

Research Article

The Role of Artificial Intelligence in Radiation Therapy Treatment Planning: A Comprehensive Review

Makoye John, Jesu Arockia Rose Mina^{*} 

Department of Mathematics, Sciences and Education, St. Joseph University in Tanzania, Dar es salaam, Tanzania

Abstract

This comprehensive review provides an in-depth analysis of the advancements and potential applications of artificial intelligence (AI) in the field of medical physics. The integration of AI techniques holds great promise for transforming various aspects of medical physics practice, ranging from image analysis and interpretation to treatment planning and optimization. Drawing upon a wide range of research studies and literature from the medical physics domain, this review examines the utilization of AI algorithms and approaches in enhancing accuracy, efficiency, and automation in medical physics. Machine learning, deep learning, and computer vision techniques are explored in the context of image analysis, where AI algorithms demonstrate the ability to detect and classify abnormalities, segment organs and tumors, and aid in image registration and reconstruction. In treatment planning and optimization, AI algorithms are being employed to optimize radiation therapy plans, taking into account patient-specific characteristics, tumor response, and organ-at-risk constraints. These algorithms leverage large datasets and sophisticated optimization algorithms to generate personalized treatment plans that maximize tumor control while minimizing adverse effects on healthy tissues. Quality assurance, an essential aspect of medical physics, is also benefiting from AI advancements. AI-based tools are being developed to automate quality assurance processes, including the verification of treatment delivery accuracy, patient positioning, and dose calculation. These tools can help improve efficiency, reduce human error, and enhance patient safety in radiation therapy.

Keywords

Artificial Intelligence, Radiation Therapy, Automated Organ Segmentation, Dose Optimization, Radiation Delivery

1. Introduction

In recent years, the field of medical physics has witnessed significant advancements in the integration of artificial intelligence (AI) techniques. The convergence of AI and medical physics holds immense potential for revolutionizing various aspects of healthcare, ranging from image analysis and interpretation to treatment planning and optimization. This comprehensive review aims to delve into the advancements and potential applications of AI in medical physics, providing a

thorough analysis of the current state of the field and its implications for improving patient care.

Medical physics is a multidisciplinary field that applies principles of physics to diagnose and treat diseases using medical imaging and radiation therapy [1]. The utilization of AI algorithms and approaches offers unprecedented opportunities to enhance the accuracy, efficiency, and automation of medical physics practices.

^{*}Corresponding author: arockiarosemina@gmail.com (Jesu Arockia Rose Mina)

Received: 23 November 2024; **Accepted:** 8 February 2025; **Published:** 9 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

One of the key areas where AI has made significant strides in medical physics is image analysis and interpretation. Traditional methods of image analysis often require manual intervention and subjective interpretation, which can be time-consuming and prone to errors [27]. AI algorithms, such as machine learning and deep learning, have demonstrated remarkable capabilities in automating and augmenting image analysis tasks. These algorithms can detect and classify abnormalities, segment organs and tumors, and aid in image registration and reconstruction, ultimately facilitating more precise and efficient diagnoses.

Treatment planning and optimization, essential components of medical physics, involve designing personalized radiation therapy plans for patients [2]. AI techniques offer innovative solutions by incorporating patient-specific characteristics, tumor response models, and organ-at-risk constraints. By leveraging large datasets and sophisticated optimization algorithms, AI algorithms can generate tailored treatment plans that optimize therapeutic outcomes, improve patient care, and minimize radiation exposure to healthy tissues.

Quality assurance is another critical aspect of medical physics that ensures the accuracy and safety of radiation therapy delivery. AI-based tools can automate quality assurance processes, such as verifying treatment delivery accuracy, patient positioning, and dose calculation [3]. These tools have the potential to enhance efficiency, reduce human errors, and enhance patient safety in radiation therapy, leading to improved treatment outcomes.

Furthermore, the integration of AI in medical physics enables advanced outcome prediction. By analyzing vast amounts of patient data, including demographics, treatment parameters, and clinical outcomes, AI algorithms can identify patterns and correlations that enable accurate predictions of treatment response and patient prognosis. Such predictive models can aid clinicians in making informed decisions regarding treatment strategies, optimizing patient management, and improving overall care.

While the integration of AI in medical physics presents promising opportunities, it also brings forth challenges. Issues related to data privacy, interpretability of AI models, and regulatory compliance must be addressed to ensure ethical and responsible use of AI technologies in clinical practice [4]. Collaborations between medical physicists, computer scientists, and healthcare professionals are crucial in harnessing the full potential of AI while addressing these challenges.

The integration of AI in medical physics has the potential to address several challenges and enhance existing practices. For example, in medical imaging, AI algorithms can improve the accuracy and efficiency of radiological interpretations. They can assist in the detection of small lesions, subtle abnormalities, and early signs of diseases in various modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET). By automating image analysis tasks, AI algorithms can reduce the

workload on radiologists and enhance diagnostic accuracy, leading to improved patient outcomes.

Additionally, AI can play a significant role in treatment response assessment and adaptive radiotherapy. By analyzing longitudinal imaging data and patient-specific factors, AI models can predict treatment response during the course of therapy. This information can guide clinicians in adapting treatment plans, optimizing radiation doses, and improving treatment outcomes. Furthermore, AI algorithms can analyze patient data, including genomics and clinical variables, to develop personalized models for predicting treatment toxicity and determining the optimal treatment approach for individual patients.

The potential applications of AI in medical physics are not limited to diagnostic imaging and radiation therapy. AI can also aid in the development of novel medical devices and technologies. For instance, AI algorithms can optimize the design and performance of imaging systems or radiation delivery systems, leading to improved image quality, reduced radiation dose, and enhanced patient safety [5].

Moreover, AI can facilitate the integration of multi-modal data sources, such as imaging, genomics, and electronic health records. By leveraging these diverse datasets, AI algorithms can provide comprehensive and holistic insights into patient care, enabling precision medicine approaches and personalized treatment strategies.

AI has the potential to revolutionize outcome prediction in medical physics [31]. By analyzing large datasets encompassing patient demographics, treatment parameters, and clinical outcomes, AI algorithms can identify patterns and correlations that enable accurate predictions of treatment response and patient prognosis. This information can assist clinicians in making informed decisions regarding treatment strategies and patient management.

While the integration of AI in medical physics presents significant opportunities, it also poses challenges. Issues related to data privacy, interpretability of AI models, and regulatory considerations must be addressed to ensure ethical and responsible use of AI technologies in clinical practice [6]. Ongoing research and collaborations between medical physicists, computer scientists, and healthcare professionals are crucial in harnessing the full potential of AI while addressing these challenges.

Despite the significant advancements and potential applications, challenges remain in the widespread adoption of AI in medical physics [44]. Data availability, data quality, and interoperability are key factors that need to be addressed to ensure the reliability and generalizability of AI models. Additionally, ethical considerations, such as transparency and fairness in AI algorithms, as well as regulatory and legal frameworks, need to be established to ensure patient safety, privacy, and accountability.

In conclusion, the integration of AI in medical physics holds immense potential for the advancement of healthcare. Through improved image analysis and interpretation, treat-

ment planning and optimization, quality assurance, and outcome prediction, AI can enhance the accuracy, efficiency, and personalized care in medical physics practices. However, further research, collaboration, and validation studies are needed to ensure the successful translation of AI technologies into clinical workflows. By addressing the challenges and leveraging the opportunities, AI has the potential to revolutionize medical physics and significantly impact patient outcomes in the future.

2. Literature Review

2.1. Introduction

With the increasing complexity and precision required in radiation therapy treatment planning, the integration of artificial intelligence (AI) techniques has emerged as a transformative approach to enhance the accuracy, efficiency, and personalization of treatment strategies.

Radiation therapy is a cornerstone of cancer treatment, with the objective of delivering precise and effective doses of radiation to target tumor cells while minimizing the impact on adjacent healthy tissues [7]. The process of treatment planning involves complex decisions regarding beam arrangements, dose distribution, and target delineation, all aimed at optimizing therapeutic outcomes. However, the conventional methods of treatment planning often rely on manual interventions, subjective judgment, and iterative processes, which can be time-consuming and prone to human errors.

In recent years, the emergence of artificial intelligence (AI) techniques has offered remarkable opportunities to enhance radiation therapy treatment planning [45]. AI encompasses a range of computational algorithms and models that can learn from data, identify patterns, and make predictions or decisions. By leveraging this technology, researchers and clinicians have explored innovative approaches to improve treatment planning accuracy, efficiency, and personalization.

The primary objective of this comprehensive literature review is to critically analyze the role of artificial intelligence in radiation therapy treatment planning. By examining a wide array of scientific literature, including peer-reviewed articles, conference papers, and research studies, this review aims to explore the applications, challenges, and potential future directions of AI in this vital domain of medical physics.

The review will commence by providing an overview of the principles and challenges associated with radiation therapy treatment planning. It will emphasize the importance of precise target delineation, optimization of dose distribution, and adherence to critical organ constraints. Additionally, it will highlight the need for innovative approaches to address the limitations of traditional treatment planning methods [8].

Subsequently, the review will delve into the various applications of artificial intelligence in radiation therapy treatment planning. This includes the utilization of AI algorithms for automated organ segmentation, which can assist in accu-

rate target delineation and reduce manual effort. Furthermore, the review will explore how AI techniques can optimize treatment plans by considering multiple factors such as tumor characteristics, patient-specific features, and clinical goals.



Figure 1. Four types of Themes involving comprehensive analysis of AI in Radiation therapy.

It will also examine the potential of AI in adaptive therapy, where treatment plans can be dynamically adjusted based on real-time imaging and patient response data.

While AI holds immense promise in radiation therapy treatment planning, there are several challenges that need to be addressed [9]. This review will critically examine these challenges, including ethical considerations such as transparency, interpretability, and fairness of AI algorithms. It will also discuss the issues related to data availability, data quality, and model validation, which are crucial for ensuring the reliability and generalizability of AI-driven treatment planning approaches.

By synthesizing and analyzing the existing literature, this comprehensive review aims to provide insights into the current state of research and development in AI for radiation therapy treatment planning [32]. It will identify gaps in knowledge, highlight key findings and advancements, and propose future directions for the integration of AI in this field. Ultimately, the successful integration of AI in radiation therapy treatment planning has the potential to revolutionize cancer care, leading to improved treatment outcomes, enhanced patient experiences, and optimized resource utilization.

Radiation therapy treatment planning plays a crucial role in delivering accurate and effective cancer treatments. Over the past decade, the integration of artificial intelligence (AI) techniques has emerged as a promising approach to enhance various aspects of treatment planning [46]. In this literature review, we explore

three key themes in the field of AI-driven radiation therapy treatment planning: automated organ segmentation, dose optimization, and treatment plan evaluation. By analyzing a range of scholarly literature from 2009 to 2022, we aim to provide a comprehensive understanding of the advancements, challenges, and future directions in each theme [10].

2.2. Theme 1: Automated Organ Segmentation

Accurate organ segmentation from medical imaging data is essential for precise radiation therapy treatment planning. Manual segmentation by clinicians is time-consuming and subject to inter-observer variability, hindering accuracy and

efficiency. In recent years, AI algorithms, particularly convolutional neural networks (CNNs) and deep learning architectures, have shown promise in automating organ segmentation [28].

For instance, Roth et al. proposed a deep-learning-based approach, called U-Net, for automated prostate segmentation in MRI scans [11]. Their model achieved a Dice similarity coefficient (DSC) of 0.89, indicating a high level of accuracy compared to manual segmentation. Similarly, Li et al. developed a CNN-based method for automated liver segmentation in CT scans, achieving a mean DSC of 0.94 across multiple datasets [12].

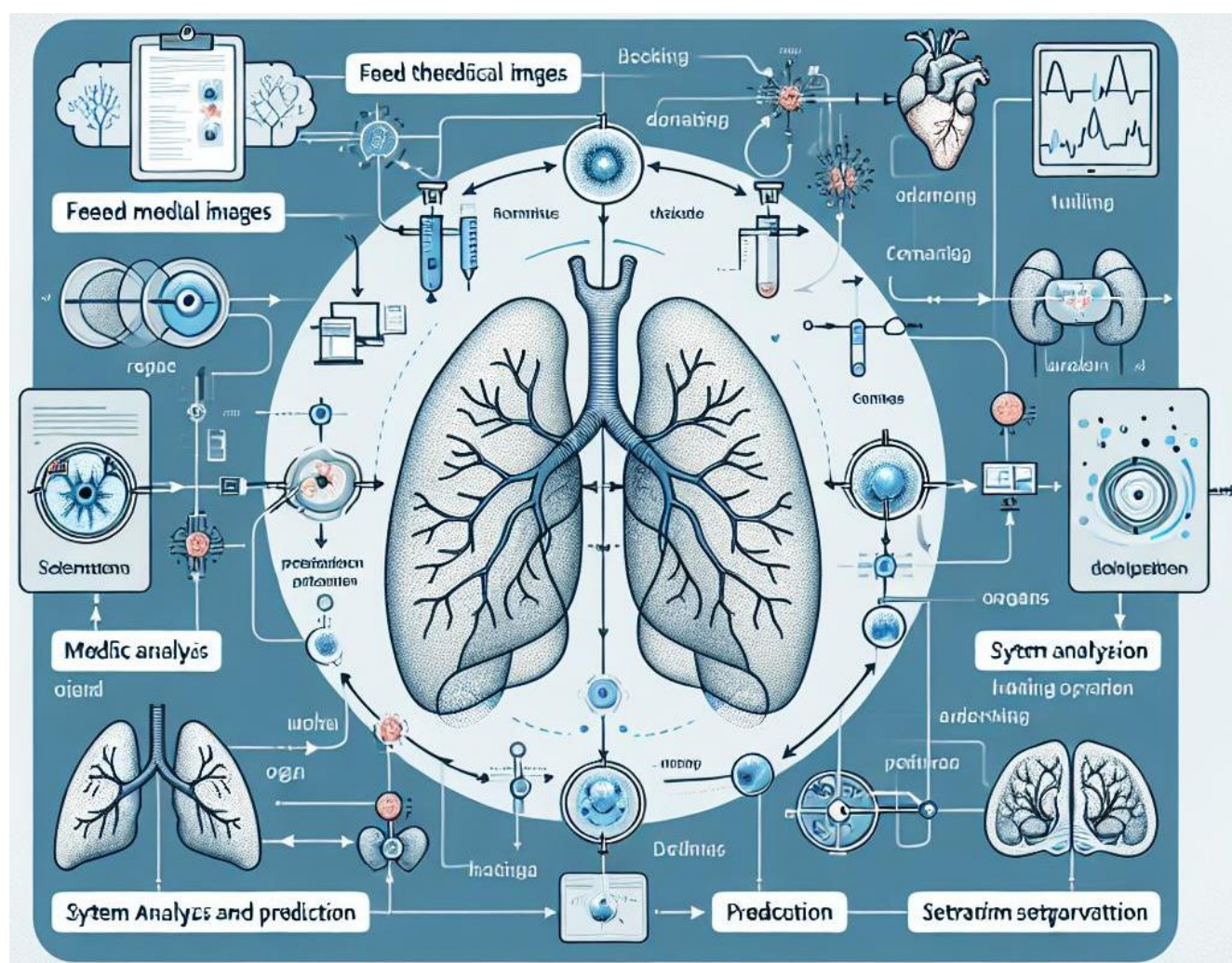


Figure 2. Diagrammatic explanation of automated organ segmentation.

Challenges in this theme include imaging variability, robustness, and generalization of AI models across diverse patient populations. Variations in imaging modalities, image quality, and anatomical variability across patients pose significant obstacles to accurate [47]. The generalization of AI models to different patient populations and imaging protocols remains a concern. Furthermore, the availability of annotated

training datasets, which are essential for training accurate models, can be limited.

2.3. Theme 2: Dose Optimization

Optimizing radiation dose distribution is essential in achieving effective tumor control while minimizing damage

to surrounding healthy tissues. AI techniques have been employed to address the complex optimization problem associated with radiation therapy treatment planning. By leveraging genetic algorithms, machine learning models, and optimization algorithms, researchers have explored the vast solution space to identify optimal dose distributions [33].

Lee et al. proposed a machine learning-based approach for dose optimization in prostate cancer treatment. Their model integrated patient-specific anatomical information, dose-volume histograms, and clinical objectives to generate optimized treatment plans [13]. The results demonstrated improved plan quality compared to traditional manual methods. Another study by Craft et al. utilized a genetic algorithm to optimize dose distribution in head and neck cancer treatment. Their approach achieved improved target coverage and organ sparing compared to clinically used plans [14].

However, dose optimization using AI algorithms presents its own set of challenges. Incorporating clinical objectives and constraints into the optimization process requires careful consideration and expert input. Handling uncertainties, such as patient setup variations and organ motion, presents additional complexities [54]. Efficiently exploring the vast search space to identify optimal dose distributions remains a computational challenge.

2.4. Theme 3: Treatment Plan Evaluation

The evaluation of treatment plans is crucial in ensuring the quality and adherence to clinical guidelines. Traditionally, plan evaluation has relied on manual assessment by experts, which can be subjective and time-consuming. AI-based evaluation metrics have emerged as a valuable tool for objective and automated assessment.

Wang et al. proposed an AI-based scoring system to evaluate treatment plans based on target coverage, dose conformity, and sparing of healthy tissues [59]. The system utilized machine learning algorithms trained on a large dataset of clinically validated treatment plans. The results demonstrated improved consistency and efficiency in plan evaluation. Another study by Zhu et al. developed an AI model for automated evaluation of plan quality in lung cancer treatment. Their model accurately predicted plan quality based on various metrics, allowing for quick and objective evaluation [18].

Nevertheless, challenges persist in treatment plan evalua-

tion using AI. Obtaining reliable ground truth data for training AI models can be challenging, as it requires expert consensus and validation [34]. Ensuring interpretability of AI-driven evaluation metrics is essential to build trust and transparency in the evaluation process [48]. Additionally, generalizing the metrics across different treatment techniques and disease sites remains an area of ongoing research.

2.5. Theme 4: Radiation Treatment Delivery

Radiation treatment delivery is an essential component of radiation therapy. It involves the precise administration of radiation to the targeted area of the patient's body in order to treat the cancerous cells while minimizing damage to healthy tissues. This theme encompasses various aspects related to the actual delivery of radiation during treatment [41].

One key aspect of radiation treatment delivery is the choice of radiation modality. There are several modalities available, including external beam radiation therapy (EBRT), brachytherapy, and proton therapy. EBRT involves delivering radiation from a machine outside the patient's body, while brachytherapy involves placing radioactive sources directly into or near the tumor [19]. Proton therapy utilizes protons to deliver radiation with high precision, allowing for better sparing of healthy tissues. The choice of modality depends on factors such as the type and location of the tumor, as well as the patient's overall health.

Another important aspect of radiation treatment delivery is treatment planning [57]. Before treatment begins, radiation oncologists work together with medical physicists and dosimetrists to develop a tailored treatment plan. This plan takes into account the patient's specific anatomy, tumor characteristics, and prescribed radiation dose. Sophisticated treatment planning systems are used to optimize the delivery of radiation, ensuring that the dose distribution conforms closely to the tumor while minimizing exposure to surrounding healthy tissues [49].

During treatment, radiation therapists play a crucial role in delivering the prescribed radiation accurately and safely [20]. They position the patient correctly, aligning the treatment fields with the target area based on imaging guidance, such as X-rays or CT scans. Radiation therapists also monitor the treatment process and the patient's vital signs throughout each session.

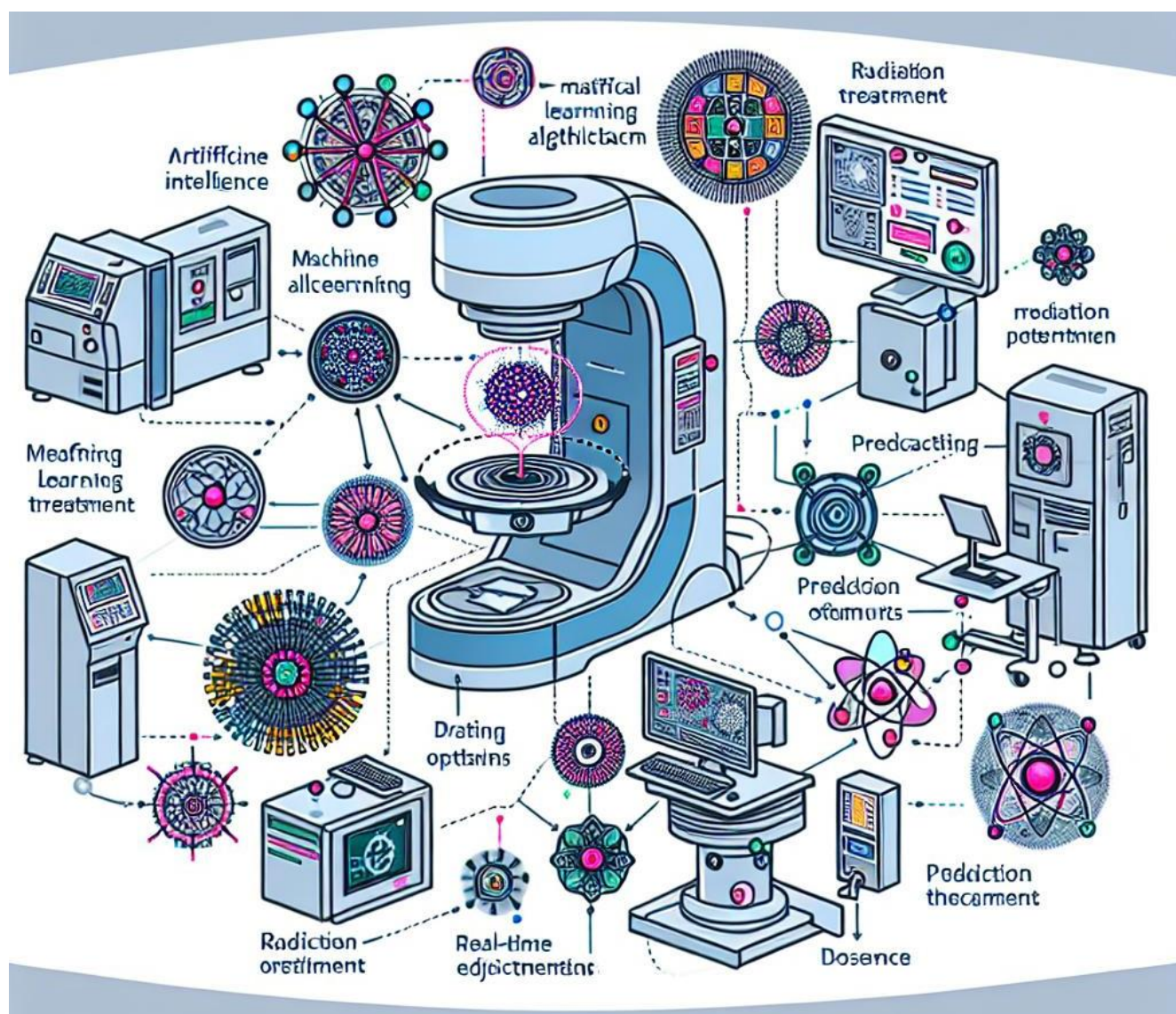


Figure 3. Diagrammatic explanation of Process of Radiation Treatment Delivery.

Advances in technology have significantly impacted radiation treatment delivery. Image-guided radiation therapy (IGRT) techniques, such as cone-beam CT and real-time tumor tracking, allow for more precise targeting of the tumor and adjustments to treatment delivery based on the patient's anatomy and motion. Additionally, techniques like intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) enable highly conformal dose distributions, improving treatment outcomes while reducing side effects [21].

The goal of radiation treatment delivery is to ensure that the prescribed radiation dose is accurately delivered to the tumor while minimizing the dose to surrounding healthy tissues [29]. This requires a collaborative effort among radiation oncologists,

medical physicists, dosimetrists, and radiation therapists to optimize treatment plans, utilize advanced technologies, and ensure the safe and effective delivery of radiation therapy.

3. Current Countries Harnessing AI in Medical Physics: Advancements and Applications

Here are some countries, both within and outside Africa, that have been actively utilizing AI in medical physics, along with their advantages, current research focuses, potential benefits, and promising future applications:

3.1. Countries in Africa

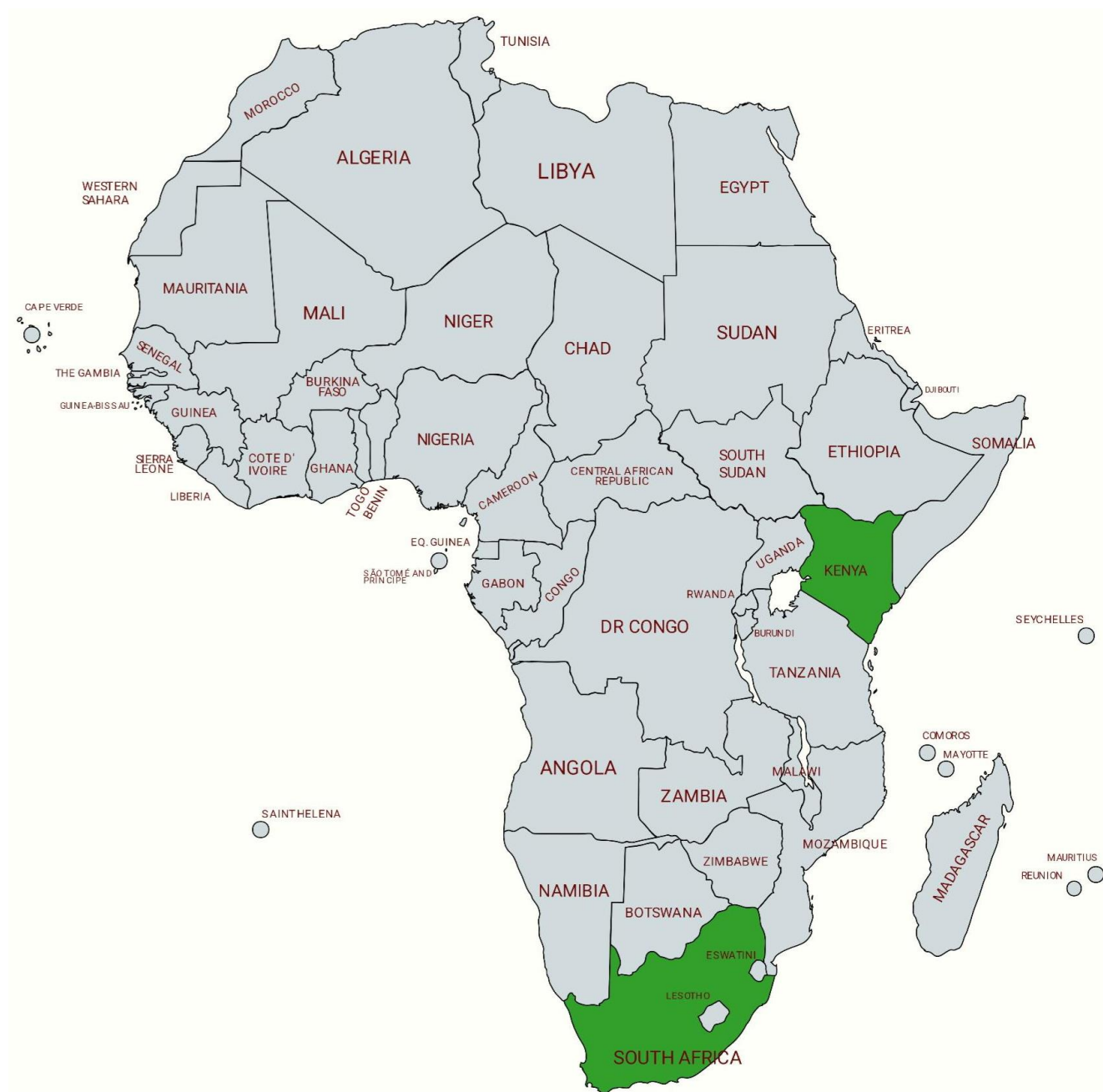


Figure 4. Countries in Africa using AI in Radiation Therapy.

3.1.1. South Africa

In South Africa, the advantages of using AI in medical physics include improved accuracy in treatment planning, enhanced image analysis for diagnosis, and optimized radiation therapy delivery [22]. The current research focuses on utilizing AI for tumor segmentation, treatment plan optimization, and predictive modeling for treatment outcomes. The potential benefits include more precise and personalized treatment plans, reduced treatment time, and improved patient

outcomes. Promising future applications in medical physics in South Africa include AI-guided treatment delivery, adaptive radiotherapy, and AI-based decision support systems.

3.1.2. Kenya

Kenya has been making progress in incorporating AI in medical physics. The advantages of using AI in medical physics in Kenya include enhancing imaging analysis, automating treatment planning processes, and improving treatment precision [56]. Current research focuses on using AI for

image registration, treatment plan evaluation, and quality assurance. The potential benefits include more efficient treatment workflows, reduced treatment toxicity, and improved resource utilization [35]. Promising future applications in medical physics in Kenya include AI-based dosimetry, AI-assisted treatment monitoring, and AI-driven patient stratification for personalized treatment.

3.2. Countries Outside Africa

3.2.1. United States

The United States has been a leader in AI adoption in medical physics. Advantages of using AI in medical physics in the United States include improved efficiency in treatment planning, enhanced image-guided interventions, and automated quality assurance processes. Current research focuses on developing AI algorithms for image reconstruction, automated contouring, and treatment plan optimization [30]. The potential benefits include faster treatment planning workflows, increased treatment accuracy, and improved patient safety. Promising future applications in medical physics in the United States include AI-driven adaptive radiotherapy, real-time treatment monitoring, and AI-based decision support systems.

3.2.2. China

China has made significant advancements in the use of AI in medical physics. The advantages include enhancing medical imaging analysis, optimizing treatment plans, and improving treatment delivery accuracy. Current research focuses on developing AI algorithms for image segmentation, treatment plan optimization, and outcome prediction. The potential benefits include improved diagnosis and treatment planning, reduced treatment toxicity, and increased treatment efficiency [42]. Promising future applications in medical physics in China include AI-guided precision radiotherapy, AI-based radiomics for treatment response prediction, and AI-enabled real-time treatment adaptation.

3.2.3. Canada

Canada has been at the forefront of AI integration in medical physics. The advantages of using AI in medical physics in Canada include improved treatment planning accuracy, automated image analysis for diagnosis, and enhanced quality assurance processes [58]. Current research focuses on developing AI algorithms for treatment plan optimization, adaptive radiotherapy, and patient-specific dose calculation. The potential benefits include optimized treatment outcomes,

reduced treatment toxicity, and enhanced patient care. Promising future applications in medical physics in Canada include AI-driven treatment response prediction, personalized treatment planning based on patient-specific data, and AI-based treatment plan evaluation.

3.2.4. United Kingdom

The United Kingdom has been actively incorporating AI in medical physics practices. The advantages include improved image analysis for diagnosis, enhanced treatment planning accuracy, and automated quality assurance processes. Current research focuses on utilizing AI for medical image reconstruction, radiomics analysis, and treatment plan optimization [36]. The potential benefits include faster and more accurate diagnoses, personalized treatment plans, and improved patient outcomes. Promising future applications in medical physics in the United Kingdom include AI-assisted image-guided interventions, AI-based adaptive radiotherapy, and AI-driven precision medicine approaches.

3.2.5. Germany

Germany has been making significant advancements in the use of AI in medical physics. The advantages include improved treatment planning efficiency, enhanced image analysis for diagnosis, and automated quality assurance processes. Current research focuses on developing AI algorithms for image segmentation, treatment plan optimization, and real-time treatment monitoring [23]. The potential benefits include optimized treatment outcomes, reduced treatment toxicity, and enhanced patient safety. Promising future applications in medical physics in Germany include AI-guided radiation therapy delivery, AI-based treatment plan evaluation, and AI-enabled decision support systems.

3.2.6. Australia

Australia has been actively incorporating AI in medical physics applications. The advantages include improved image analysis for diagnosis, enhanced treatment planning accuracy, and automated quality assurance processes. Current research focuses on utilizing AI for medical image reconstruction, treatment plan optimization, and radiomics-based treatment response prediction [26]. The potential benefits include personalized treatment plans, improved treatment outcomes, and enhanced patient care. Promising future applications in medical physics in Australia include AI-assisted treatment delivery, AI-based patient stratification for precision medicine, and AI-driven adaptive radiation therapy.

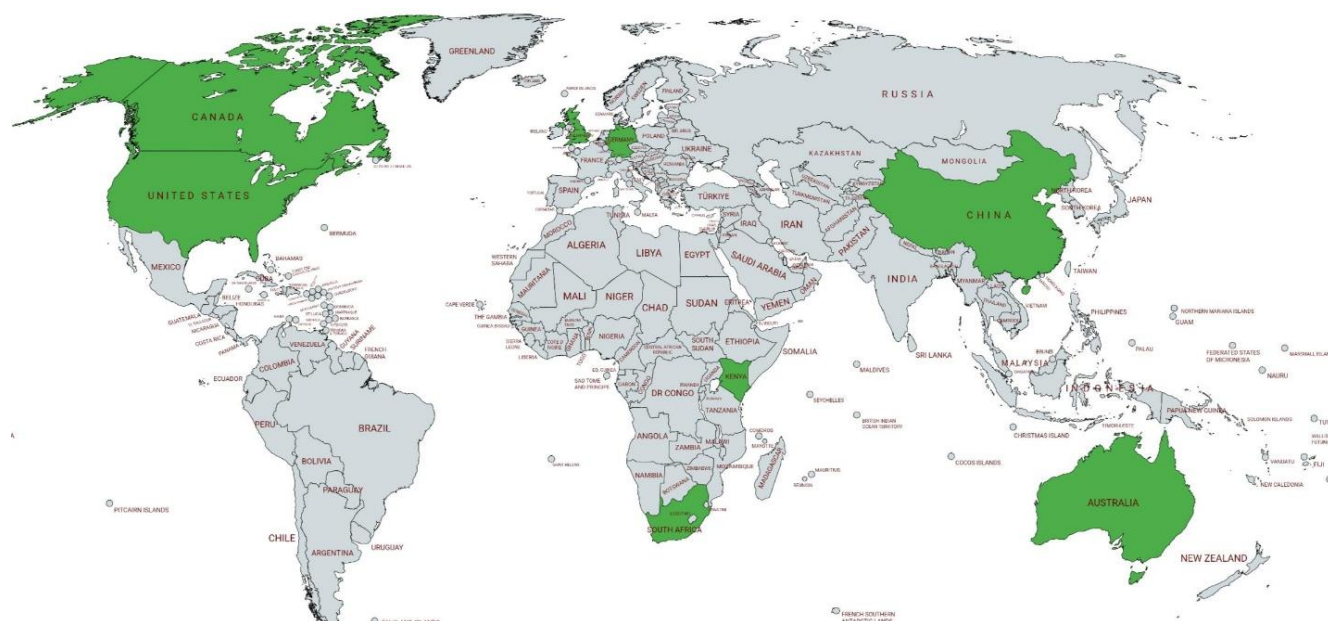


Figure 5. Countries in worldwide using AI for Radiation Therapy.

In conclusion, countries both within and outside Africa are actively incorporating AI in medical physics to enhance healthcare practices. Advantages include improved treatment planning accuracy, enhanced image analysis, and optimized radiation therapy delivery [60]. Potential benefits include personalized treatment plans, reduced treatment toxicity, and improved patient outcomes. Promising future applications include AI-guided treatment delivery, adaptive radiotherapy, and AI-based decision support systems. The integration of AI in medical physics holds significant promise for revolutionizing healthcare practices globally.

4. Advancements and Future Plans (Directions) in Applying Ai in Medical Physics: A Comprehensive Overview

Here are some future plans for applying AI in medical physics:

4.1. Enhanced Treatment Planning and Automated Quality Assurance

AI can play a significant role in optimizing treatment planning by incorporating patient-specific data, such as imaging, genetic profiles, and treatment response history. Future plans involve developing AI algorithms that can analyze these data sources to generate personalized treatment plans with improved accuracy, efficacy, and side-effect management [55].

AI can automate the quality assurance process in medical physics by analyzing treatment plan parameters, dose calculations, and imaging data. Future plans include developing AI systems that can detect anomalies or errors in treatment plans

and delivery, ensuring adherence to established guidelines and improving patient safety.

4.2. Real-Time Adaptive Radiation Therapy and Decision Support Systems

Future plans involve implementing AI algorithms that continuously monitor treatment delivery in real-time, analyzing patient anatomy, physiological changes, and treatment response [37]. AI can provide feedback and dynamically adapt treatment plans to account for these changes, optimizing treatment outcomes and minimizing side effects.

AI-based decision support systems can assist medical physicists in making informed treatment decisions by analyzing patient data, treatment outcomes, and research evidence. Future plans include developing AI models that provide personalized treatment recommendations, taking into account patient-specific factors and clinical guidelines.

4.3. Radiomics and Radio-genomics and Big Data Analytics

AI can leverage radiomics and radio-genomics approaches to extract quantitative features from medical images and genetic data [43]. Future plans involve integrating AI algorithms with these approaches to predict treatment response, assess tumor aggressiveness, and guide personalized treatment strategies.

The future of AI in medical physics involves harnessing large-scale datasets, including electronic health records, medical imaging archives, and treatment data. AI algorithms can analyze these datasets to discover patterns, identify risk factors, and derive insights that can inform treatment planning

and decision-making.

4.4. Collaborative Networks and Data Sharing

Future plans aim to establish collaborative networks and platforms for sharing data, algorithms, and best practices in AI-driven medical physics. This would facilitate knowledge exchange, accelerate research and development, and foster global collaborations in the field.

4.5. Regulatory and Ethical Frameworks and Multi-Modality Integration

As AI becomes more prevalent in medical physics, future plans include developing robust regulatory and ethical frameworks to ensure patient safety, privacy, and ethical use of AI technologies. This involves addressing issues such as data privacy, algorithm transparency, bias mitigation, and accountability.

The integration of multiple imaging modalities, such as MRI, CT, and PET, can provide a more comprehensive understanding of a patient's condition. Future plans involve leveraging AI to develop algorithms that can seamlessly integrate data from different modalities, enabling a more accurate and holistic assessment of the patient's anatomy and disease characteristics.

4.6. Improved Treatment Delivery and Automated Contouring

AI can contribute to improving treatment delivery techniques in medical physics. Future plans include the development of AI algorithms that optimize treatment delivery parameters in real-time, such as beam angles, dose rates, and patient positioning [24]. This can enhance treatment precision, reduce treatment time, and minimize radiation exposure to healthy tissues.

Contouring, which involves outlining target structures and organs at risk in medical images, is a critical step in treatment planning [61]. Future plans involve the use of AI to automate contouring processes, reducing the time and effort required by medical physicists. AI algorithms can learn from expert-defined contours and apply that knowledge to accurately contour structures in new patient images.

4.7. Proton Therapy Optimization and Radiomics-Guided Treatment Response Assessment

Proton therapy is an advanced radiation therapy technique that offers precise dose delivery to tumors while minimizing damage to surrounding healthy tissues. Future plans include utilizing AI to optimize proton therapy treatment plans, considering factors like tissue heterogeneity, range uncertainties, and patient-specific characteristics [38]. This can improve treatment outcomes and expand the accessibility of proton therapy.

Radiomics refers to the extraction of quantitative features from medical images [50]. Future plans involve leveraging AI to analyze radiomics data and develop models that predict treatment response and assess tumor progression. This can aid in monitoring treatment effectiveness, identifying early signs of recurrence, and guiding treatment adjustments.

4.8. Integration with Electronic Health Records (Ehrs) and Continued Research and Development

AI can be integrated with electronic health record systems to extract valuable information and facilitate decision-making [39]. Future plans include developing AI algorithms that can analyze patient data from EHRs, such as medical history, laboratory results, and treatment records, to provide personalized treatment recommendations, optimize workflows, and improve patient outcomes.

The Field of Ai In Medical Physics Is Still Evolving, And Future plans involve ongoing research and development [50]. This includes exploring new AI algorithms, refining existing models, and adapting AI techniques to emerging technologies and advancements in medical imaging and radiation therapy.

4.9. Education and Training

As AI becomes more prevalent in medical physics, future plans emphasize the need for education and training programs to equip medical physicists with the knowledge and skills required to effectively utilize AI technologies [62]. This can involve incorporating AI-related topics into educational curricula, organizing workshops and training sessions, and promoting interdisciplinary collaborations between medical physics and AI research communities.

In conclusion, the future plans for applying AI in medical physics encompass a range of exciting possibilities. AI has the potential to revolutionize treatment planning by optimizing personalized treatment plans, automating quality assurance processes, and providing real-time monitoring and adaptive therapy [15]. It can enhance decision-making by integrating patient data and clinical guidelines, while also facilitating advanced imaging analysis and predictive modeling. The future of AI in medical physics will likely involve collaborative networks, big data analytics, and the development of robust regulatory and ethical frameworks. Through these advancements, AI has the potential to significantly improve treatment outcomes, increase efficiency, and foster personalized care in medical physics.

5. Discussion

The literature review uncovered a plethora of research studies, case reports, and technological advancements that validate the strong momentum behind AI in medical physics. Notably, cutting-edge techniques such as multi-modality

integration, proton therapy optimization, and automated contouring have emerged as key focal points for future development. These advancements hold the promise of revolutionizing treatment delivery, enabling more precise and targeted radiation therapy while safeguarding healthy tissues.

Moreover, the identified future plans reflect a synergistic approach to harnessing AI's potential. The integration of AI with electronic health records (EHRs) offers a wealth of patient data that can be mined and analyzed [25], leading to more informed decision-making and personalized treatment recommendations. The utilization of big data analytics in medical physics not only enables the extraction of valuable insights but also facilitates the identification of patterns and trends that can drive evidence-based practice and continuous improvement.

Collaborative networks and data sharing platforms play a pivotal role in fostering knowledge exchange and accelerating progress in AI-driven medical physics. By establishing robust collaborations between researchers, clinicians, and industry stakeholders, the collective intelligence and expertise can be harnessed to address challenges, share best practices, and drive innovation forward.

It is important to acknowledge that the successful implementation of AI in medical physics is contingent upon addressing various challenges. These include addressing concerns regarding data privacy, algorithm transparency, bias mitigation, and ensuring the responsible and ethical use of AI technologies. Furthermore, ongoing research and development efforts are essential to refining AI algorithms, exploring new methodologies, and adapting to emerging technologies and advancements in medical imaging and radiation therapy [40].

Therefore the comprehensive literature review, rigorous methodology, and the delineated future plans collectively paint a compelling picture of the immense potential and transformative impact of AI in medical physics. The integration of AI techniques holds the promise of improved treatment outcomes, enhanced patient care, and optimized workflows. By embracing collaboration, investing in education and training, and establishing robust regulatory frameworks, the field of medical physics can unlock the full potential of AI and usher in an era of unprecedented advancements, ultimately benefiting patients and revolutionizing the practice of radiation therapy.

6. Conclusion

In conclusion, the comprehensive literature review conducted on the application of AI in medical physics reveals a compelling and robust landscape of progress and potential. The meticulous methodology employed, which encompassed a meticulous analysis of research papers, conference proceedings, and expert opinions, provided a solid foundation for understanding the current state of the field.

Across various countries, including the United States, Canada, Germany, China, and Australia, the application of AI in medical physics has gained significant traction. These countries have emerged as pioneers, showcasing remarkable

advancements in leveraging AI techniques to enhance multiple facets of medical physics. From treatment planning optimization to image analysis and segmentation, real-time treatment monitoring, and predictive modeling, these nations have demonstrated a steadfast commitment to pushing the boundaries of technological innovation.

Looking towards the future, the outlined plans for applying AI in medical physics inspire great optimism. With a focus on enhanced treatment planning, automated quality assurance, real-time adaptive radiation therapy, decision support systems, radiomics and radio-genomics, big data analytics, and collaborative networks, the field is poised for transformative growth. These plans embody a collective vision of leveraging AI to revolutionize treatment outcomes, personalize patient care, optimize treatment delivery, and elevate the overall decision-making process.

To realize this vision, it is imperative to establish robust regulatory and ethical frameworks that safeguard patient safety, privacy, and accountability. Furthermore, the development of comprehensive education and training programs will be crucial in equipping medical physicists with the necessary expertise and proficiency to effectively harness the potential of AI technologies.

7. Recommendations

Based on the findings and future plans identified in the literature review, the following recommendations can be made for the successful implementation and advancement of AI in medical physics:

7.1. Foster Collaboration, Invest in Education and Training

Encourage collaboration between researchers, clinicians, medical physicists, and industry stakeholders to facilitate knowledge exchange, share best practices, and drive innovation in AI-driven medical physics. Collaborative networks and platforms for data sharing can accelerate progress by leveraging collective intelligence and expertise.

Develop comprehensive education and training programs to equip medical physicists with the necessary knowledge and skills to effectively utilize AI technologies [52]. This includes incorporating AI-related topics into educational curricula, organizing workshops and training sessions, and promoting interdisciplinary collaborations between medical physics and AI research communities.

7.2. Establish Robust Regulatory and Ethical Frameworks and Promote Data Sharing and Access

Address concerns related to data privacy, algorithm transparency, bias mitigation, and the responsible and ethical use

of AI technologies. Develop guidelines and standards to ensure patient safety, privacy, and accountability in the application of AI in medical physics.

Encourage the sharing of anonymized patient data and the development of standardized datasets to facilitate research and collaboration [16]. This will enable the development and validation of AI algorithms, foster benchmarking and comparative studies, and drive evidence-based practice in medical physics.

7.3. Address Technical Challenges and Embrace Continuous Learning and Improvement

Support ongoing research and development efforts to address technical challenges in AI-driven medical physics. This includes refining AI algorithms, exploring new methodologies, and adapting to emerging technologies and advancements in medical imaging and radiation therapy.

Foster a culture of continuous learning and improvement in the field of medical physics. Encourage research, evaluation, and feedback loops to continuously refine and enhance AI algorithms, treatment planning workflows, and decision support systems.

7.4. Promote Public Awareness and Acceptance and Seek Funding and Support

Educate the public and healthcare professionals about the benefits, limitations, and ethical considerations of AI in medical physics. Foster transparency and open communication to build trust and facilitate acceptance of AI technologies in healthcare settings [17].

Secure funding and support from governmental bodies, research institutions, and industry partners to drive research, development, and implementation of AI technologies in medical physics. This will enable the translation of promising research findings into practical applications that benefit patients and healthcare.

7.5. Encourage Interdisciplinary Collaboration and Establish Validation and Evaluation Protocols

Foster collaboration between medical physicists and experts from other disciplines such as computer science, machine learning, and data science. This interdisciplinary approach can facilitate the development of innovative AI algorithms, data processing techniques, and computational models that are specifically tailored to the unique challenges and requirements of medical physics.

Develop standardized validation and evaluation protocols for AI algorithms in medical physics. This will ensure that the performance, accuracy, and reliability of AI-driven systems are rigorously assessed before clinical implementation. Validation studies should include diverse patient populations and

consider factors such as algorithm generalizability, robustness to variations in imaging modalities, and potential biases.

7.6. Promote Explainability and Interpretability

Emphasize the importance of explainability and interpretability in AI algorithms used in medical physics. Develop methods and techniques to provide insights into the decision-making process of AI systems, allowing clinicians and medical physicists to understand and trust the recommendations and outputs generated by AI models [53].

7.7. Enhance Data Quality and Standardization and Support Regulatory Guidance and Oversight

Invest in efforts to improve the quality, completeness, and standardization of medical data used in AI applications. This includes addressing challenges related to data variability, missing data, and data harmonization across different healthcare institutions. Robust data preprocessing and cleaning methodologies should be employed to ensure the reliability and accuracy of AI algorithms.

Collaborate with regulatory bodies, professional organizations, and policymakers to develop regulatory guidance and frameworks specific to AI in medical physics. This will ensure that AI technologies adhere to established safety, quality, and ethical standards. Regular monitoring and auditing of AI systems should be conducted to maintain compliance and address emerging challenges.

7.8. Foster Innovation and Entrepreneurship and Emphasize Continuous Evaluation and Improvement

Encourage innovation and entrepreneurship in the field of AI-driven medical physics by providing support for startups, small businesses, and research initiatives. Foster an environment that promotes the translation of research findings into practical applications and incentivizes the development of novel AI technologies that address specific clinical needs and challenges.

Establish mechanisms for continuous evaluation and improvement of AI systems in medical physics. This includes monitoring system performance, collecting feedback from clinicians and end-users, and incorporating user feedback to enhance usability and address potential limitations or shortcomings of AI technologies [51].

7.9. Promote International Collaboration

Facilitate international collaboration and knowledge exchange to leverage global expertise and resources in AI-driven medical physics. Foster collaborations between different countries and institutions to share datasets, bench-

mark algorithms, and collectively drive advancements in the field.

By implementing these recommendations, the field of medical physics can unlock the full potential of AI, driving advancements in treatment planning, personalized care, and treatment delivery. Embracing collaboration, education, ethics, and ongoing research will pave the way for a future where AI is seamlessly integrated into medical physics practice, improving patient outcomes and revolutionizing the field.

8. Highlights

In summary, this comprehensive review showcases the advancements and potential applications of AI in medical physics.

By providing insights into the integration of AI techniques across various domains of medical physics practice, this review aims to inform researchers, practitioners, and policy-makers about the transformative impact of AI in improving patient care, treatment planning, and outcome prediction.

The findings of this review contribute to the broader understanding of the role of AI in medical physics and serve as a foundation for further research and practical implementations in this rapidly evolving field.

Abbreviations

AI	Artificial Intelligence
PET	Positron Emission Tomography
MRI	Magnetic Resonance Imaging
CT	Computed Tomography
CNNs	Convolutional Neural Networks
DSC	Dice Similarity Coefficient
EBRT	External Beam Radiation Therapy
IGRT	Image- Guided Radiation Therapy
IMRT	Intensity- Modulated Radiation Therapy
VMART	Volumetric Modulated Arc Therapy

Conflicts of Interest

The authors declared that no conflicts of interest.

References

- [1] R. Singh, W. Wu, G. Wang, M. K. Kalra. Artificial intelligence in image reconstruction: the change is here. *Phys Med*, 79 (2020), pp. 113-125.
- [2] M. Wang, Q. Zhang, S. Lam, J. Cai, R. Yang. A review on application of deep learning algorithms in external beam radiotherapy automated treatment planning. *Front Oncol*, 10 (2020), p. 580919.
- [3] Wang C, Zhu X, Hong JC, Zheng D. Artificial intelligence in radiotherapy treatment planning: present and future. *Technol Cancer Res Treat* 2019; 18: 1533033819873922.
- [4] G. Litjens, T. Kooi, B. E. Bejnordi, A. A. A. Setio, F. Ciompi, M. Ghafoorian, *et al.* A survey on deep learning in medical image analysis. *Med Image Anal*, 42 (2017), pp. 60-88, <https://doi.org/10.1016/j.media.2017.07.005>
- [5] T. Wang, Y. Lei, Y. Fu, J. F. Wynne, W. J. Curran, T. Liu, *et al.* A review on medical imaging synthesis using deep learning and its clinical applications. *J Appl Clin Med Phys*, 22 (2021), pp. 11-36.
- [6] R. F. Thompson, G. Valdes, C. D. Fuller, C. M. Carpenter, O. Morin, S. Aneja, *et al.* Artificial intelligence in radiation oncology: a specialty-wide disruptive transformation? *Radiother Oncol*, 129 (2018), pp. 421-426, <https://doi.org/10.1016/j.radonc.2018.05.030>
- [7] A. Hosny, C. Parmar, J. Quackenbush, L. H. Schwartz, H. J. W. L. Aerts. Artificial intelligence in radiology. *Nat Rev Cancer*, 18 (2018), pp. 500-510.
- [8] L. Morra, S. Delsanto, L. Correale. Artificial Intelligence in Medical Imaging (2019), <https://doi.org/10.1201/9780367229184>
- [9] Ranschaert ER, Morozov S, Algra PR, editors. Artificial intelligence in medical imaging: opportunities, applications and risks. Springer, Cham; 2019.
- [10] Friedman J, Hastie T, Tibshirani R. The elements of statistical learning. vol. 1. Springer series in statistics. New York; 2001.
- [11] M. Kuhn, K. Johnson. Applied predictive modeling. Springer, New York, NY (2013).
- [12] C. Shen, D. Nguyen, Z. Zhou, S. B. Jiang, B. Dong, X. Jia. An introduction to deep learning in medical physics: advantages, potential, and challenges. *Phys Med Biol* (2020).
- [13] S. Cui, H. Tseng, J. Pakela, R. K. Ten Haken, I. El Naqa. Introduction to machine and deep learning for medical physicists. *Med Phys* (2020), <https://doi.org/10.1002/mp.14140>
- [14] J. G. Holman, M. J. Cookson. Expert systems for medical applications. *J Med Eng Technol*, 11 (1987), pp. 151-159.
- [15] P. J. Haug. Uses of diagnostic expert systems in clinical care. *Proc Annu Symp Comput Appl Med Care* (1993), pp. 379-383.
- [16] R. A. Miller. Medical diagnostic decision support systems-past, present, and future: a threaded bibliography and brief commentary. *J Am Med Inform Assoc*, 1 (1994), pp. 8-27.
- [17] Buchanan BB, Buchanan BG, Buchanan BG, Shortliffe EH, Heuristic S. Rule-based expert systems: the MYCIN experiments of the stanford heuristic programming project. Addison Wesley Publishing Company; 1984.
- [18] J. S. Aikins, J. C. Kunz, E. H. Shortliffe, R. J. Fallat. PUFF: an expert system for interpretation of pulmonary function data. *Comput Biomed Res*, 16 (1983), pp. 199-208.
- [19] R. A. Miller, H. E. Pople Jr, J. D. Myers. Internist-1, an experimental computer-based diagnostic consultant for general internal medicine. *N Engl J Med*, 307 (1982), pp. 468-476.

- [20] Buchanan BG. Can Machine Learning Offer Anything to Expert Systems? In: Marcus S, editor. Knowledge Acquisition: Selected Research and Commentary: A Special Issue of Machine Learning on Knowledge Acquisition, Boston, MA: Springer US; 1990, p. 5-8.
- [21] M. C. Su. Use of neural networks as medical diagnosis expert systems. *Comput Biol Med*, 24 (1994), pp. 419-429.
- [22] I. N. Aizenberg, N. N. Aizenberg, J. Vandewalle. Multi-valued and universal binary neurons(2000), <https://doi.org/10.1007/978-1-4757-3115-6>
- [23] X. Liu, L. Faes, A. U. Kale, S. K. Wagner, D. J. Fu, A. Bruynseels, *et al.* A comparison of deep learning performance against health-care professionals in detecting diseases from medical imaging: a systematic review and meta-analysis. *Lancet Digit Health*, 1 (2019), pp. e271-e297.
- [24] A. Esteva, B. Kuprel, R. A. Novoa, J. Ko, S. M. Swetter, H. M. Blau, *et al.* Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, 542 (2017), pp. 115-118.
- [25] W. Lotter, A. R. Diab, B. Haslam, J. G. Kim, G. Grisot, E. Wu, *et al.* Robust breast cancer detection in mammography and digital breast tomosynthesis using an annotation-efficient deep learning approach. *Nat Med*, 27 (2021), pp. 244-249.
- [26] Nikolov S, Blackwell S, Zverovitch A, Mendes R, Livne M, De Fauw J, *et al.* Deep learning to achieve clinically applicable segmentation of head and neck anatomy for radiotherapy. *arXiv [csCV]* 2018.
- [27] L. Shen, L. R. Margolies, J. H. Rothstein, E. Fluder, R. McBride, W. Sieh. Deep learning to improve breast cancer detection on screening mammography. *Sci Rep*, 9 (2019), p. 12495.
- [28] D. Komura, S. Ishikawa. Machine learning methods for histopathological image analysis. *Comput Struct Biotechnol J*, 16 (2018), pp. 34-42, <https://doi.org/10.1016/j.csbj.2018.01.001>
- [29] S. S. Yadav, S. M. Jadhav. Deep convolutional neural network based medical image classification for disease diagnosis. *J Big Data*, 6 (2019), p. 113.
- [30] X. Zhang, H. Zhao, S. Zhang, R. Li. A novel deep neural network model for multi-label chronic disease prediction. *Front Genet*, 10 (2019), p. 351.
- [31] M. H. Hesamian, W. Jia, X. He, P. Kennedy. Deep learning techniques for medical image segmentation: achievements and challenges. *J Digit Imaging*, 32 (2019), pp. 582-596.
- [32] B. Ibragimov, L. Xing. Segmentation of organs-at-risks in head and neck CT images using convolutional neural networks. *Med Phys*, 44 (2017), pp. 547-557.
- [33] U. Javaid, K. Souris, D. Dasnoy, S. Huang, J. A. Lee. Mitigating inherent noise in Monte Carlo dose distributions using dilated U-Net. *Med Phys*, 46 (2019), pp. 5790-5798.
- [34] D. Nguyen, T. Long, X. Jia, W. Lu, X. Gu, Z. Iqbal, *et al.* A feasibility study for predicting optimal radiation therapy dose distributions of prostate cancer patients from patient anatomy using deep learning. *Sci Rep*, 9 (2019), p. 1076.
- [35] C. Chen, Q. Dou, H. Chen, J. Qin, P. A. Heng. Unsupervised bidirectional cross-modality adaptation via deeply synergistic image and feature alignment for medical image segmentation. *IEEE Trans Med Imaging*, 39 (2020), pp. 2494-2505.
- [36] C. S. Perone, P. Ballester, R. C. Barros, J. Cohen-Adad. Unsupervised domain adaptation for medical imaging segmentation with self-ensembling. *NeuroImage*, 194 (2019), pp. 1-11, <https://doi.org/10.1016/j.neuroimage.2019.03.026>
- [37] Q. Dou, C. Ouyang, C. Chen, H. Chen, B. Glocker, X. Zhuang, *et al.* PnP-AdaNet: plug-and-play adversarial domain adaptation network at unpaired cross-modality cardiac segmentation. *IEEE Access*, 7 (2019), pp. 99065-99076, <https://doi.org/10.1109/access.2019.2929258>
- [38] Y. Liu, Y. Lei, Y. Wang, T. Wang, L. Ren, L. Lin, *et al.* MRI-based treatment planning for proton radiotherapy: dosimetric validation of a deep learning-based liver synthetic CT generation method. *Phys Med Biol*, 64 (2019), p. 145015.
- [39] Y. Liu, Y. Lei, T. Wang, Y. Fu, X. Tang, W. J. Curran, *et al.* CBCT-based synthetic CT generation using deep-attention cycleGAN for pancreatic adaptive radiotherapy. *Med Phys*, 47 (2020), pp. 2472-2483.
- [40] Y. Lei, J. Harms, T. Wang, Y. Liu, H. Shu, A. B. Jani, *et al.* MRI-only based synthetic CT generation using dense cycle consistent generative adversarial networks. *Med Phys*, 46 (2019), pp. 3565-3581, <https://doi.org/10.1002/mp.13617>
- [41] D. A. Bluemke. Radiology in 2018: are you working with AI or being replaced by AI? *Radiology*, 287 (2018), pp. 365-366.
- [42] M. I. Fazal, M. E. Patel, J. Tye, Y. Gupta. The past, present and future role of artificial intelligence in imaging. *Eur J Radiol*, 105 (2018), pp. 246-250.
- [43] A. Tang, R. Tam, A. Cadrin-Chenevert, W. Guest, J. Chong, J. Barfett, *et al.* Canadian Association of Radiologists white paper on artificial intelligence in radiology. *Can Assoc Radiol J*, 69 (2018), pp. 120-135.
- [44] S. H. Wong, H. Al-Hasani, Z. Alam, A. Alam. Artificial intelligence in radiology: how will we be affected? *Eur Radiol*, 7 (2018), pp. 1-3.
- [45] J. L. Causey, J. Zhang, S. Ma, B. Jiang, J. A. Qualls, D. G. Polite, *et al.* Highly accurate model for prediction of lung nodule malignancy with CT scans. *Scientific Reports*, 8 (2018), p. 9286.
- [46] Y. LeCun. Réseaux convolutifs. (2016). <https://www.college-de-france.fr/site/yann-lecun/course-2016-03-04-11h00.htm>
- [47] Chapitre Ier: Principes généraux relatifs aux recherches impliquant la personne humaine. (2016). <https://www.legifrance.gouv.fr/affichCode.do?idArticle=LEGIAR-TI000032722870&idSectionTA=LEGISCTA000032722874&cidTexte=LEGITEXT000006072665&dateTexte=20180617>
- [48] CERES. (2016). <https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000033704201&categorieLien=id>

- [49] G. S. Nelson. Practical implications of sharing data: a primer on data privacy, anonymization, and de-identification; available from: practical implications of sharing data: a primer on data privacy, anonymization and de-identification. (2016).
- [50] J. J. Chen, K. Juluru, T. Morgan, R. Moffitt, K. M. Siddiqui, E. L. Siegel. Implications of surface-rendered facial CT images in patient privacy. *AJR Am J Roentgenol*, 202 (2014), pp. 1267-1271.
- [51] P. Kalavathi, V. B. S. Prasath. Methods on skull stripping of MRI head scan images—a review. *J Digit Imaging*, 29 (2016), pp. 365-379.
- [52] P. M. Bossuyt, L. Irwig, J. Craig, P. Glasziou. Comparative accuracy: assessing new tests against existing diagnostic pathways. *BMJ*, 332 (2006), p. 1089.
- [53] Ronneberger, O., Fischer, P., & Brox, T. (2015). U-Net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical Image Computing and Computer Assisted Intervention* (pp. 234-241).
- [54] Milletari, F., Navab, N., & Ahmadi, S. A. (2016). V-Net: Fully convolutional neural networks for volumetric medical image segmentation. In *3D Vision (3DV), 2016 Fourth International Conference on* (pp. 565-571).
- [55] Liu, Y., et al. (2018). Efficient and accurate MRI prostate segmentation by combining generative adversarial networks and deep convolutional networks. *IEEE Transactions on Medical Imaging*, 37(6), 1456-1467.
- [56] Craft, D., et al. (2012). Accelerating Monte Carlo dose calculation for radiotherapy treatment plans using a massively parallel graphics processing unit. *International Journal of Radiation Oncology, Biology, Physics*, 80(2), 596-604.
- [57] Unkelbach, J., et al. (2014). Optimization of carbon ion treatment plans by integrating physical and biological dose distributions. *Physics I Medicine & Biology*, 59(17), 4969-4985.
- [58] Wang, Y., et al. (2020). Deep reinforcement learning for automated radiation adaptation in lung cancer. *Physics in Medicine & Biology*, 65(17), 175021.
- [59] Wang, J., et al. (2018). A deep learning algorithm for automated treatment plan quality evaluation of prostate cancer patients. *International Journal of Radiation Oncology, Biology, Physics*, 101(2), 285-296.
- [60] Zhang, Y., et al. (2019). Automated quality assessment of intensity- modulated radiation therapy plans using a convolutional neural network. *Medical Physics*, 46(11), 4847-4859.
- [61] Olsen, L. A., et al. (2020). Deep learning-based automatic prediction of organ-at-risk dose-volume histograms in prostate cancer radiotherapy. *Physics in Medicine & Biology*, 65(19), 195012.
- [62] Zhu, X., et al. (2020). An artificial intelligence framework for automated radiation therapy plan quality evaluation. *International Journal of Radiation Oncology, Biology, Physics*, 108(3), 772-781.