, there needs to be a clear definition of automatised diagnosis. What do you think this entails?

One of the most pressing concerns in radiology today is the exponential growth of data and the shortage of medical staff to handle the complex and ever-increasing amounts of information. The important base material for AI-powered "outcomes" is an important "connector"- individual electronic health records (EHR) that help aggregate patient histories with in-vitro, in-vivo, genomics information, lab data and much more. With patient permission and understanding, AI-powered technology will take this vast amount of data and transform it into actionable insights. This AI-assisted technology generally has been dubbed the diagnostic decision support system (DDSS), and surveys have shown it could improve diagnostic accuracy by nearly 9%. Significant gains have especially been reported in recent years, for instance, in AI-assisted cardiac risk assessment. AI can cull through hundreds of thousands of cases to calculate where a heart patient fits into a risk stratification to inform cardiologists' decision-making. AI algorithms must be properly trained. Our Siemens Healthineers' Artificial Intelligence is based on algorithms trained with an extensive amount of curated data. I'm talking about more than 1.4 billion entries, and we run more than 1,200 AI experiments a day on our supercomputer and today, we have more than 800 patent families related to artificial intelligence.

Which next-generation AI-based radiology tools do you foresee in the future?

The radiology community is largely coming to terms with the fact that AI is not a threat but rather a tool that helps them become more precise, effective and efficient. Nowadays, AI is already playing a transformative role. In the long term, with AI-assisted image analysis and triaging algorithms improving by the day, radiology, as we traditionally know it, will have a very different and pivotal role to play in the future where it will help to centre and integrate data from various

Can AI also address the impact of staff shortages and access to qualified clinicians in remote areas?

Healthcare, like much of the rest of the economy, is facing a labour shortage. AI can lighten the load for overworked providers through everything from automation to triaging patients. It has the potential to significantly improve access to high-quality healthcare and also improve diagnosis and therapies. Not only in highly specialised centres but also in remote, poorly populated areas and emerging countries. It can automate repetitive tasks, allowing healthcare providers to focus on higher-level cognitive tasks and patient care. Through digital technology, it is possible for clinicians to provide care at a distance. Some specialties, including radiology and pathology, have already adopted technology to enable consultations from a distance. With radiologists in short supply, teleradiology brings continuous radiology coverage to even smaller or remote locations, allowing more patients to benefit from specialist care.

There have been numerous problems with EHRs. Do you think AI could address some of these issues and make EHRs more efficient and easy to use?

Health systems struggle with fragmented systems of care, and interoperability between hospital and primary care physicians' data is often lacking. As a result, information during care transactions can be lost, and patient data is not fully leveraged when developing care plans. Here the concept of "moving information, not patient" should be embraced by healthcare institutions, shifting toward that digital enterprise model where data are collected and connected to secure and easily accessible data platforms from segmented sources. Clinicians will be able to collaborate and share information productively, reducing information loss during care transitions.

AI has potential in healthcare. However, are there any limitations that need to be kept in mind?

What needs to be understood is that change and transformational speed in healthcare institutions isn't the same as in other industries (e.g. consumer-related industries). Healthcare is a heavily regulated environment; the demands are rigorous and very specific. Moreover, the regulations can differ from country to country. As much as hospitals and clinics may be keen on using AI technologies for informed decision-making, these technologies must always be validated in clinical studies. By doing so, healthcare institutions gain a solid understanding of what the transformation will be and if it will do good for the patient, ultimately leading the patient to a better situation. Digitalisation in healthcare is the key enabler in providing high-value patient care. ■

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Cybersecurity:

Preventing the Worst-Case Scenario

What Can the NHS Learn from Public Sector Supply Chain Attacks?

Jonathan Lee | UK Director of Public Sector Relations | Sophos | UK

As organisations become increasingly connected through technology, there is a rising threat of becoming collateral in cyberattacks. It is imperative to evaluate the security practices and stances taken within any third-party organisation involved.

Key Points

- The NHS plans to launch 42 Integrated Care Systems (ICS) across England this year.
- The goal will be to share resources, drive efficiency and improve healthcare provision.
- While this is likely to increase collaboration, it also creates a greater attack surface area for cybercriminals.
- The NHS should take heed and evaluate the security practices and stances taken within any third-party organisation they work with.

In July of this year, the NHS plans to launch 42 Integrated Care Systems (ICS) across England. The NHS states that these Integrated Care Systems will be "new partnerships between the organisations that meet health and care needs across an area, to coordinate services and to plan in a way that improves population health and reduces inequalities between different groups". Ultimately, the goal will be to share resources, drive efficiency and improve healthcare provision.

While we believe this will be an incredibly effective framework, the increased collaboration between healthcare organisations comes at a cost. This newfound interconnectedness creates a greater attack surface area for cybercriminals and makes individual organisations more susceptible to supply chain attacks.

In 2021, we saw a number of devastating ransomware attacks that impacted not just the victim organisation, but all those in its supply chain. Most memorable of these was Kaseya. Attackers exploited a vulnerability in its software in July 2021 against MSPs and their customers, meaning about 1,500 SMEs were impacted by the attack.

When you consider the role of the NHS, a similar attack on an ICS could have dire consequences.

As plans for this framework are put in motion, the NHS should take heed of attacks like Kaseya to avoid a similarly devastating supply chain attack on these critical services, and consider the following steps.

Safeguarding Your Business Against Third-Party Attacks

As organisations become increasingly connected through technology, leveraging shared applications and infrastructure to enable more seamless integration, there is a rising threat of becoming collateral in cyberattacks – even when your organisation isn't the one getting hit. Not only may you depend on software or solutions that have been knocked offline, but when you connect your IT infrastructure with another organisation it's very possible for a criminal to move laterally through your partner or supplier's network and make its way to yours.

For that reason, it is imperative that NHS IT leaders rigorously evaluate the security practices and stances taken within any third-party organisation they work with. This can generally be done by asking a list of security-related questions about their practices and control environment, either as part of the procurement process or with existing suppliers.

Once assured of your partner's security posture, it's integral that NHS bodies adopt best practice when allowing contractors or third parties onto their network. Operate under the principle of zero trust: trust nothing, verify everything. As individual users and their devices join the network, it's important that they aren't just given all the implied trust and access that usually comes with this. It might feel like a daunting task, but is one that will pay dividends in the long-run – and there are a wealth of solutions on the market to simplify and manage this process.

Protect Yourself, Protect Your Supply Chain

You pose as much of a risk to your partners and supply chain as they pose to you. Not only do you have to think about the importance of robust cybersecurity for the health of your organisation, but all of those that could likely be impacted if you fall foul of an attack. In the case of these ICSs, each organisations security posture will be integral to patient safety. Cybercriminals tend to go after privileged access accounts, which act like a master key that can unlock every door in a technology environment. In an interconnected environment, it's these accounts that pose the greatest risk and so need to be given additional layers of protection. Applying Privileged Access Management enables organisations to safeguard accounts with special access or advanced capabilities, by monitoring them and putting enhanced controls in place such as multi-factor authentication, regular password changes or password vaults.

Likewise, adding layers of security at each access point is essential to deterring or impeding an attack effectively. One common misconception organisations have is that if they have an antivirus or antimalware solution in place, then they are protected. The reality, however, is quite different. On its own, it's unlikely that a single security solution will block an attack. When combined, each layer works in concert to plug any possible flaws or gaps in your defences – so the more layers you have in place, the more likely you are to prevent an attacker from getting in.

The nature of today's threat landscape means that it's no longer a viable option to sit back and hope for security solutions to block or detect malicious behaviour on the network. In many instances, an attacker will be lurking within the IT infrastructure undetected for days or even weeks before deploying ransomware. Actively threat hunting means you have a greater chance of neutralising a cybercriminal before they can release the payload.

Operate under the principle of zero trust: trust nothing, verify everything

In It Together

This might feel out of reach for many healthcare organisations whose IT teams are already under immense pressure to keep things going. We're increasingly seeing interest from public sector organisations for third-party support, which will help them monitor their environments and respond to threats as they see them. For these newly instated ICSs, managed security services will be an invaluable resource – enabling them to focus on the day-to-day with the peace of mind that cybersecurity experts are on-hand at all times.

Working together offers great opportunities to drive efficiencies, but this must extend to a collaborative effort towards implementing a robust cybersecurity posture. There are clear, simple steps an organisation can take to secure itself – as well as those it works with – and in light of recent third-party attacks, this is essential.

Conflict of Interest

None. ■

Telemedicine Care Combined with AI: Capabilities & Benefits

Charlotte Hubault I e-Health Consultant I Comarch Healthcare I Brussels, Belgium

An overview of the application of AI (artificial intelligence)-enabled systems in telemedicine and the Comarch healthcare strategy to develop building blocks of this new care system.

Key Points

- The management of chronic disease and geriatric disorders is one of the biggest challenges for healthcare systems.
- Telemedicine solutions bring innovative answers to the needs of healthcare providers.
- AI (artificial intelligence)-enabled systems can unlock the potential of telemedicine at every step of the patient pathway.
- AI-based virtual medical assistants can support telemedicine tools in the development of preventive medicine.
- Systems combining telemedicine and AI technologies can support healthcare providers to make the right diagnosis and choose the right treatment.
- Beyond remote monitoring, AI technologies enable the distant delivery of care to specific groups of patients thanks to smart robots and chatbots.

Introduction

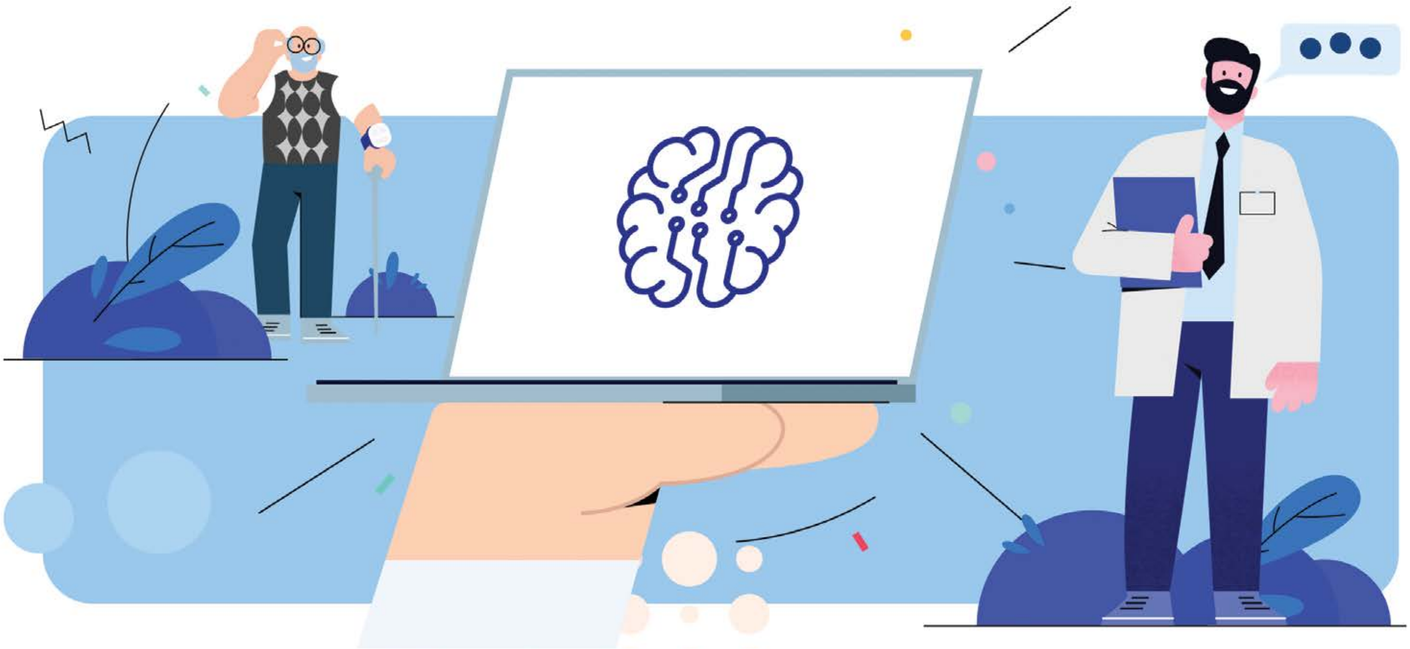
The management of chronic disease and geriatric disorders such as cardiovascular disease, osteoporosis, diabetes, dementia and obesity is one of the biggest challenges for our healthcare systems. The population of patients affected by these disorders is dramatically growing, while the nature of a chronic condition requires prompt and continuous care. In this context, telemedicine solutions bring innovative answers to the needs of healthcare providers suffering from work overload, while proposing more fluid care pathways and better quality of life for patients.

Telemedicine systems, from preventive care to telediagnosis, remote monitoring and treatment management, are based on the digital exchange of data between patients and healthcare players. This data-driven positioning paves the way for the use of another key innovative trend in the healthcare ecosystem: AI (artificial intelligence)-enabled systems. Indeed, AI is the key lever for developing the potential of telemedicine at every step of the patient pathway, with different levels of maturity and various benefits. This paradigm in the core of the Comarch healthcare strategy, as the company is actively developing building blocks of this new care system enabled by telemedicine and AI.

AI-based virtual medical assistants supporting remote preventive care

Preventive care is the key to countering the development of chronic disorders in healthy populations, as well as for those who find self-care challenging. In this area, telemedicine solutions such as patient-operated applications and self-diagnostic booths paired with connected medical devices are great tools to help individuals engage with preventive care. AI-based virtual medical assistants can be used in this particular case. They generate synchronous and task-oriented computer-generated dialogue with the patients, similar to a dynamic questionnaire that directs the conversation to collect relevant health-related data. In addition to enhancing data collection, AI medical assistants can also generate automatic pre-diagnosis and health advice based on the generated data.

Comarch has brought to the market two patient-operated applications for preventive care: a health diary in the shape of a mobile application, Comarch HealthNote, and a self-diagnosis booth, Comarch Diagnostic Point. Both solutions are continuously developed and improved, notably thanks to AI tools such as the medical assistants cited above.



AI combined with telemedicine supporting healthcare providers to analyse clinical data

The saturation of healthcare facilities unfortunately leads to delays in diagnosis as patients encounter difficulties getting appointment quickly. It is even more critical in the context of complex diseases that require several appointments with different specialists in order to make a diagnosis. This organisational barrier is now overcome by a new patient pathway based on telemedicine and AI. Instead of performing physical visits, clinical data can be generated remotely through a connected medical device or phone camera (for example, ECG data in cardiology, face pictures in genetics, skin pictures in dermatology). Data are then transmitted to healthcare providers through a telemedicine application which is where AI comes into play. Algorithms based on machine learning are able to analyse these single points of data to propose a diagnosis, by comparing them with huge quantities of existing data. The Los Angeles County Department of Health Services foresees the related benefits in the context of diabetic retinopathy, for example, as a new protocol for diagnoses using an AI analysis tool will enable diagnosis using only retinal pictures (Varshneya 2021).

In addition to analysis of single points of data, AI can also unlock the management of the huge amount of data generated remotely during long-term testing or screening. These large sets of data require powerful AI-enabled algorithms to expedite the diagnosis process. At Comarch, we already offer cardiac telemonitoring services, which analyse and detect silent atrial fibrillation in a 30-day ECG examination thanks to AI tools (Wiśniewski 2021).

AI systems can also perform remote triage of patients by analysing early signs of deterioration thanks to connected medical devices and a patient-operated application. For example, the Department of Health Science and Technology at Aalborg University (Denmark) recently launched a clinical study aimed at testing an AI-enabled algorithm in telemonitoring to predict exacerbations in patients with COPD (Secher et al. 2022).

Decision-making tools supporting treatment decisions and AI applications improving treatment adherence

Systems combining telemedicine and AI technologies can support healthcare providers when deciding on the most suitable treatment for each individual. While telemedicine applications allow the collection of real-time data, AI-algorithms can perform rapid analysis of this information to provide the most relevant proposal for treatment based on the current condition of the patient. The NextDREAM Consortium Group headed a large-scale study assessing the efficiency and safety of an automated AI-based decision-support system which produces a full insulin titration recommendation and personalised management tips for healthcare providers who are remotely monitoring patients with diabetes. The study demonstrated that remote insulin adjustments suggested by the AI advisor perform as well as expert physician dosage changes.

In the context of remote care, AI application also improves treatment adherence. Indeed, when patients are at home, it makes it harder for healthcare providers to supervise the intake of medicine – and adherence is a key success factor for each drug-based therapy. For this reason, the AiCure company developed a mobile application dedicated to schizophrenia. It integrates with a face recognition system and checks whether prescribed drugs have been taken. During their pilot study in 2017, the company reported an 89.7% drug adherence rate [compared to 71.9% for traditional drug adherence monitoring] (Bain et al. 2017).

mobile body and screen for patient-doctor communication. The camera moves in accordance with the doctor's instructions, and the robots can measure clinical parameters of the patient thanks to telemedicine functionalities [for example, electronic stethoscope, blood pressure, temperature, ECG and pulse-oximetry] (AIP Conference Proceedings 2018).

AI is the key lever for developing the potential of telemedicine at every step of the patient pathway

AI-enabled robots and chatbots delivering care in the context of telemedicine

Beyond remote monitoring, AI technologies enable the distant delivery of care to specific groups of patients thanks to smart robots and chatbots. Indeed, it is now a priority to create new care delivery ensuring better access and continuity of care to counter the lack of availability of healthcare providers, and to reduce the high costs of homecare. To this end, some synchronous and task-oriented computer-generated dialogues have been developed for mental health applications. They allow constant access to care for this target group, which may require assistance at any time of the day.

Elderly people could also benefit from AI-enabled care with the development of smart robots assisting them in their daily tasks and in the management of their health issues. For example, the Dr Rho Medical Telepresence Robot allows elaborate teleconsultations to be carried out thanks to its

Conclusion

Regarding the various applications of the combination of telemedicine and AI presented here, three main categories of solutions can be identified, each at different levels of maturity. First, the AI-based decision-making tools supporting healthcare providers in making a diagnosis or selecting the relevant treatment are quite mature, as they are already in use in various care facilities. AI virtual assistants who support patients during self-diagnoses or deliver care in the context of mental health issues (for example) are promising solutions but have not yet been integrated into care practices. Last, smart robots also represent a great opportunity to unlock telemedicine capabilities, but are still at the development stage. Indeed, the two last applications require additional clinical studies to prove their efficiency and their safety, and represent large investments in research and development at the technological and organisational levels. ■

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Innovative Technologies Will Address Health System Challenges

Thales I France

Innovation is the fuel for any improvement in society because technology always pushes back limitations. Thales envisions to build on its advanced expertise to meet the healthcare challenges of tomorrow. Bringing performant secure healthcare access to anyone, anywhere, will overcome critical medical issues.

New Challenges

After the pandemic revealed the weakness of global health systems, our societies have seen public health concerns coming back at their core preoccupations: ageing populations, the rise of chronic diseases, increased cost of health care, and inequalities. Entire parts of societies stalled in accessing care in the past decades: rural and suburban locations, lower-income neighborhood and minorities, elderly and disabled people. Although they displayed outstanding resilience and commitment, healthcare professionals faced shortages issues, with critical impact on patients. These factors are an immediate threat to the sustainability of healthcare systems, in Europe and worldwide.

Governments have implemented ambitious public policies to mitigate this short-term risk, and build more efficient care pathways, in the benefit of the patients. This historical investment effort focusses on recruitment, facilities, equipment and digitalisation. Also, medical desertification is a reality for many patients, and needs to be addressed. Private players need to join forces and help address these challenges.

Technological Answers

Healthcare in 2030 will not look like healthcare in 2020. Digitalisation, territorial mobility, and technological advances will drive significant improvements for the common benefit of all.

Renouncement to care is often a matter of distance. In the coming years, we will see the development of mobile solutions in the territories. They bring the service closer to the patient, relieve the emergency services and tackle the problem of equal access to care. These fleets of lightweight, high-performance connected systems will have to go with fleet monitoring and preventive maintenance solutions to avoid downtime.

Teleradiology will expand to solve the unequal distribution of radiologists worldwide, while providing high-quality diagnosis to every patient. The deployment of 5G makes rapid telediagnosis possible, regardless of where the patient is located. This high connectivity comes with new cybersecurity threats, and requires protecting any component of the chain, from systems to data transfer.

Artificial Intelligence (AI) and data analysis will play an increasingly important role in healthcare. Indeed, AI helps radiologists worldwide as a diagnosis companion, and is a way to free up time and resources. The collection of data bundles, from the system component to the clean image, is vital to break new frontiers.

Our Contribution

Thales, a global innovation company in security and critical operational missions, is at the forefront of this urgent tall order. We aim to build an innovation network to pool experts from SMEs, start-ups as well as public organisations. We leverage our expertise to provide our customers with:

- Lightweight, high-end flat panel detectors to unlock the next generation of portable x-ray systems
- User-defined imaging solutions, to smooth the operator's workflow
- Innovative remote maintenance and fleet monitoring solution,
- Cybersecured solutions, leveraging the expertise that Thales already deploys in critical activities such as aerospace, defense and government

More is yet to come, and we look forward bringing these advancements to the market while paving the way for a better healthcare. ■

Thales will be present at ECR 2022 in Vienna, We welcome you to our booth #229 (Hall X2).

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