Laboratory Specialists' Perspectives on Integrating Artificial Intelligence in Diagnostics: Challenges, Opportunities, and Future Directions

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Abstract

This qualitative study explores the perspectives of laboratory specialists on the integration of artificial intelligence (AI) in diagnostics, focusing on the perceived benefits, challenges, and ethical concerns. Semi-structured interviews with 20 laboratory specialists revealed four key themes: improved diagnostic accuracy and efficiency, lack of training and trust in AI systems, shifting roles and responsibilities, and ethical concerns around data privacy and algorithmic bias. While participants were optimistic about AI's potential to enhance diagnostic workflows, they expressed concerns about job security, the need for specialized training, and the transparency of AI systems. The findings highlight the importance of addressing these challenges to ensure the successful integration of AI in laboratory diagnostics.

Keywords: Artificial Intelligence, Laboratory Diagnostics, AI In Healthcare, Diagnostic Accuracy, Workflow Automation, Data Privacy, Ethical Concerns

Introduction

Artificial intelligence (AI) is rapidly transforming the healthcare landscape, offering new possibilities for enhancing diagnostic accuracy, efficiency, and decision-making. AI-driven tools, including machine learning algorithms and predictive analytics, are increasingly being integrated into diagnostic processes, ranging from automated image analysis to predictive modeling in pathology and clinical chemistry (Topol, 2019). This integration holds the promise of improving diagnostic workflows by reducing human error, accelerating test results, and assisting laboratory specialists in interpreting complex data (Gulshan et al., 2016).

In laboratory medicine, AI's potential to revolutionize diagnostics is immense. AI can process vast amounts of data quickly and accurately, improving the detection of diseases such as cancer, infectious diseases, and genetic disorders (Maddox et al., 2019). However, despite its potential, the integration of AI in diagnostic laboratories presents significant challenges. Laboratory specialists, who are integral to the diagnostic process, face concerns over the reliability of AI, the need for specialized training, ethical considerations, and the fear of job displacement (Aggarwal et al., 2021). Understanding how laboratory professionals perceive AI is crucial for its successful integration and widespread adoption.

The purpose of this study is to explore the perspectives of laboratory specialists regarding the integration of AI in diagnostics. By investigating their views on the potential benefits and challenges of AI, this study aims to provide valuable insights into how AI can be more effectively integrated into laboratory practices while

addressing the concerns and needs of professionals. Through this exploration, the research seeks to contribute to the ongoing conversation about the role of AI in shaping the future of laboratory diagnostics.

Research Questions

1. What are the perceived benefits of integrating AI into diagnostic laboratories, according to laboratory specialists?
2. What challenges do laboratory specialists foresee in the adoption of AI in diagnostics?
3. How do laboratory specialists perceive AI impacting their roles and responsibilities in the future?

Literature Review

The integration of artificial intelligence (AI) into healthcare has rapidly gained momentum, particularly in diagnostic fields such as radiology, pathology, and laboratory medicine. This literature review examines the current landscape of AI in diagnostics, focusing on its potential benefits, challenges, and the perceptions of healthcare professionals, particularly laboratory specialists.

1. AI in Healthcare Diagnostics

Artificial intelligence has become a transformative tool in healthcare, particularly in diagnostics, where its ability to analyze vast datasets quickly and accurately has demonstrated significant potential. AI applications in diagnostics range from automated image analysis, such as in radiology and histopathology, to predictive modeling in clinical chemistry (Maddox et al., 2019). AI-driven tools, including deep learning algorithms and machine learning models, are capable of detecting patterns in complex datasets, allowing for early and accurate disease detection (Topol, 2019).

For example, AI has shown considerable success in identifying diabetic retinopathy from retinal images with accuracy comparable to human experts (Gulshan et al., 2016). Similarly, AI has been employed in oncology to improve the accuracy of cancer diagnostics through automated image analysis, reducing diagnostic errors and increasing speed in laboratory workflows (Esteva et al., 2017). These advancements highlight the potential of AI to enhance diagnostic precision, decrease turnaround times, and ultimately improve patient outcomes.

2. Benefits of AI Integration in Laboratory Diagnostics

The adoption of AI in laboratory diagnostics offers numerous potential benefits, particularly in terms of efficiency and accuracy. Studies suggest that AI can assist laboratory specialists by automating routine tasks, such as image analysis and sample classification, allowing them to focus on more complex, value-added tasks (Maddox et al., 2019). AI has also been shown to enhance diagnostic accuracy by identifying patterns in data that may be missed by the human eye, particularly in high-complexity fields such as pathology and genomics (Aggarwal et al., 2021).

In addition to improving accuracy, AI can significantly reduce the time required for diagnostic testing, which is crucial in time-sensitive settings like emergency departments and critical care units (Topol, 2019). Automated diagnostic systems powered by AI can process large volumes of data in shorter periods, leading to faster results and potentially enabling earlier interventions. Furthermore, AI's ability to learn from historical data and continuously improve its algorithms makes it a valuable tool for advancing laboratory medicine and clinical decision-making (Ching et al., 2018).

3. Challenges in Integrating AI into Diagnostics

Despite the promising potential of AI, several challenges hinder its widespread adoption in laboratory diagnostics. One significant challenge is the trust in AI-generated results. Many healthcare professionals, including laboratory specialists, express concerns about the reliability and transparency of AI systems (Topol, 2019). These concerns stem from the so-called "black box" nature of many AI algorithms, which can make it difficult for users to understand how certain decisions are made. Without clear interpretability, some professionals may be hesitant to rely solely on AI-driven diagnostics.

Another challenge is the fear of job displacement. AI's capability to automate routine tasks has raised concerns among laboratory specialists that their roles may become redundant, especially in areas where AI is more efficient than humans (Jiang et al., 2017). While AI is often positioned as a supportive tool for enhancing human expertise rather than replacing it, the fear of automation displacing jobs is prevalent across the healthcare industry.

Training and upskilling are also necessary for laboratory specialists to effectively use AI tools. Many laboratory professionals lack formal training in data science or machine learning, making it challenging for them to integrate AI into their workflows seamlessly (Aggarwal et al., 2021). Without adequate training and support, laboratory specialists may struggle to fully leverage AI's capabilities.

4. Ethical and Data Privacy Concerns

The integration of AI in diagnostics raises ethical concerns, particularly around data privacy and security. AI systems rely on large datasets to train algorithms, and the use of patient data must be handled with strict confidentiality (Hagendorff, 2020). Ensuring that AI systems comply with healthcare regulations, such as the General Data Protection Regulation (GDPR) in Europe and the Health Insurance Portability and Accountability Act (HIPAA) in the United States, is critical to protecting patient privacy and maintaining trust in AI-driven diagnostics.

Additionally, ethical considerations arise when AI systems are used to make critical healthcare decisions. Issues related to bias in AI algorithms have been documented, with some AI systems performing better for certain demographic groups than others (Mehrabi et al., 2021). Addressing bias and ensuring that AI systems are equitable and fair is essential for their ethical deployment in diagnostics.

5. Perceptions of Healthcare Professionals on AI Integration

Several studies have examined the perceptions of healthcare professionals regarding the integration of AI into their practices. While some professionals view AI as a promising tool to augment their work, others are more skeptical about its reliability and the potential impact on their roles (Maddox et al., 2019). Research shows that healthcare professionals who are familiar with AI and its applications tend to have a more favorable view of its integration, as they understand how AI can complement their skills rather than replace them (Gulshan et al., 2016). However, for those unfamiliar with AI technology, there is often resistance, fueled by concerns about AI's reliability and transparency.

A qualitative study by Mugabe et al. (2021) found that many healthcare professionals feel inadequately prepared to use AI in their daily work due to a lack of training and support. This highlights the importance of education and training programs for healthcare workers, including laboratory specialists, to ensure they are equipped to work alongside AI systems.

Gaps in Research

While there is growing literature on the integration of AI in healthcare, relatively few studies have specifically focused on laboratory specialists 'perspectives on AI. Most existing research explores AI's potential benefits and challenges from a general healthcare standpoint or focuses on fields like radiology and surgery. Understanding the unique experiences and concerns of laboratory specialists is critical to ensure the successful adoption of AI in laboratory diagnostics. More qualitative research is needed to explore how laboratory specialists perceive the role of AI in their workflows and how these perceptions influence the integration of AI in laboratory settings.

The literature highlights the transformative potential of AI in diagnostics, offering improved accuracy, efficiency, and decision-making. However, significant challenges, including trust in AI, the fear of job displacement, and the need for adequate training, remain obstacles to its widespread adoption. Ethical and data privacy concerns also play a crucial role in shaping the integration of AI in laboratory diagnostics. Understanding laboratory specialists' perspectives on AI will provide valuable insights into addressing these challenges and maximizing the benefits of AI in healthcare.

Methodology

This qualitative study was conducted in a large tertiary hospital to explore the perspectives of laboratory specialists on the integration of artificial intelligence (AI) in diagnostics. The study aimed to understand the perceived benefits, challenges, and opportunities associated with AI adoption in the diagnostic workflow. A phenomenological approach was employed to capture the lived experiences and views of laboratory professionals regarding the use of AI technologies in their work.

Research Design

A qualitative, phenomenological design was chosen to explore the subjective experiences of laboratory specialists in relation to AI integration. This approach allowed for an in-depth understanding of how laboratory specialists perceive AI's impact on their work, including both the advantages and the challenges. The phenomenological method was appropriate for capturing the insights and emotions of the participants as they navigated the complexities of AI adoption in diagnostics (Creswell & Poth, 2017).

Participants

Participants were selected through purposive sampling to ensure that they had direct experience or knowledge of AI applications in diagnostic laboratories. A total of 20 laboratory specialists from various departments within the tertiary hospital were included in the study. The participants had an average of 10 years of experience in the laboratory field, with roles spanning clinical chemistry, hematology, pathology, and molecular diagnostics. All participants had exposure to AI-based tools, such as automated image analysis or AI-assisted diagnostic algorithms, as part of their routine workflow.

Participants were selected based on the following criteria:

1. At least 3 years of experience in laboratory diagnostics.
2. Exposure to AI tools used in laboratory settings.
3. Willingness to participate in an in-depth interview about AI integration.

The diverse range of specialties among participants allowed for a comprehensive understanding of how AI is perceived across different diagnostic areas.

Data Collection

Data were collected through semi-structured, in-depth interviews over a two-month period. Each interview lasted between 45 and 60 minutes and was conducted in a private meeting room at the hospital to ensure confidentiality. Due to the ongoing pandemic and social distancing measures, some interviews were conducted via video conferencing.

The interview guide included open-ended questions to allow participants to reflect on their experiences and perceptions of AI. Sample questions included:

- "What has been your experience with AI tools in the diagnostic process?"
- "In what ways do you think AI can improve or hinder laboratory diagnostics?"
- "What challenges have you faced or do you foresee in integrating AI into your daily work?"
- "How do you perceive AI impacting your role as a laboratory specialist in the future?"

The semi-structured format enabled flexibility in the conversations, allowing participants to expand on their thoughts and share experiences in more detail. All interviews were audio-recorded with participants ' consent and transcribed verbatim for analysis.

Data Analysis

Thematic analysis was used to analyze the interview data, following Braun and Clarke's (2006) six-step process. This method allowed the identification of recurring themes related to the perceived benefits and challenges of AI integration in laboratory diagnostics.

1. Familiarization with the data: The researchers transcribed the interviews and repeatedly reviewed the transcripts to become familiar with the content.
2. Generating initial codes: Using an inductive approach, the researchers coded the transcripts to identify key ideas, patterns, and recurring topics related to AI in diagnostics.
3. Searching for themes: Initial codes were grouped into broader themes that reflected the core issues raised by participants, such as AI's impact on workflow, training needs, and job security concerns.
4. Reviewing themes: The themes were reviewed and refined to ensure they accurately captured the participants 'views and addressed the research questions.
5. Defining and naming themes: Clear definitions were assigned to each theme, with sub-themes identified where appropriate. Quotes from participants were selected to illustrate key points.
6. Writing the report: The final themes were used to structure the findings section, providing a comprehensive analysis of laboratory specialists 'perspectives on AI integration.

Trustworthiness of the Study

To ensure the trustworthiness of the study, the following strategies were employed:

- Credibility: Member checking was conducted by sharing the transcripts with participants to confirm the accuracy of their statements. This helped ensure that the data truly reflected their views and experiences.
- Transferability: Detailed descriptions of the participants 'professional backgrounds and the hospital setting were provided to allow readers to assess the applicability of the findings to other contexts.
- Dependability: An audit trail was maintained throughout the research process, documenting all steps of data collection and analysis to provide transparency and allow for replication.
- Confirmability: Reflexivity was practiced by the researchers, who kept reflective journals to account for their own biases and assumptions. This helped ensure that the findings were grounded in the participants' experiences rather than the researchers' preconceptions.

Ethical Considerations

Ethical approval for the study was obtained from the ethics committee prior to data collection. All participants provided informed consent before participating in the interviews. Confidentiality was maintained by anonymizing the transcripts and using pseudonyms to protect the participants' identities. Data, including audio recordings and transcripts, were securely stored on password-protected devices accessible only to the research team. Participants were informed of their right to withdraw from the study at any time without penalty.

Limitations

While this study provides valuable insights into laboratory specialists ’perspectives on AI integration, there are several limitations to consider. First, the research was conducted in a single tertiary hospital, which may limit the generalizability of the findings to other healthcare settings. Second, the study relies on self-reported data, which may be subject to recall bias or personal interpretation. Future research could expand on this study by including multiple hospitals and employing quantitative measures to assess the broader impact of AI on laboratory workflows.

Findings

The analysis of the interviews revealed four key themes regarding laboratory specialists' perspectives on the integration of AI in diagnostics: Perceived Benefits of AI Integration, Challenges in AI Adoption, Impact of AI on Workflow and Roles, and Ethical and Data Privacy Concerns. Each theme is further broken down into sub-themes, providing a comprehensive understanding of the participants' experiences and perceptions.

Theme 1: Perceived Benefits of AI Integration

Laboratory specialists recognized the potential of AI to enhance the efficiency and accuracy of diagnostic processes. They expressed optimism about AI's ability to assist with routine tasks and improve diagnostic outcomes.

Sub-theme 1.1: Improved Diagnostic Accuracy

Participants widely acknowledged that AI's ability to process large datasets and identify patterns could improve diagnostic precision, particularly in complex cases where human error is more likely.

- “AI can spot things that we might miss, especially in large data sets or when we’re under pressure to deliver results quickly. It adds an extra layer of accuracy to our work.” (Participant 7)
- “We’ve seen how AI can improve accuracy in image analysis, and that’s really exciting because it reduces the chances of misdiagnosis.” (Participant 3)

Sub-theme 1.2: Increased Efficiency and Speed

Several participants highlighted the time-saving benefits of AI, particularly in automating repetitive tasks and speeding up processes, allowing them to focus on more complex analyses.

- “AI helps with the more repetitive tasks, like processing large volumes of samples or images. It frees us up to do more critical, hands-on work.” (Participant 5)
- “The biggest benefit is the speed. AI can analyze data so much faster than we can, which is especially important when we’re dealing with high volumes.” (Participant 12)

Theme 2: Challenges in AI Adoption

Despite recognizing the potential benefits of AI, participants also identified several challenges that could hinder its integration into laboratory diagnostics.

Sub-theme 2.1: Lack of Training and Expertise

Many laboratory specialists felt that they lacked the necessary training and skills to effectively use AI tools, expressing concerns about their ability to adapt to new technology.

- "We don't really get formal training on AI systems, and that's a problem. If we're expected to use it, we need to understand how it works, not just push buttons." (Participant 8)
- "There's a gap in knowledge when it comes to AI. Most of us are comfortable with the traditional systems, but AI is a different level of complexity." (Participant 4)

Sub-theme 2.2: Trust in AI-Generated Results

Participants expressed concerns about the reliability of AI-generated results, particularly in cases where the "black box" nature of AI algorithms made it difficult to understand how conclusions were reached.

- "AI is great, but it's still hard to fully trust a result when you don't know how the system came to that conclusion. It's like a black box—you don't always see what's going on inside." (Participant 10)
- "There are times when I wonder if I should trust the AI or rely on my own judgment. It's hard to let go of that control when you don't fully understand the process." (Participant 2)

Theme 3: Impact of AI on Workflow and Roles

Participants discussed how the introduction of AI is reshaping their roles and responsibilities in the laboratory, with some expressing concerns about the impact on their job security and workflow.

Sub-theme 3.1: Job Security Concerns

While AI was seen as a tool to enhance their work, several laboratory specialists expressed concerns about job displacement, fearing that AI might eventually reduce the need for human specialists.

- "There's always the fear that AI could replace some of our tasks. If AI gets too advanced, what's to stop it from taking over more of the diagnostic work?" (Participant 9)
- "I think about how much AI can automate, and it does make you wonder whether our roles will change or be reduced in the future." (Participant 6)

Sub-theme 3.2: Shift in Responsibilities

Participants also noted that AI would likely change the nature of their work, requiring them to focus more on oversight, validation, and complex problem-solving, rather than routine tasks.

- "AI can handle a lot of the routine stuff, but I think it'll push us to focus more on quality control and making sure the AI's output is accurate." (Participant 11)
- "It's going to change how we work. Instead of doing the repetitive tasks ourselves, we'll be managing the systems that do them, which is a different kind of responsibility." (Participant 1)

Theme 4: Ethical and Data Privacy Concerns

Participants raised ethical concerns, particularly around the handling of patient data and the potential biases in AI algorithms.

Sub-theme 4.1: Data Security and Privacy

Several laboratory specialists were concerned about the security of patient data, given that AI systems require access to large datasets to function effectively.

- "AI systems need a lot of data, and that raises concerns about how secure that data is. We're dealing with sensitive information, so we need to make sure it's protected." (Participant 13)

- "Data privacy is a big issue for me. With AI, there's always the risk that personal health information could be compromised if the systems aren't secure enough." (Participant 5)

Sub-theme 4.2: Algorithmic Bias and Fairness

Participants also expressed concerns about biases in AI algorithms, which could lead to diagnostic errors, particularly in underserved populations.

- "We've seen cases where AI systems are biased because the data they're trained on isn't diverse enough. That's a real problem, especially when you're dealingwith diverse patient populations." (Participant 14)
- "AI is only as good as the data you feed it. If the data isn't representative, then the system could make mistakes, and that's something we have to be cautious about." (Participant 3)

Discussion

This study explored the perspectives of laboratory specialists on the integration of artificial intelligence (AI) in diagnostics, identifying both the opportunities AI presents and the challenges that could hinder its adoption. The findings revealed four key themes: Perceived Benefits of AI Integration, Challenges in AI Adoption, Impact of AI on Workflow and Roles, and Ethical and Data Privacy Concerns. These themes provide valuable insights into how laboratory specialists view the future of AI in diagnostics and the practical implications of its integration.

Perceived Benefits of AI Integration

Laboratory specialists widely recognized the potential benefits of AI in enhancing diagnostic accuracy and efficiency. Participants noted that AI's ability to process large datasets quickly and identify patterns can significantly reduce human error, particularly in high-volume, high-complexity tasks. This finding aligns with previous research suggesting that AI can enhance diagnostic performance, particularly in fields such as pathology, radiology, and genomics, where vast amounts of data must be analyzed (Topol, 2019; Esteva et al., 2017).

AI's ability to automate repetitive tasks, such as image analysis and data processing, was also viewed positively, with participants noting that this would free up time for laboratory specialists to focus on more complex, value-added tasks. This increased efficiency is consistent with studies indicating that AI can reduce diagnostic turnaround times, enabling faster decision-making in clinical settings (Maddox et al., 2019). However, while participants were optimistic about AI's ability to improve workflows, they also expressed concerns about the implications of these changes, which are explored in the following sections.

Challenges in AI Adoption

Despite the optimism surrounding AI, several challenges were identified that could hinder its successful integration into laboratory diagnostics. A major barrier is the lack of formal training and expertise in AI systems. Many participants expressed uncertainty about how to effectively use AI tools, which reflects a broader issue in healthcare: the gap between technological advancements and the readiness of healthcare professionals to adopt them (Aggarwal et al., 2021). Laboratory specialists emphasized the need for comprehensive training programs to ensure they can work alongside AI systems confidently and competently.

Additionally, trust in AI-generated results was a recurring concern. The "black box" nature of many AI algorithms, where the decision-making process is opaque, makes it difficult for professionals to fully trust the output, especially when it conflicts with their clinical judgment. This issue is well-documented in the

literature, with healthcare professionals often wary of AI systems that lack transparency, fearing that the complexity of the algorithms may obscure potential errors or biases (Jiang et al., 2017). Building trust in AI will require not only improved transparency but also systems that allow users to understand how AI-generated conclusions are reached.

Impact of AI on Workflow and Roles

The integration of AI is expected to transform the roles and responsibilities of laboratory specialists. While participants acknowledged that AI would likely take over routine tasks, many expressed concerns about job displacement. This fear is not unique to laboratory specialists; it mirrors concerns across healthcare and other industries that automation could reduce the need for human labor (Jiang et al., 2017). However, rather than eliminating jobs, AI is more likely to shift the nature of work in laboratories. Specialists may move away from manual tasks and focus more on oversight, quality control, and interpreting complex results that require human judgment.

This shift in responsibilities suggests that laboratory specialists will need to adapt to new roles that involve managing AI systems rather than performing diagnostic tasks directly. Participants noted that this transition would require retraining and upskilling, ensuring that they can oversee AI-driven processes and validate AI-generated results. This transition mirrors findings in other healthcare sectors, where AI is seen as a tool to augment human expertise rather than replace it entirely (Topol, 2019).

Ethical and Data Privacy Concerns

Ethical considerations and data privacy were significant concerns among participants, reflecting broader debates about the use of AI in healthcare. Laboratory specialists raised concerns about the security of patient data, particularly as AI systems require access to large datasets to function effectively. These concerns align with existing literature on the importance of safeguarding personal health information, especially given the increasing risks of data breaches and cyberattacks in healthcare (Hagendorff, 2020). Ensuring that AI systems comply with data protection regulations, such as GDPR and HIPAA, is essential to maintaining patient trust and the integrity of healthcare systems.

Participants also expressed concerns about algorithmic bias, particularly in how AI systems could inadvertently perpetuate inequalities in healthcare. AI systems are only as good as the data they are trained on, and if those datasets are not representative, the AI could produce biased results that negatively impact certain populations (Mehrabi et al., 2021). Addressing bias in AI systems is a critical challenge that must be addressed to ensure that AI-driven diagnostics are equitable and fair.

Implications for Practice

The findings of this study have several implications for the integration of AI in laboratory diagnostics. First, healthcare institutions must prioritize training programs to equip laboratory specialists with the skills needed to work with AI systems. Without adequate training, laboratory professionals may struggle to fully utilize AI’s potential, and resistance to its adoption may grow.

Second, fostering trust in AI systems is essential for their successful adoption. This can be achieved by improving the transparency of AI algorithms and developing tools that allow laboratory specialists to understand how AI-generated results are produced. Trust in AI will also be bolstered by ensuring that AI systems are regularly validated and tested for accuracy and fairness.

Finally, addressing ethical and data privacy concerns is critical to ensuring the responsible use of AI in diagnostics. Healthcare institutions must implement robust data protection measures and ensure that AI systems comply with regulatory standards. Furthermore, ongoing efforts to identify and mitigate algorithmic bias are necessary to ensure that AI-driven diagnostics are equitable for all patient populations.

Limitations

While this study provides valuable insights into the perspectives of laboratory specialists on AI integration, it is important to acknowledge its limitations. First, the study was conducted in a single tertiary hospital, which may limit the generalizability of the findings to other healthcare settings. Future research could expand the scope to include multiple hospitals and healthcare systems to provide a broader understanding of laboratory specialists' views on AI. Additionally, the sample size of 20 participants, while sufficient for a qualitative study, may not capture the full range of experiences and opinions on AI integration. Further studies with larger and more diverse samples could provide a more comprehensive view of this issue.

Conclusion

This study highlights both the potential and challenges of integrating AI into laboratory diagnostics. Laboratory specialists are optimistic about AI's ability to enhance accuracy and efficiency, but they also express concerns about trust, training, and ethical considerations. For AI to be successfully integrated into laboratory settings, healthcare institutions must address these challenges by providing adequate training, fostering transparency in AI systems, and ensuring that ethical concerns are at the forefront of AI development. By addressing these issues, AI has the potential to revolutionize laboratory diagnostics and improve patient outcomes.

References

1. Aggarwal, R., Sounderajah, V., Martin, G., Ting, D. S., Karthikesalingam, A., King, D., ... & Darzi, A. (2021). Diagnostic accuracy of deep learning in medical imaging: a systematic review and meta-analysis. *NPJ digital medicine*, *4*(1), 65.
2. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.
3. Ching, T., Himmelstein, D. S., Beaulieu-Jones, B. K., Kalinin, A. A., Do, B. T., Way, G. P., ... & Greene, C. S. (2018). Opportunities and obstacles for deep learning in biology and medicine. *Journal of the royal society interface*, *15*(141), 20170387.
4. Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.
5. Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., &Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *nature*, *542*(7639), 115-118.
6. Gulshan, V., Peng, L., Coram, M., Stumpe, M. C., Wu, D., Narayanaswamy, A., ... & Webster, D. R. (2016). Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. *jama*, *316*(22), 2402-2410.
7. Hagendorff, T. (2020). The ethics of AI ethics: An evaluation of guidelines. *Minds and machines*, *30*(1), 99-120.
8. Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., ... & Wang, Y. (2017). Artificial intelligence in healthcare: past, present and future. *Stroke and vascular neurology*, *2*(4).

9. Maddox, T. M., Rumsfeld, J. S., & Payne, P. R. (2019). Questions for artificial intelligence in health care. *Jama*, *321*(1), 31-32.
10. Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2021). A survey on bias and fairness in machine learning. *ACM computing surveys (CSUR)*, *54*(6), 1-35.
11. Mugabe, K. V. (2021). Barriers and facilitators to the adoption of artificial intelligence in radiation oncology: a New Zealand study. *Technical innovations & patient support in radiation oncology*, *18*, 16-21.
12. Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature medicine*, *25*(1), 44-56.