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ARTIFICIAL INTELLIGENCE IN RADIOLOGY

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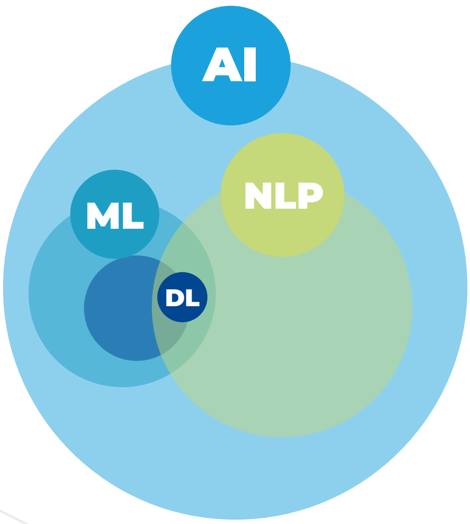
The rapid development of Artificial Intelligence (AI) in recent years has led to profound changes in numerous professional fields - AI is polarizing. The beginnings of AI date back quite some time. The following graphic provides a simple overview of the history and how AI is related to Natural Language Processing, Machine Learning, and Deep Learning.

EXPLORING THE HISTORICAL JOURNEY OF ARTIFICIAL INTELLIGENCE

1942	1950	1955	1964	1995	1997	1998	2008	2011	2020
1	2	3	4	5	6	7	8	9	10
Enigma broken with AI	Test for machine intelligence by Alan Turing	The father of AI - John McArthy	The first chatbot - Eliza	The chatbot - ALICE	Man VS Machine - DeepBlue beats chess legend	The emotionally equipped robot - Kismet	Voice recognition future	The Q/A computer system - IBM Watson	A revolutionary tool for automated conversations - GPT model

UNDERSTANDING THE RELATIONSHIP BETWEEN AI, Machine Learning (ML), Deep Learning (DL) and Natural Language Processing (NLP)[1]



- AI is a broad field that include anything related to making machine smart.
- NLP is a branch of AI focused on teaching machines to understand, interpret, and generate human language
- ML is a subset of AI that involves systems that can learn by themselves.
- DL is a subset of ML that uses models built on deep neural networks to detect patterns with minimal human involvment.

[1]Cf. Knappertsbusch/Gondlach (2021), S. 322

The development of intelligent algorithms has made AI-based applications an indispensable part of everyday life. There are many areas where AI applications simplify the lives of millions of people. Whether it's voice assistants like Siri or Alexa, search engines like Google, or recommendation algorithms like YouTube, AI has long been established in everyday life. Those who resist this development risk falling behind. While this may not be of great significance in the private sphere, it can have serious consequences in the professional environment, particularly in the medical field. A medication mix-up or a missed diagnosis can be especially critical there.

Especially due to the ongoing digitalization, which is the result of the foundational innovations in the field of communication and information technology from the 5th Kondratieff cycle (Kondratieff cycles are long-term economic cycles first described by Nikolai D. Kondratieff in 1926), and the associated increase in globally accessible data, AI applications are becoming increasingly powerful and important, including in the medical context. The healthcare sector faces significant challenges such as rising cost pressures, demographic changes, staff shortages, and the increase in chronic diseases and multimorbidity.[2]

[2]Cf. Hosten (2020), S. 1.

AI in diagnostic imaging

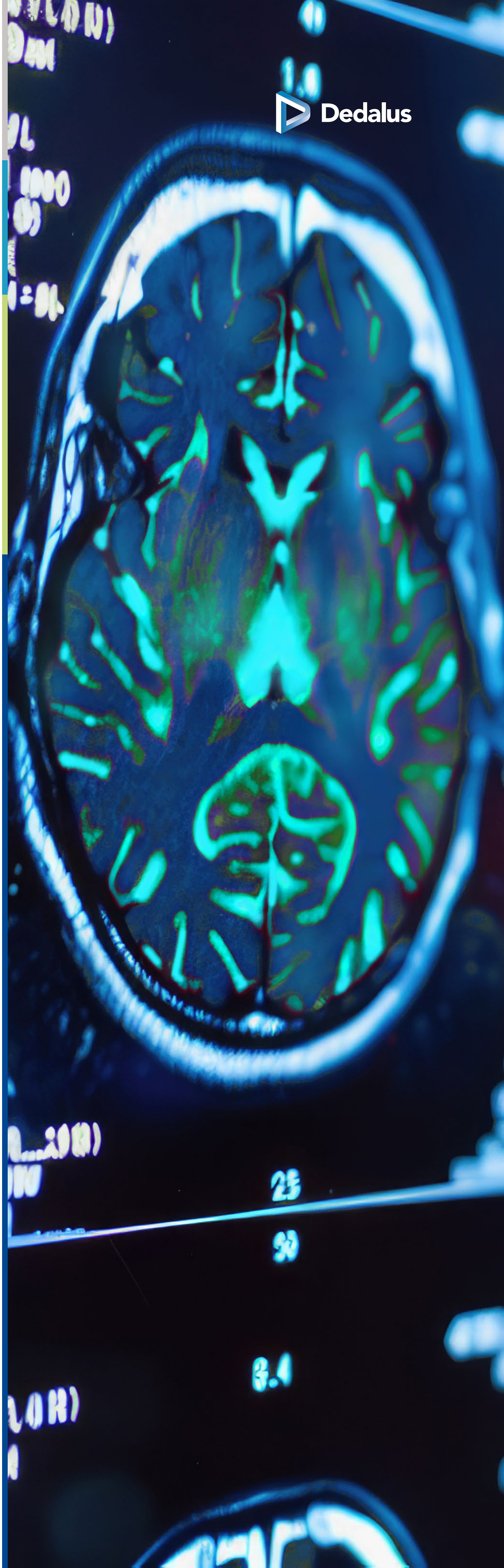
X-rays, ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) are imaging techniques that have revolutionized medicine by enabling insights into the living organism. It is estimated that approximately 90% of all medical data comes from imaging procedures, making them particularly suitable for use in self-learning systems. Especially where medical information is already digitally available, machine learning can significantly improve diagnostics.[3]

In the mid-20th century, imaging made significant advances through the application of the same technology used for television sets. Additionally, digital cameras significantly contributed to the establishment of digital archives in hospitals. In radiology, these systems are referred to as PACS (Picture Archiving and Communication System), which allow medical professionals to access diagnostic findings.[4]

For several years now, machine learning has been able to help distinguish between benign and malignant tumors. The so-called “radiomics” identify specific structures in the imaging findings and analyze the data. Based on this, they create a connection between the patient and the appropriate therapeutic approach to assist doctors in decision-making.[5]

In oncology and dermatology, AI-supported diagnostic programs are expected to provide valuable decision support, as the characteristic features of various cancer types are difficult to discern even for experienced eyes.[6]

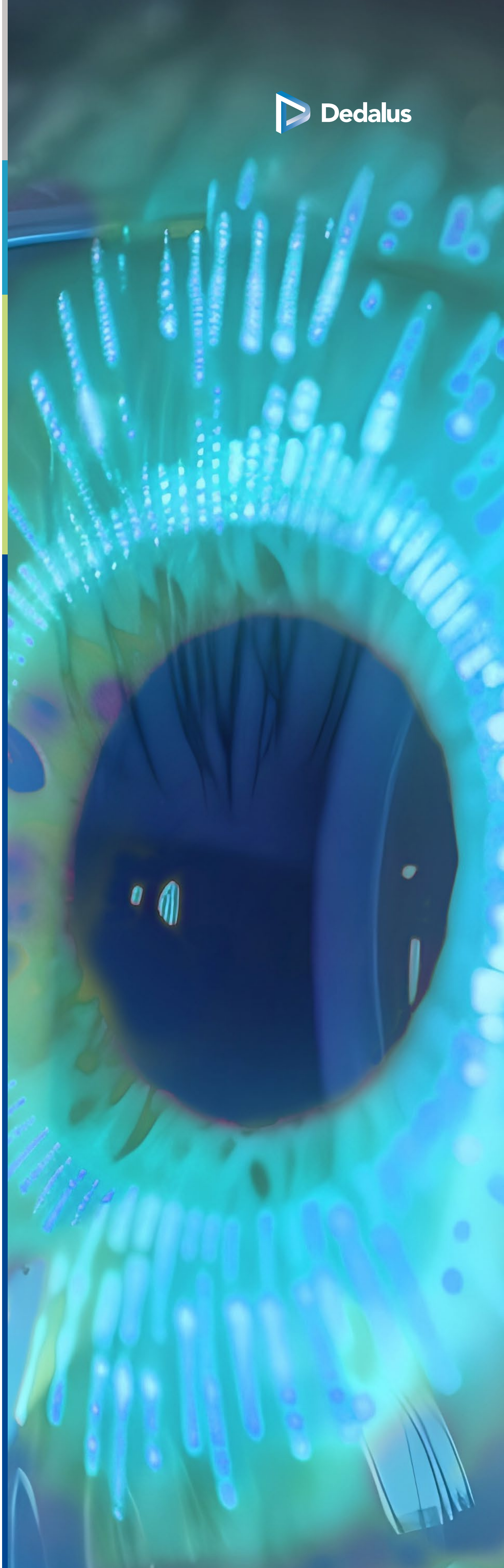
[3]Cf. Knappertsbusch/Gondlach (2021), S. 322
[4]Cf. Hosten (2020), S. 1.
[5]Cf. Hosten (2020), S. 2.
[6]Cf. Knappertsbusch/Gondlach (2021), S. 322



Early demonstrations show the performance of AI in image evaluation: In 2019, the University of Heidelberg had over 150 dermatologists compete against a computer algorithm that had previously been trained with a large number of annotated open-source images. The task was to classify suspicious skin lesions on 100 images, particularly distinguishing between benign moles and melanoma. The algorithm outperformed 136 of the 157 dermatologists in terms of average specificity and sensitivity.[7]

Similar results were achieved in the largest study to date on automated skin cancer diagnosis, also conducted in 2019 under the leadership of the Medical University of Vienna.[8]

Self-learning algorithms will not only transform classical imaging through X-rays, CT, and MRI. The collaboration between medicine and computer science will lead to the development of new technologies. An example is the "4D + nanoSCOPE" project, in which the Friedrich-Alexander-University Erlangen-Nuremberg (FAU) plays a leading role. The goal is to apply X-ray microscopy to the living organism for the first time to better understand the bone structure and anatomy of humans and to detect damage caused by stress. These tomographic calculations could also be used outside medical research, such as in the examination of microfractures or corrosion processes in natural and synthetic materials. [9]



[7] Cf. Brinker et al. (2019).
[8] Cf. Tschandl et al. (2019).
[9] Cf. Knappertsbusch/Gondlach (2021), S. 323.

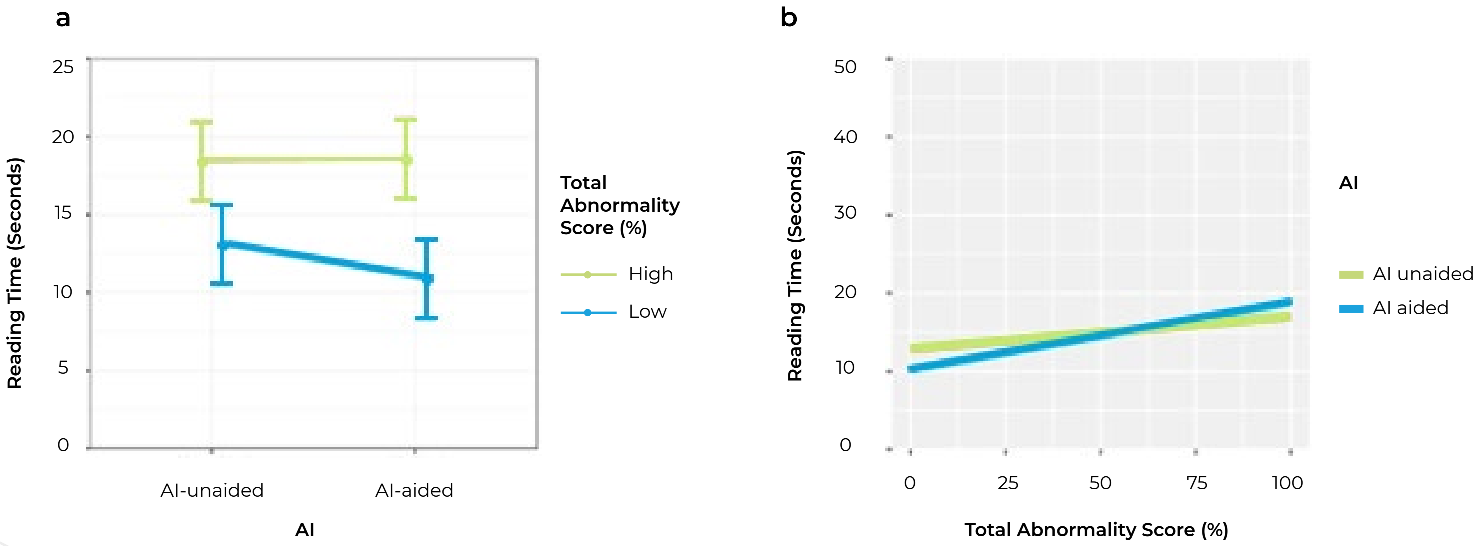
AI in Radiology - Changing Reading Time in CXRs[10]

Not only in oncology and dermatology but also in radiology, efficiency advantages are beneficial. Radiologists typically create an average of 60 reports per day. They have to examine numerous images in the process – AI is intended to assist them.
In a study conducted in 2023, the aim was to present findings on the reading times during daily chest X-ray (CXR) interpretations conducted by 11 radiologists over a period of 4 months and investigate whether the introduction of artificial intelligence (AI) impacts these reading times. Given the escalating workload faced by radiologists, the potential role of AI in alleviating fatigue and enhancing diagnostic accuracy is a compelling area of inquiry.

The study adopted an observational approach, leveraging the routine practice of CXR readings within the institution, where radiologists adhere to preset monthly requirements. Using the Picture Archiving and Communication System (PACS) log records, the display of AI results in the PACS interface was monitored on a monthly basis and corresponding time data was extracted.

Throughout the study period, radiologists had the option to review CXRs with or without AI assistance. The analysis revealed that overall reading times were influenced by the utilization of AI, particularly showing a reduction in reading times for normal CXRs. However, there was no statistically significant difference in reading times when AI was employed for CXRs displaying abnormalities.

Interestingly, as the severity of abnormalities detected on CXRs increased, radiologists spent more time on interpretation. This observation suggests that radiologists may exhibit greater confidence in diagnosing normal CXRs after referring to AI results, leading to expedited decision-making. Conversely, when AI identified lesions, radiologists tended to invest additional time in evaluating the AI's findings and providing comprehensive reports, irrespective of the AI's accuracy.



a According to the presence or absence of a lesion on chest radiographs (total abnormality scores - high: >=15% representing the absence of any lesion by AI).

b According to the total abnormality scores (0-100%).

[10]Cf. Shin et al. (2023).

This study demonstrated that the reading times of CXRs among radiologists were influenced by the availability of AI results.

As a result, AI has the potential to enhance the efficiency of radiologists by reducing the time spent on normal images, thereby enabling them to allocate more time to interpreting CXRs with abnormalities.

Interesting is that an earlier study by Kim et al.[11] in 2020 is in contradiction to the results shown by Shin et al. using the same AI software. The study reviewed radiologists' interpretations of all chest X-rays (CXRs) taken over a two-month period, both with and without the integration of AI on the Picture Archiving and Communication System (PACS). They observed a concordance rate of 86.8% between the reports generated by AI and those by radiologists, noting that the median reading time increased from 14 to 19 seconds when AI was utilized. Further subgroup analysis revealed that reading times increased for normal CXRs but decreased for abnormal CXRs when AI was employed.[12]

Studies which were conducted under different circumstances are always difficult to compare. An explanation for the differences can lie in the differences of the study cohort or the older version of the software being used as well as the experience and expertise level of the radiologists which can be an important research area for future studies.

Nevertheless, it is to mention that the underlying Data sets are getting more extensive on which AI-Algorithms can be trained to continuously improving AI software.

[11]Cf. Kim et al. (2022).
[12]Cf. Kim et al. (2022).

Vulnerabilities and Development Potential of AI in the Medical Context

AI can be a great help, but it also has its limitations. It can be trained to identify exactly one normal finding or one specific disease. Other diseases are not considered during the examination, and differential diagnoses are not made.[13]

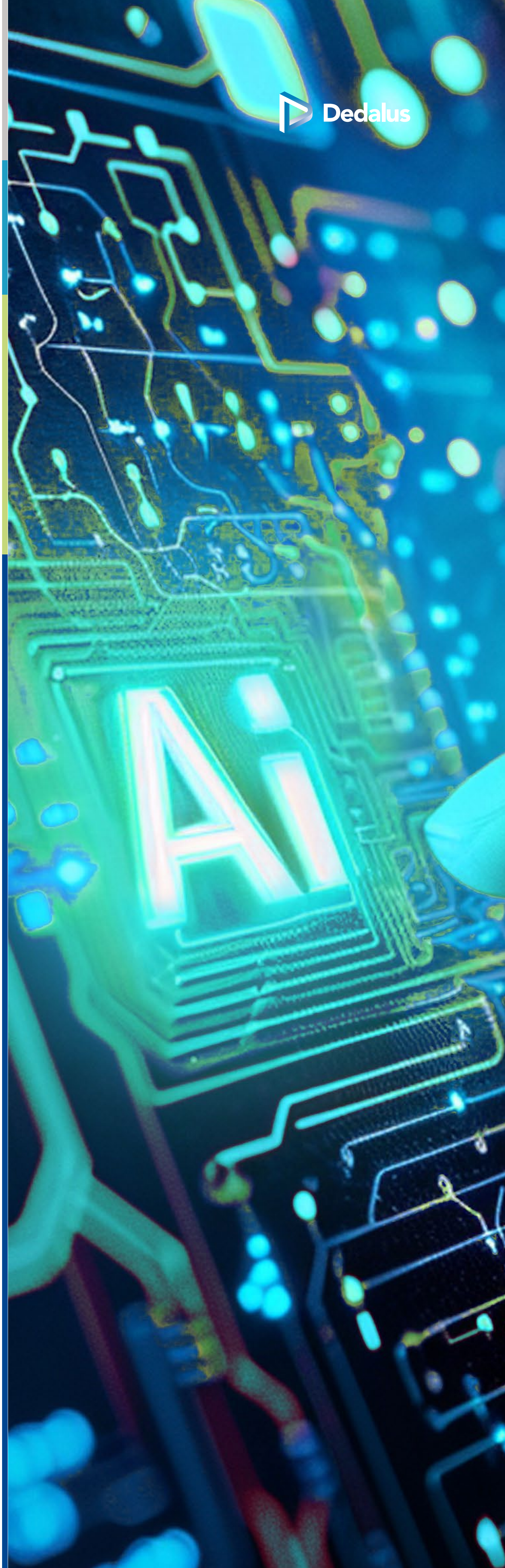
Restructuring and implementation take time and money. Many hospitals cannot currently afford this. Even if these resources are available, it does not automatically lead to better treatment quality.[14]

A financial risk is the potential for data theft. In 2020, there was damage of over 100 billion euros due to, among other things, hacker attacks. Therefore, a secure infrastructure plays a major role, but it is currently difficult to achieve due to a lack of financial resources.[15]

In addition to financial aspects, there is also the problem of transparency. If the solution path of the algorithm cannot be understood, this is referred to as the black-box problem.[16] In radiology, for example, it would not be possible to understand on what basis a finding was analyzed and how the result was derived. However, initial solutions to this problem are already being tested.

findings and providing comprehensive reports, irrespective of the AI's accuracy.

[13]Cf. Lingscheid (2023).
[14]Cf. Czypionka/Hobodites (2020).
[15]Cf. Buxmann/Schmidt (2021), S. 209 f.
[16]Cf. Kulkarni et al. (2020).



Purchasing AI in Radiology[17]

When considering the introduction of AI tools into clinical practice, purchasers should evaluate several critical aspects to ensure sustainable benefits. Firstly, regulatory approval from agencies like the FDA confirms compliance with relevant regulations but does not guarantee successful implementation. Potential purchasers should assess the intended use, benefits, risks, and economic impact of the AI tool. Integration into workflows and verification of commercial claims are essential, as is training users and addressing psychological effects of human-AI interaction. Additionally, purchasers need to ensure that the AI tool's accuracy on local data is sufficient for practical use and user engagement.

To measure the positive impact of an AI tool, objective and quantifiable goals should be set. Identifying areas for improvement and setting measurable goals is crucial. AI tools should address specific, real problems within the institution. Benefits should extend beyond radiologists to include patients, the institution, and society, such as improved detection in high-volume screenings and reduced costs. Economic impact and return on investment should be carefully evaluated, considering both direct and indirect costs, such as licensing, integration, training, and maintenance.

Evaluating the vendor's reliability, compatibility, and potential for collaboration is also vital. Local validation of AI performance on site-specific data is recommended to ensure accuracy and effectiveness. Understanding the potential risks, including algorithmic errors, user over-reliance, and healthcare disparities, is essential. Continuous monitoring and risk assessment are necessary to mitigate these issues and ensure the successful integration of AI in clinical practice.

[17] Cf. Brady et al. (2024).

Implementing AI in Radiology[18]

The significance of artificial intelligence (AI) in healthcare is widely acknowledged, yet its seamless integration often faces challenges.

A longitudinal, qualitative case study spanning three years was conducted at a prominent academic medical center (MC) in the Netherlands, focusing on AI integration in radiology. Through abductive reasoning, three key themes of change initiatives were unearthed, addressing specific challenges encountered during AI integration.

The study highlights hurdles encountered at various levels of AI integration in radiology, advocating for a holistic approach to surmount them:

- At the technological level, challenges revolve around the absence of standardized user interfaces for multiple narrow AI applications.
- Workflow bottlenecks arise from AI results offering limited interaction opportunities for radiologists
- At the people and organizational level, differing expectations and limited AI experience pose significant barriers.

The case study serves as a testament to the efficacy of long-term initiatives that harmonize social and technological aspects of clinical practice in maximizing the benefits of AI integration.

The implementation of artificial intelligence (AI) in clinical workflows lacks standardization, leading to significant variations in its use. To address this challenge, the MC adopted a comprehensive approach to AI integration, focusing on standardization, local validation, and continuous learning.

The MC established the Image Processing Group (IPG) within its radiology department as a central hub for deploying and integrating advanced technologies, including AI. Radiographers in the IPG utilize technology to analyze radiological images and pre-populate reports, shifting tasks from radiologists to optimize workflow efficiency.

One key challenge in AI integration is the variance in performance when applied to local datasets. To mitigate this, technical physicians in the IPG validate algorithms locally, measure performance metrics, and ensure seamless integration into the clinical workflow. Collaboration with AI vendors and retrospective analyses validate AI applications, enhancing radiologists' confidence in AI-generated results.

Another challenge lies in AI's limited real-time interaction with radiologists. The MC addressed this by collaborating with vendors to make AI results modifiable, allowing radiologists greater control over reports. Although this required extensive collaboration and delayed integration, it increased radiologists' acceptance and eagerness to utilize AI.

At the people and organizational level, the MC established the Clinical AI Implementation Group (CAI Group) to assess AI project proposals, promote learning among clinicians, and prevent redundant efforts. The CAI Group facilitates cross-departmental communication and knowledge sharing, ensuring efficient AI implementation hospital-wide.

The MC also appointed AI champions from each radiology subspecialty to gather potential use cases and prioritize projects. This bottom-up approach fosters peer-to-peer teaching and informed decision-making, resulting in more realistic expectations and grounded AI applications.

Overall, MC's holistic approach to AI integration addresses challenges at multiple levels and promotes continuous learning and collaboration, paving the way for successful AI adoption in clinical practice.

In conclusion, the study emphasizes the critical importance of a holistic approach to AI integration, offering pragmatic insights and solutions for successful adoption in radiological care. Key takeaways underscore the need for practical insights, alignment of technology, workflow, and organizational aspects, and the transformative potential of a holistic approach in fostering sustainable benefits through AI integration.

[18]Cf. Kim et al. (2024).

Afraid of Job replacement through AI

Study about Job replacement

Considering all industries, some studies express significant pessimism regarding AI and the future of work. Perhaps the most well-known study comes from the University of Oxford and addresses the risk of job automation. The authors estimated that almost half of the jobs performed by humans in the U.S. (47%) are highly likely (>70%) to be at risk by 2033. For Germany, they calculated this risk for 42% of all jobs. Jobs with a high proportion of repetitive tasks, but increasingly also cognitively demanding activities involving the analysis of large data sets, are particularly affected. This prognosis was subsequently endorsed by several other authors.[19]

The World Economic Forum, in its «Future of Jobs Report 2020,» estimates that by 2025, technological advancements will replace around 85 million jobs worldwide, but at the same time, create 97 million new jobs. Others also believe that technological unemployment is overestimated and see at least as many new employment opportunities as endangered positions.[20]

[19]Cf. Frey/Osborne (2017).
[20]Cf. van Echtelt (2020).

Job replacement in radiology[21]

In a bachelor’s thesis focused on analyzing the current and future potential of AI in radiology, some interviews were conducted, revealing differing opinions on the replacement of radiologists.
For instance, a project manager at the Agaplesion Diakonieklinikum in Rotenburg views AI and particularly Generative Pre-trained Models (GPT) as promising aids for radiologists and questions whether all radiologists will still be needed in the future or if AI software will suffice.

The chief radiologist at Agaplesion Diakonieklinikum Rotenburg believes that radiologists will only be replaced if they resist AI and sees AI as particularly beneficial for breast cancer diagnostics and tumor detection in general, as well as having great potential for time savings.

The chief radiologist at Klinikum Bad Hersfeld views AI as a risk to the radiologist profession and believes that AI will become an integral part of the work routine sooner or later, even though he does not wish to accelerate this process.

Despite the different opinions, as long as the current legal framework requires a medical diagnosis, AI should not be seen as an enemy but rather as a helping hand.

Looking at the acceptance of AI-generated diagnoses, there are already some patients who would trust AI. A study conducted by Appinio in 2023 shows that both AI and doctors are trusted. 55 percent of respondents indicate that they generally (very) trust their doctors, and 40 percent have great confidence in the support of medical diagnoses by AI. 33 percent fully trust the use of AI in the medical field. Men show greater confidence in AI than women (36 percent vs. 30 percent). There is particular trust in the evaluation of X-rays/MRI/CT scans by AI (34 percent). 23 percent trust AI for health diagnoses.[22]

Aside from patient acceptance, there are still some hurdles to overcome to fully realize the potential of AI.

[21] Cf. Brockmann (2023), S. 22.
[22] Cf. Appinio (2023).

Conclusion

In summary, the rapid development of artificial intelligence (AI) has profoundly changed numerous professional fields, particularly in the medical sector. The integration of AI into everyday applications - from voice assistants to diagnostic tools - illustrates its pervasive influence and the need to adapt. The field of radiology is a good example of the potential of AI, where significant advances have been made in diagnostic accuracy and efficiency, particularly through AI-driven image analysis.

Studies have shown that AI is able to reduce reading times for radiologists, especially for normal chest X-rays, allowing them to focus more on complex cases. However, these results are not universal, indicating the need for further research and refinement of AI tools. Successfully integrating AI into clinical workflows requires a holistic approach that addresses technological, organizational and educational challenges. The Medical Center case study highlights the importance of local validation, standardized interfaces and collaborative efforts between medical professionals and AI developers.

While AI promises to improve medical diagnostics and workflow efficiency, it also poses challenges, such as the need for transparency, a secure infrastructure and overcoming financial constraints. The risk of job displacement remains a concern, although many experts believe that AI will create new opportunities as well as new tasks. Acceptance of AI-generated diagnoses is growing among patients, pointing to a future where AI and human expertise work together to improve healthcare outcomes.

Ultimately, the transformative potential of AI in medicine is enormous and offers solutions to pressing challenges such as rising healthcare costs, demographic changes and the increasing complexity of diseases. By fostering a synergistic relationship between AI technology and medical practice, the healthcare sector can leverage AI to achieve sustainable benefits, improve patient care and drive innovation..

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