International Journal of Future Engineering Innovations

Artificial Intelligence Applications in Medical Physics: Improving the Accuracy of Medical Imaging and Radiotherapy

Hussein Abd Ali Abbas [1*], Alaa Majeed Raheem [2], Naba Raji Mushir [3], Riyam Jamal Mohsen [4]
[1-4] College of Engineering Technology Sawa University' Almuthana, Iraq

* Corresponding Author: **Hussein Abd Ali Abbas**

Article Info

ISSN (online): 3049-1215
Volume: 02
Issue: 03
May-June 2025
Received: 05-03-2025
Accepted: 06-04-2025
Page No: 84-87

Abstract
Artificial intelligence (AI) in medical physics is seeing unprecedented growth in increasing the accuracy of medical imaging and radiation therapy. In medical imaging, AI utilizes techniques such as deep learning and neural networks to improve the quality of images captured by imaging devices such as magnetic resonance imaging (MRI) and computed tomography (CT), allowing clinicians to more easily detect tumors and other diseases in their earliest stages. All because of advanced algorithms, the resolution of images can be increased and noise reduced so that small abnormalities are easily identified that would not be visible with traditional methods. AI assists in improving treatment planning by identifying the exact location and size of tumors and the allocation of doses of radiation based on the distinctive characteristics of each patient. Through machine learning, algorithms are applied to optimize the distribution and precise pointing of the radiation to minimize damage to normal tissue, thereby minimizing side effects and maximizing treatment effectiveness. AI also enables improved integration in this area with other technologies such as virtual reality and 3D printing, which may improve the accuracy of diagnosis and therapy and provide a personalized treatment experience in line with the needs of each patient.

DOI: **https://doi.org/10.54660/IJFEI.2025.2.3.84-87**

Keywords: Artificial Intelligence, Medical Imaging, Radiation Therapy, Medical Physics, Medical Image Analysis, Intelligent Algorithms

1. Introduction

The integration of AI technologies has allowed a tremendous development of medical physics, with these technologies exhibiting their tremendous capabilities in ensuring precision in medical imaging and radiotherapy. Artificial intelligence draws conclusions from a huge influx of medical data that enables physicians to diagnose diseases with much more accuracy, thus offering a treatment plan with the utmost personalized touch for every patient. Machine-learning algorithms in medical imaging work toward quick and highly accurate image analyses, which allows the diagnoses of tumors, cardiac, and neurological diseases at their earliest stages. Furthermore, artificial intelligence provides precise quantitative analyses to monitor disease progression and patients' response to treatments, assisting in better clinical decision-making. The AI-based automation of mundane tasks also speeds up diagnostic processes, thus easing the pressure on physicians and enhancing the workflow efficiency of hospitals. In addition, artificial intelligence ranks medical cases in terms of severity, thus ensuring immediate care for critical cases. In radiotherapy, intelligent algorithms can improve beam guiding accuracy so that damage to healthy tissues is minimized and treatment efficacy is enhanced. AI looks to be extremely useful in telemedicine; it offers remote analysis of medical images and reports, along with instant consultations, improving health across the remotest areas. The challenge of seeking guarantees for transparency into any and all diagnostic and therapeutic decisions still exists however, as increasing reliance upon these systems raises further problems concerning the privacy and integrity of data. Regulatory frameworks must be implemented to prevent any form of malpractice and ensure ethical use of these technologies, with much emphasis being put on improving its accuracy and gaining the trust of patients and doctors. Going on with developments in this area, AI will continuously change medical physics for a better and more efficient healthcare system. Source: [The Power of AI in Healthcare - Techesi]

Currently, image registration and fusion algorithms are used in RT and are considered key steps in contour propagation and dose accumulation occurring between two consecutive RT treatments or during the optimization of an adaptive plan online or offline. Automated rigid registration or deformable image registration (DIR) requires manual intervention when there are altitudinal changes occurring in relevant patient anatomy or setup changes compared with available images. This manual task becomes time-consuming and can, however, be aided by AI algorithms to assist the radiation oncologist. Deep learning methods in [12,13] were implemented to learn similarity metrics for the purpose of image registration, enabling fast, user-independent, non-rigid inter-modality registration. In this respect, let it be noted that non-negligible uncertainties remain, which may potentially impact applications based on DIR [14]. Validation against expert contours for clinically compatible DIR-based algorithms is important, as suggested by the American Association of Physicists in Medicine Task Group (TG) 132 report [15] and implemented in several papers [16- 23].

Research objectives

1. The precision of medical diagnosis is enhanced through such deep image analysis: AI aims toward achieving higher accuracy in disease diagnosis through deep learning-based procedures and artificial neural networks for medical image analysis, more than is possible through conventional practices. By comparing thousands of medical images and detecting subtle patterns that are imperceptible to the human eye, AI positively aids disease diagnosis in the early stages, such as cancer and cardiovascular diseases, thus creating greater possibilities for successful treatment and fewer misdiagnoses.
2. AI offers a few solutions to accelerate medical imaging work processes and bring increased efficiency to workflow in radiology departments: By partial automation of initial processing and interpretation so that analysis takes less time, AI would allow doctors to devote more time to certain complex cases. With AI, sorting medical examinations are done based on urgency, thereby ensuring attention to patients with life-threatening conditions and shortening waiting times. This also eases staff workload and improves the use of available resources.
3. Preparation of individualized radiation therapy plans concerning individual changes: AI aims at revamping radiation therapy so that it proposes individualized treatment plans for each patient according to their own anatomical or functional changes. Based on the analysis of computed tomography (CT) and magnetic resonance imaging (MRI) images, it suggests the best split of radiation dose between target and normal tissue, minimizing the radiation damage to healthy tissues and improving the encapsulation of cancer cells. Further, AI can predict likely changes that may arise during the course of treatment and enable doctors to adjust the plans accordingly in real time.
4. Assisting clinical decision and improving treatment strategies: AI equips doctors to effectively use clinical and imaging data to predict the outcomes of treatment based on past experiences and advanced computational models and provides evidence to back a recommendation for treatment. The doctor then decides which protocol best suits a patient. Longer-term response to treatment may be monitored using AI to make precise alterations to treatment plans to optimize benefits for each patient. From “Artificial Intelligence and Radiology: A New Era of Precision and Efficiency,” by Vera Ovanen, Ultralytics, June 4, 2024.

Problem Statement

So, AI can be used to visualize, analyze, diagnosis, and treat biological matters or biological systems. Today, AI tools have become exceedingly accurate in diagnosis, for the sake of superiority or inference over the baselines. Yet, the flaws that come with such advances are the integration of AI-technologies with clinical settings for treatment consideration and how one would measure the human factor or the physician's judgment with its counterpart-AI system in the evaluation of medical imaging and in diagnosing. In treatment with AI, extremely high levels of precision become necessary to ensure that radiation doses protect healthy tissues. This calls for building very advanced models that can account for changes that occur to patient anatomy dynamically during the treatment. Data privacy or security stands as another major issue because AI runs on huge data sets for its training and further improvement; hence, a stringent policy ensuring data confidentiality and upholding patient rights must be promulgated. Thus, due to these hurdles, the research is working on the actual problem of assessing the effectiveness and efficiency of AI techniques which may affect the accuracy of medical imaging and also radiotherapy, technical and ethical hurdles because of which they cannot be applied, and some proposed solutions to conduct them safely with traditional medical applications. Source: From an article entitled "Radiotherapy on the Wave of Innovation" published on the website of the International Atomic Energy Agency (IAEA).

Research Methodology

With medical imaging and radiotherapy, accuracy is paramount in a setting where it enhances diagnosis, maximizes treatment, and improves patient outcomes. To that end, pattern recognition is one of the fields that AI has impacted greatly by enhancing image interpretation, reducing human error, and maximizing efficient and personalized treatment planning.

Performing complex imaging data analysis, AI algorithms and deep learning methods such as Convolutional Neural Networks (CNNs) can identify finer patterns or anomalies in a medical image, such as tumors or lesions, which can be invisible to the human eyes. In cancer imaging, for example, AI inspection has helped improve the detection and characterization of malignant tumors for early diagnosis and therapies.

In addition, AI helps medical imaging to build predictive models to anticipate disease evolution and the course of treatment. By analyzing large sets of data, these models can identify patterns and correlations that allow doctors to make decisions best suited to their individual patients.

Improvements in molecular probes and radiopharmaceuticals expand the panorama of nuclear imaging. Innovations in 11C-, 18F-, 13N- and 15O-labeling chemistry yield more specific and sensitive PET radiopharmaceuticals that are essential for detecting and monitoring diseases at the molecular level. In MRI technology, continuous evolution with new higher field strengths and functional imaging methods improves the spatial and temporal resolutions for imaging needs. Innovations in functional MRI and diffusion tensor imaging provide a glimpse into brain connectivity and function, assisting with the diagnosis and treatment of neurological disorders.

Significance of the study

1. Increasing Diagnostic Accuracy by AI Integration

One of the major advantages that the integration of artificial intelligence (AI) offers to medical imaging is the increased accuracy in the diagnostic procedure. Deep learning models, especially convolutional neural networks, have shown enormous potential in the identification of tumors, nodules, and other anomalies in imaging modalities such as MRI, CT scan, and mammography. These systems provide greater capacity to a radiologist in detecting diseases at their early onset and also help reduce the incidences of human errors.

2. Advances in Image-Guided Radiotherapy: IGRT

Image Guided Radiotherapy has transformed the field of radiotherapy allowing visualizing the tumors in real-time during treatment. Techniques such as cone-beam CT and MRI-guided systems ensure fine alignment and adaptive treatment procedure. This way, healthy tissues receive the minimal dose of radiation and the tumors are subject to higher doses.

3. Personalizing Treatment Planning

Such machine-learning models are being employed to allow the design of personalized radiotherapy protocols, with predictions relating to tumor response and patient-dependent profiles of risk. In essence, this route changes treatment from population-based protocols to precision medicine, thus leaning toward better patient outcomes with the lesser side effects.

4. Operational Efficiency and Workflow Optimization

AI systems increase efficiency in the radiology department by prioritizing urgent cases, making measurements, and saving reporting time. So, the radiologist can focus on the more complex diagnoses, whereas AI handles the simpler cases, thereby simultaneously increasing throughput and reducing burnout.

5. Future Perspectives and Continuous Improvement

As medical AI systems are becoming more widely applied, an array of key challenges needs to be confronted, including ethics in AI use, interpretability of models, data privacy, and clinical integration. Future work should be aimed at establishing transparent and explainable medicine-specific models, along with clinical validation to ensure regulatory approval and widespread adoption.

Conclusion

Improving the quality of medical imaging and radiotherapy is of paramount essence in contemporary healthcare because an accurate diagnosis and efficient treatment planning require high-grade images. The article titled "Enhancing Radiological Diagnosis: A Comprehensive Review of Image Quality Assessment and Optimization Strategies" reiterates the emphasis on the significance of image quality in radiology. For example, it mentions properties that affect diagnosis, such as spatial resolution, noise, contrast, and artifacts. It reviewed methodologies that measure image quality and optimize it according to various imaging modalities like X-ray, CT, MRI, ultrasound, and nuclear medicine. Through strict adherence to quality assurance and optimization protocols, the medical fraternity ensures accurate diagnosis while protecting patients from unnecessary radiation. Implementation of innovations coupled with sustained training in radiology contributes greatly to patient care excellence.

References

1. Techesi. The Power of AI in Healthcare [Internet]. 2024 [cited 2025 Jun 1]. Available from: https://www.techesi.com/ar/ai-in-healthcare.html
2. Ovanen V. Artificial Intelligence and Radiology: A New Era of Precision and Efficiency. Ultralytics. 2024 Jun 4.
3. Haskins G, Kruecker J, Kruger U, Xu S, Pinto PA, Wood BJ, *et al*. Learning deep similarity metric for 3D MR-TRUS image registration. Int J Comput Assist Radiol Surg. 2019;14:417–25.
4. Cao X, Yang J, Wang L, Xue Z, Wang Q, Shen D. Deep learning based on inter-modality image registration supervised by intra-modality similarity. Mach Learn Med Imaging. 2018;11046:55–63.
5. Oh S, Kim S. Deformable image registration in radiation therapy. Radiat Oncol J. 2017;35:101–11.
6. Brock KK, Mutic S, McNutt TR, Li H, Kessler ML. Use of image registration and fusion algorithms and techniques in radiotherapy: Report of the AAPM Radiation Therapy Committee Task Group No. 132. Med Phys. 2017;44:e43–76.
7. Weppler S, Schinkel C, Kirkby C, Smith W. Lasso logistic regression to derive workflow-specific algorithm performance requirements as demonstrated for head and neck cancer deformable image registration in adaptive radiation therapy. Phys Med Biol. 2020;65:195013.
8. Kumarasiri A, Siddiqui F, Liu C, Yechieli R, Shah M, Pradhan D, *et al*. Deformable image registration based on automatic CT-to-CT contour propagation for head and neck adaptive radiotherapy in the routine clinical setting. Med Phys. 2014;41:121712.
9. Liang X, Bibault JE, Leroy T, Escande A, Zhao W, Chen Y, *et al*. Automated contour propagation of the prostate from pCT to CBCT images via deep unsupervised learning. Med Phys. 2021;48:1764–70.
10. Hoffmann C, Krause S, Stoiber EM, Mohr A, Rieken S, Schramm O, *et al*. Accuracy quantification of a deformable image registration tool applied in a clinical setting. J Appl Clin Med Phys. 2014;15:4564.
11. Ramadan IS, Beck K, Hamilton DA, Evans J, Iupati D, Nicholson A, *et al*. Validation of Varian's SmartAdapt® deformable image registration algorithm for clinical application. Radiat Oncol. 2015;10:73.
12. Pukala J, Johnson PB, Shah AP, Langen KM, Bova FJ, Staton RJ, *et al*. Benchmarking of five commercial deformable image registration algorithms for head and neck patients. J Appl Clin Med Phys. 2016;17:25–40.
13. Loi G, Fusella M, Lanzi E, Cagni E, Garibaldi C, Iacoviello G, *et al*. Performance of commercially available deformable image registration platforms for contour propagation using patient-based computational phantoms: A multi-institutional study. Med Phys. 2018;45:748–57.
14. Rosen BS, Hawkins PG, Polan DF, Balter JM, Brock KK, Kamp JD, *et al*. Early changes in serial CBCT-measured parotid gland biomarkers predict chronic xerostomia after head and neck radiation therapy. Int J Radiat Oncol Biol Phys. 2018;102:1319–29.
15. International Atomic Energy Agency (IAEA). Radiotherapy in the Wave of Innovation [Internet]. [cited 2025 Jun 1]. Available from: https://www.iaea.org/

16. Park A. Radiology's Future: AI and Innovation [Internet]. TIME. 2023 Nov 4 [cited 2025 Jun 1]. Available from: https://time.com/
17. Deng F, He S, Cui S, Shi Y, Tan Y, Li Z, *et al*. A molecular targeted immunotherapeutic strategy for ulcerative colitis via dual-targeting nanoparticles delivering miR-146b to intestinal macrophages. J Crohns Colitis. 2019;13(4):482–94.
18. Deng X, Rong J, Wang L, Vasdev N, Zhang L, Josephson L, *et al*. Chemistry for positron emission tomography: recent advances in 11C-, 18F-, 13N-, and 15O-labeling reactions. Angew Chem Int Ed. 2019;58(9):2580–605.
19. Geethanath S, Vaughan JT Jr. Accessible magnetic resonance imaging: a review. J Magn Reson Imaging. 2019;49(7):e65–77.
20. Xia Y, *et al*. Artificial intelligence in radiology: applications and challenges. Intell Based Med. 2020;1:100001.
21. Jaffray DA. Image-guided radiotherapy: from current concept to future perspectives. Nat Rev Clin Oncol. 2012;9(12):688–99.
22. Kickingereder P, *et al*. Radiogenomics of glioblastoma: machine learning–based classification of molecular subtypes. Clin Cancer Res. 2016;22(23):5812–21.
23. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18(8):500–10.
24. McNitt-Gray M, *et al*. The importance of reproducibility and standardization in radiomics and AI in medical imaging. Med Phys. 2020;47(6):2348–51.
25. Varghese AP, Naik S, Andrabi SAUH, Luharia A, Tivaskar S. Enhancing radiological diagnosis: a comprehensive review of image quality assessment and optimization strategies. Cureus. 2024;16(6):e63016.