The Application of Artifical Intelligence in Breast Cancer Prevention and Early Detection

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***Abstract*—This paper discusses the technological aspects of Artificial Intelligence, Machine Learning, and Deep Learning, and the potential of their application in the early detection and prevention of breast cancer. To gain a complete overview of the potential utilization, the paper highlights the critical challenges in oncology care today through various stages of the patient journey – screening, diagnosis, staging, treatment planning, and therapy outcome prediction. The goal is to identify the bridge between the pain points of preventing and diagnosing breast cancer and the core functionalities of AI systems, such as detection, classification, characterization, and risk stratification. The research indicates that the impact of integrating AI in oncology care is significant and highlights the benefits of collaborative work between healthcare professionals and AI to achieve more precise diagnosis, evaluate the future risk with more certainty, screen more potential breast cancer patients in the same timeframe, and address healthcare communication problems.**

Keywords—Artificial intelligence, Oncology, Machine learning, Deep learning, Large language models, Medical imaging,

I. Artificial Intelligence, Machine learning, deep learning: fundamental concepts and terminological framework

Artificial Intelligence (AI) today not only simulates but, in specific ways, surpasses human cognitive abilities, which can be attributed to the fact that AI can process significant volumes of data in just a few time units [1]. The advancement in AI technologies can be explained by the progress made in Artificial Neural Networks (ANN) training, which are based on human brain neural networks [2]. Their role in data processing is to enable Machine Learning (ML) mathematical models to solve complex problems, enabling the computer system to learn from the existing database by recognizing patterns in the process of problem-solving without the need for additional programming efforts [3]. Therefore ANN allow the computer system to fulfil the demands of "intelligent" systems, such as humans, but in a more efficient timeframe [3]. ML unifies statistical methods, interpolation, and data mining methods not only to enable complex problem-solving but also to achieve optimization of the problem-solving process, making AI a relevant support in making data-driven decisions [3].

To grasp all the relevant technical concepts of an intelligent system that can successfully resemble human cognitive ability, needed for solving unstructured complex issues, Deep Learning methods must be mentioned, as a critical subsegment of ML. Unlike ML, DL uses Deep Neural Networks (DNN) and does not require human expert prework on database alterations and can independently make interpretations based on raw data [4]. DNN architecture consists of a sequence of hidden neuron layers that divide the input and output layers [2]. The ability of DL to solve almost any problem type known to humans, accounts for a more delicate and time-consuming training process [2]. However, it enables AI systems to perform critical functions, such as image classification and Natural Language Processing (NLP) [2].

DL methodology is the sole foundation of the application of AI in oncology, due to its capability to process large volumes of heterogeneous data, which may include images in different forms and sizes, different languages, natural speech, etc. [4]. In the context of healthcare system, an AI algorithm is trained by creating the viable connections between various inputs – different tissue samples, blood, radiological images (X-rays, MRIs, CT scans, Ultrasounds) – and corresponding labels such as "benign" or "malignant" under the supervision of specialized healthcare provider [4]. Healthcare data underlines the significance of context-dependent information and spatial orientation, which is successfully achieved through the integration of Convolutional Neural Network (CNN) models, despite their shortcomings in processing speed and simplicity [5].

As the goal of this paper is to give a further insight in the potential of AI technology applience in prevention and diagnostics of breast cancer, main AI concepts that will be explored in this paper are ML, DL, Computer Vision and Risk Prediction Models for supporting early diagnoses and interpretation of medical imaging results gatehred from screening methods and Large Language Models (LLM) and NLP for aiding pevention of breast cancer by providing health information to ley public and concerned individuals.

II. Emerging trends and the significance of LLM, ML, and DL application in oncology

Cancer is a pressing health issue on a global level, which is confirmed by the fact that every year, approximately half of newly diagnosed oncological patients lose the battle with the disease [6]. *Globocan* database recorded 8,084,971new cancer cases in 2022 in Europe with highest incidence in following therapeutic areas, respectively: breast cancer, prostate cancer, and colorectum cancer [7]. The burden of cancer is best grasped by reviewing severe mortality rates, that make cancer the second leading cause of death worldwide [8]. Concerning trajectory is also tangible on a local level. To be precise, Serbia is among second-highest group of countries in terms of cancer-related deaths with 41,578 new cases recorded in 2022, and 19,350 deaths in the same year caused by cancer [7], [9]. The leading cancer sites in both sexes, in terms of number of new cases and deaths were respectively: lung and bronchus, colorectal and breast cancer [9]. Accordingly, the focus of this paper will be on breast cancer, as malignant diseases in general entail a wide area of research.

Given the severity of the global burden of cancer, the application of new technologies is often the subject of research. The choice of technology model and its application vary according to the problem that needs to be addressed in the cancer patient journey. Therefore, understanding the challenges in diagnosing and treating cancer patients is the foundation of understanding the application of advanced technologies in oncology.

A. *Common Challenges in Achieving Better Statistics in Oncology Therapeutic Areas*

Above all, oncology is a multidisciplinary field characterized by the pressing need for continuous and effective communication between different healthcare provider subspecialists, which, in practice, poses a grand challenge [10]. Reducing omissions and other errors in communication results in higher satisfaction rates among healthcare providers and delivery of better care for cancer patients [11]. Achieving more efficient interdisciplinary communication is, in fact, a prerequisite for any potential advancement in diagnosing and treating malignant diseases [12].

The complexity and heterogeneity of healthcare systems are followed by equally complex and heterogeneous data, which originates from different screening, diagnostic, and therapeutic procedures [13]. The data in question, characterized by different origin sources, different formats, and no given structure, implicates significant challenges in the process of analyzing and transforming raw data into insights and actionable knowledge [13].

A significant obstacle in achieving lower mortality rates of oncological patients, globally, is that cancer is commonly diagnosed in advanced phases [12]. Nevertheless, early detection of malignant diseases can significantly influence the course and outcome of the treatment, open the possibility of treating precancerous lesions, and therefore impact the reduction of mortality rates on a global scale [12]. To further highlight the importance of early diagnoses – if lung cancer is diagnosed in the first stage the five-year survival rate is 75%, but if diagnosed in the fourth stage the same rate drops to less than 5% [14], implicating that achieving more efficient national screening programs is the key matter to be addressed.

The financial burden of treating cancer patients is yet another challenge with a wide area for improvement and potential for innovation. The yearly cost of treating cancer patients in the USA in 2015 was 183 billion dollars, with the prognosis that this cost has the potential to rise to 246 billion dollars by 2030 [15].

B. *Domains of AI Technology Application in Healthcare*

The application of AI in healthcare entails engineering support systems for healthcare providers to aid and optimize diagnostic processes, course of therapy formulation, and risk and therapy outcome prediction [16]. The integration of ANN in the diagnostic and therapeutic procedures is the core pillar of such systems, allowing the system to play a crucial role in medical imaging, setting diagnosis, error reduction, determining therapy course, and decision-making support, as an intelligent virtual assistant [17]. Therefore, the areas of AI technology application in healthcare today can be summarized as follows:

- Medical imaging and radiology (AI system has the role in processing X-rays, CT scans, MRIs, and Ultrasounds),
- Clinical trials (AI system has proven helpful in optimizing the process of patent selection for studies, in achieving better efficiency in monitoring, and in timelier data processing),
- Electronic data management,
- Diagnosis and data-driven decision making,
- Personalized medicine,
- Risk assessment,
- Drug development,
- Surgery,
- Telemedicine and virtual health assistants,
- Patient monitoring [17].

C. *Common AI System Functionalities in Different Steps of Cancer Patients' Journey*

Today, AI has found its role in every step of the cancer patient journey from prevention, diagnosis, staging, setting the course of therapy, hospital and post-hospital care, and monitoring [18]. The utilization of AI in the initial stages of the cancer patient journey is reflected through the following functionalities: decision-making automation, therapy outcome prediction, further analysis requirement assessment, result interpretation, and patient triage [18]. Deploying these AI functionalities in cancer patient care throughout the patient journey increases accuracy and overall reduces care time [18].

D. *Impact of AI Deployment in Medical Imaging*

Medicine today poses a significant need for high precision medical imaging analysis along the patient journey [5]. Substantial visual complexity of medical imaging outputs, such as those obtained through whole slide imaging methods, proceeds not only from large image sizes, but also from the necessity to examine different tissue coloration, tissue thickness at varying magnifications, and to examine images with no anatomic positioning context [19]. Examining medical imaging results is often the initial step of detection and diagnosing breast cancer [19]. Healthcare systems everywhere generate this type of data in large volumes, making their processing and examination challenging due to the lack of pathologists and radiologists, which implies the need for AI support in detecting the patterns in the data and providing interpretation of medical images [4]. The main obstacle to this integration could be that AI systems demand structured and formatted databases and require assigned contextual meaning to the process, implicating a continuous need for healthcare expert support in delivering optimal AI output [4]. Nevertheless, as DL methods facilitate the automation of raw data transformation, eliminating the need for a healthcare expert resource, AI technology can successfully support processing and interpretation of the data coming from medical imaging methods [4], which is proven by the fact that today, numerous healthcare systems on a global scale use already established AI software with this purpose.

The specific functionalities performed by AI systems in the domain of medical imaging analysis can be described as follows:

Detection - refers to the ability of an AI system to recognize different elements and patterns in an image [13]. In practice, this functionality is most commonly deployed for the identification of precancerous and cancerous lesions [13].

Classification - After detection, AI systems can support healthcare professionals in accurately classifying identified lesions [13]. In practice, this functionality is often deployed for mammogram analysis in breast cancer screening.

Characterisation - Detecting patterns and deviations within data that are not necessarily visible to the human eye is one of the key benefits AI systems bring to diagnosing breast cancer, especially when characterisation is in question [13]. The term characterisation refers to the interpretation of radiological and pathological findings:

Radiomics - computer analysis, based on high data extraction methods in quantitative imaging, of radiological findings that provides extensive insights about the tumor's biological composition, risk stratification, and response to therapy [20]. Quantitative imaging in radiology is an automated process of assigning numerical values to the existing changes in biomarkers, which allows seamless integration with predictive models for diagnosis and staging [21].

Pathomics - refers to the digital tissue sample analysis, or, to be more precise, pathomics is a digital approach to tissue phenotyping that enables the transformation of an extensive unstructured database to actionable knowledge by assigning quantitative values to various tissue segments and cells, therefore building a structured, machine-processable database [10]. Deployment of DL methods in phatomics enables a computer system to analyse tissue data on a pixel level [10].

Monitoring - AI can assist in monitoring, optimizing, and even predicting therapy outcomes, thanks to its ability to detect a range of discriminative features while examining medical inputs [13].

Today, many AI software solutions on the market actively assist medical personnel in meeting the demands of analysis and interpretation of data obtained by medical imaging methods. While software solutions vary across different oncological therapeutic areas, it is evident that AI solutions are most extensively utilized in screening and diagnostic processes for lung and breast cancer, likely due to the significant role medical imaging plays in these therapeutic areas. The research identified a rising trend in the development of AI algorithms for support in screening and diagnosing breast cancer that are approved by the FDA and European Commission and are widely used across hospitals, such as MiaIQ, developed by the English company *Kheiron Medical Technologies*, or MammoScreen, created by the French company *Therapixel*. The evaluation of MammoScreen software, conducted to measure the impact of specialized AI algorithm usage on radiologists' performance, indicated that the combined effort of radiologists and AI solution can decrease the number of falsely negative results and impact the general success of radiologists' work [22]. Other than mentioned, the research identifies various companies like *Predilife*, *Deep Health*, and *Ibex Medical Analytics* with innovative platforms developed to help pathologists and radiologists be more efficient during the screening and early detection of breast cancer.

III. The Potential of Generative Artificial Intelligence Models for Breast Cancer Patients' Support

Large Language Models (LLMs) based on NLP models are raising significant attention on a global scale, likely due to the wide range of their deployment across various industries [23]. NLP models have proven successful in analyzing human speech input, whether in written or spoken form, interpreting its meaning and providing outputs in the form of text generation, image generation, code generation, language-to-language translation, and others [4]. Generally, generative AI models are trained on massive public datasets or specialized datasets provided by interested parties [23]. The quality of their output is a continuous matter of improvement processes, which often require deployment of reinforcement learning techniques, giving expert inputs a crucial role in the training process [23]. Amongst the most recognized and widely deployed LLM models are ChatGPT by *OpenAI* and Google Gemini [23].

A. *ChatGPT's potential in providing support for breast cancer patients*

When faced with a diagnosis, breast cancer suspicion, or just a need to learn more about the disease, Internet search of available information is often the first point of reference. Accordingly, Miles et al. evaluated available content for relevant keywords related to three malignant diseases, eight types of benign breast lesions, and other popular search terms in breast cancer treatment. The conclusion implied that, although various educational materials are accessible online, understanding and interpreting them requires a certain level of medical literacy, leaving an average patient confused and misinformed [24].

The potential of ChatGPT deployment in providing necessary support to patients diagnosed with breast cancer can be viewed through the lens of the following dimensions:

Provision of required information on breast cancer prevention and early detection - In March and August of 2023, Haver et al. examined the suitability of the ChatGPT model as a tool for providing breast cancer screening and prevention information. Output quality was tested via two variables: clarity and readability. Study findings implicated that 92% of the provided responses were clinically acceptable, while 100% of the generated output met the clarity demands [25]. Suggesting that the ChatGPT model is suitable for providing information on breast cancer screening and prevention topics to the general public, although expert oversight remains a necessity [25].

Education on breast cancer therapy - The study conducted in July of 2023, found that 24% of total responses generated on topic of breast cancer therapy was clinically inaccurate and in 41% of total cases, sources were not provided [26], highlighting the fact that the role of ChatGPT in educating patients on breast cancer therapy options remains unclear. Additionally, patients ought to be cautioned against relying solely on information generated by ChatGPT on this topic [26]. Another study, founded on the same premise, implicated that the ChatGPT model can generate medically acceptable responses regarding radiotherapy and identified the area for improvement in meeting readability and comprehensibility demands, highlighting the need for substantial expert training of the model [27].

Post-surgery ultrasound interpretation support - In 2023, Liu et al. examined the ChatGPT model's ability to interpret breast ultrasound reports. The study identified the model's potential for generating structured reports and treatment management recommendations [28]. Nevertheless, the model's performance in characterization of benign and malignant changes had an AUC (Area Under the Receiver Operating Characteristic Curve, metric used for assessing the quality of binary classification model) of 0.9317, compared to 0.9763 AUC achieved by an experienced radiologist [28]. Accordingly, the ChatGPT model cannot be considered an independent ultrasound interpretation tool, but it holds potential as a support tool for radiologists.

Clinical decision-making support - Premise that ChatGPT can support multidisciplinary breast cancer tumor boards in decision-making was investigated in the study conducted by Sorin et al., which included ten patients with various breast cancer diagnoses. A study found that in seven out of ten cases, therapy course recommendations generated by ChatGPT were closely aligned with those of the tumor board [29]. Specialists rated the performance of the model with a grade of 4.2 out of 5, taking into consideration the recommendation provided by the model, quality of the summary and argumentation, implicating a significant potential of ChatGPT's model deployment in one of the critical phases of cancer care: treatment planning [29]. Nevertheless, further studies with higher sample volumes and advanced prompt engineering are required to fulfill this potential and secure consistency in output quality [27], [29].

IV. Benefits and Challenges of AI Utilization in Prevention and Early Detection of Breast Cancer

As discussed in previous chapters, utilizing AI models in oncology has the potential to address critical challenges in the successful prevention and early detection of malignant diseases.

Key benefits of this utilization can be summarized as follows:

- AI solutions can help achieve more financially efficient national screening programs and positively impact achieving more early diagnosis [13].
- They can help reduce frustration and additional cost caused by unnecessary repetition of medical tests and analyses, reducing patients' unnecessary exposure to invasive methods such as biopsies and MRI radiation.
- Utilization of DL models can optimize the process of identifying and characterizing lesions, providing a high-precision risk of cancer development prediction [13].
- AI models can help radiologists and pathologists perform their tasks more efficiently, addressing the issue of healthcare workforce shortages [22].
- Integrating AI in Electronic Health Record databases opens the possibility for implementing personalized screening programs [13].
- Reducing errors through healthcare workflow optimization enables better communication between different specialists [11].
- AI solutions can impact error reduction by decreasing false-negative results from 35% to 5% (low-risk tumors) and false-positive results from 53% to 6% (high-risk tumors) [13].
- With their ability to process large data volumes, DL methods can positively impact decision-making, optimization, and increased diagnostic accuracy [1].
- AI models have the potential to substitute genetic procedures for tissue molecule analysis, address immunotherapy access challenges, and assist in the identification of at-risk families [13].

Nevertheless, there are still significant challenges to AI implementation in oncology, which can be summarized as follows:

- Hallucinations, inconsistency, and unreliability of AI-generated outputs [26].
- The AI training process requires substantial, high-demand expert resources [2].

Ethical implications must be taken into consideration when talking about making AI solutions an integral part of the prevention and early detection of breast cancer:

- Insufficient diversity in training datasets prevents equal access to AI healthcare solutions for different ethnic groups and can imply bias in the algorithm [18].
- The lack of a legal and regulatory framework [30].
- Data protection and cybersecurity challenges. Integration of AI into healthcare systems may compromise patient privacy [18].
- Challenges in maintaining transparent process of initiating AI tools in patient journey, making patients fully aware of what are they consenting to [30].
- Defining the difference in role and responsibilities for both AI solutions and physicians [30].

V. Review of Key EU Initiatives on AI for Breast Cancer Prevention and Early Detection

Addressing the burden of cancer has been on the radar of the European Commission for a long time. Their strategy to address alarming statistics in cancer is represented through the EU Cancer Mission, and Europe’s

Beating Cancer Plan, an embodiment of a political commitment to proactively fight and prevent cancer with a total funding of €4 billion. EU efforts to turn numbers in cancer imply a significant volume of initiatives launched in previous years. One of them is the European Commission Initiative on Breast Cancer (ECIBC), which aids healthcare providers and patients across Europe. To support the level of quality care development, ECIBC issued the Quality Assurance (QA) Scheme for Breast Cancer, designed to offer guidelines and service requirements for the entire breast cancer pathway. Although AI platforms still have not found their role and place in this type of standardized QA guidelines, the use of AI solutions is defined in European guidelines on breast cancer screening and diagnosis. Guidelines recommend that AI be used to support double reading in mammography screening processes [31]. Justification of this recommendation entails that with the support of AI, one more breast cancer will be detected in every 1,000 screening cases [31]. Also, a significant EU-funded project, REBECAA, was established to enhance post-treatment care for breast cancer patients. By leveraging real-world data, including clinical records, online consumer behavior, wearables, and other national patient-related datasets, it aims to unlock a deeper understanding of chronic comorbidities in breast cancer [32]. REBECCA 360, the project's output platform based on DL technology, enables preservation of privacy, cross-country data analysis, and is intended for shaping the future of European guidelines for integrating AI solutions in breast cancer patients' journey [32]

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VI. Conclusion

A growing number of companies on the global market with the core business of developing AI healthcare solutions specialized for oncology therapeutic areas highlight the increasing need for AI utilization in this field. This trend is driven by the numerous benefits this technology has on cancer patient care. Existing solutions include functionalities for risk prediction and classification, analyzing medical imaging reports, optimization of workflow for pathologists and other oncology healthcare professionals, and patient triage. However, existing solutions have not yet proven entirely independent. The research implicated that the highest diagnostic success and precision are achieved with the collaborative work of healthcare professionals and AI models [22].

Further development of AI healthcare solutions in oncology should focus on achieving greater consistency and reliability, which would imply a higher level of autonomy in meeting the demands of prevention and early detection of breast cancer. This development will ensure further reduction in repetitive and administrative burden on healthcare specialists in oncology.

Another course of development in AI models' utilization in oncology is the development of LLM models for patent support, education, and communication tools, purpose-built for patient-healthcare system communication. Research implies that currently available online educational material does not meet the demands of readability, clarity, and personalization. On the other hand, LLM models, such as ChatGPT, are not proven adequate for providing clinically reliable and consistent information. Accordingly, further research should follow the course of prompt engineering, expert and relevant data inclusion in model training.

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