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Artificial Intelligence in Radiation Oncology: A Deep Dive into the Latest Breakthroughs and Future Horizons

Artificial intelligence (AI) is revolutionizing radiation oncology, becoming a potential practice-changer from treatment planning to clinical decision-making. Recognizing this swift shift, we wanted to highlight the latest developments and to give an insightful perspective by selecting three recent manuscripts.

These articles represent three critical facets of AI in radiation oncology: ranging from real-world clinical applications, passing through incorporation into clinical trials, and coming up to the evolving perceptions of our patients.

The first article presents an innovative approach to online adaptive radiotherapy for cervical cancer, and it shows how AI-based decision-making can potentially mitigate inter-observer variability while improving treatment efficiency. This study exemplifies real-world applicability, showing AI's potential to enhance clinical outcomes.

The second manuscript provides an extensive review from NRG Oncology, exploring AI's role in automated treatment planning within radiation therapy clinical trials, addressing current advancements and the challenges ahead. In this article, the authors highlight the significant potential of AI in streamlining workflows and enhancing treatment consistency, vital aspects for successful clinical trials.

Finally, we selected a study focused on patients' perceptions of AI and machine learning within radiation oncology. Understanding how our patients view these technological advancements is crucial, as it directly affects acceptance and integration into clinical care. This cross-sectional study provides important insights into patient preferences, their desire for transparency, and the ethical considerations surrounding AI in healthcare.

Together, these manuscripts encompass the current landscape, opportunities, and challenges associated with AI in radiation oncology. They highlight the promising future ahead, underscored by the necessity of ongoing dialogue and thoughtful implementation of these powerful technologies.

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Fully Automated Online Adaptive Radiotherapy Decision Making for Cervical Cancer Using Artificial Intelligence

(Sun DS et al. Int J Radiat Oncol Biol Phys. 2025 Mar 29:S0360-3016(25)00305-0. doi: 10.1016/j.ijrobp.2025.03.045. Epub ahead of print. PMID: 40164355)

- **AI-based automation in online adaptive radiotherapy (oART)** for cervical cancer enables objective, consistent decision-making, reducing interobserver variability and improving workflow efficiency in daily radiotherapy.
- **Three predictive models** were developed to decide when oART should be triggered:
    - A machine learning (ML) model using 101 handcrafted morphological, radiomic, and dosimetric features.
    - A deep learning model using contours only (DL_C).
    - A deep learning model combining contours and dose data (DL_D).
- **DL_C demonstrated the best performance**, achieving an AUC of 0.917 and an average accuracy of 86.9%, indicating strong ability to detect anatomically significant variations using imaging features alone.
- **Heatmap analyses** showed that the deep learning models concentrated on areas where the daily FBCT-defined CTV_U diverged from the reference CT contours, indicating clinically relevant cues for triggering plan adaptation.
- **AI models outperformed physicians in triggering decisions:** the AI model reached an accuracy of up to 86.7%, outperforming the 79.5% achieved by the consensus of three radiation oncologists, and demonstrated significantly higher recall while preserving comparable precision.
- **The most frequent trigger for replanning** was insufficient target coverage (58.1%), followed by excessive small bowel dose (17.8%), and a combination of both (24.4%).
- **Model performance was consistent:** independent validation dataset was used supporting robustness and broad utilization of the approach.

- **Incorporating dose information (DL_D) slightly reduced performance**: probably related to feature integration challenges or increased input complexity causing overfitting.
- **Deep learning models showed a tendency toward higher sensitivity**: higher rates of false positives than false negatives, a favorable trade-off in clinical scenarios where missing necessary adaptations poses higher risk.
- **Main limitation:** relatively small patient cohort (24 patients, 671 fractions).
- **Future directions**: combining ML's interpretability with DL's accuracy, quantifying the expected dosimetric benefit of oART, and clinical integration through multi-institutional validation.

NRG Oncology Assessment of Artificial Intelligence for Automatic Treatment Planning in Radiation Therapy Clinical Trials: Present and Future

(Jia X et al. Int J Radiat Oncol Biol Phys. 2025 Mar 29:S0360-3016(25)00305-0. doi: 10.1016/j.ijrobp.2025.03.045. Epub ahead of print. PMID: 40164355)

- **AI-driven automation in clinical trials** might enhance planning speed, protocol compliance, and standardization, potentially ensuring high-quality treatment plans that consistently adhere to trial guidelines.
- **Interobserver variability** significantly affects plan quality, highlighting the importance of AI-driven standardization. Identical planning goals and contours can yield vastly different doses depending on planning technique or device.
- **Quality reviews in clinical trials** increasingly employ AI models trained on high-quality historical data to assess and ensure prospective plan compliance and improve overall plan quality.
- **Translational AI models** developed from clinical trial data hold potential for broader clinical application, automating routine treatment planning while maintaining high standards of care.
- **AI-based Automated Treatment Planning (ATP) leveraging deep learning** accelerates treatment planning, improves dose prediction, optimizes plan quality, and minimizes human-related variability. It can be fully automated or semi-automated, integrating human and computer intelligence.
- **Knowledge-Based Planning (KBP)** uses patient-specific anatomical and dosimetric features in machine learning models to predict optimal dose distributions, facilitating planning in IMRT and VMAT.

- **Deep Reinforcement Learning (DRL)** creates virtual treatment planners that autonomously learn and replicate human planning decisions, improving the efficiency and consistency of treatment plans.
- **Large language models (LLMs)** have potential roles in summarizing clinical trials, designing eligibility criteria, automating patient matching, and facilitating comprehensive RT plan generation through structured and unstructured data analysis.
- **Challenges to AI adoption** include algorithm transparency and interpretability, integration into clinical workflows, resistance due to concerns about job security, and resource constraints for model training and validation.
- **Regulatory and ethical concerns** underscore the need for explainable AI models, increasing clinician trust and facilitating regulatory compliance and transparency audits.
- **Resource disparities** among institutions, particularly in low-resource settings, pose significant barriers to the widespread adoption of AI-based automatic planning in clinical trials.
- **Collaborative engagement** between investigators, physicists, and dosimetrists from early trial phases is essential for successful AI model implementation, validation, and clinical adoption, ultimately standardizing optimal clinical outcomes.

AIRO GIOVANI

Radiation oncology patients' perceptions of artificial intelligence and machine learning in cancer care: a multi-centre cross-sectional study

(Chan J et al. Radiother Oncol. 2025 Apr 13:110891. doi: 10.1016/j.radonc.2025.110891. Epub ahead of print. PMID: 40233873)

- **Baseline definition** of Artificial Intelligence (AI) and Machine Learning (ML) perception by radiation oncology patients.
- **One main limitation to AI/ML integration** in daily clinical practice could be patient trust in automated cancer treatments
- **Patients with self-rated knowledge of AI/ML** resulted to be more confident in general benefits of AI/ML in radiation oncology.
- **The desire to be informed and aware of AI/ML** is the main factor influencing patient's supportiveness of the use of AI/ML in radiation oncology.
- **Patients strongly believed that anonymization represent a non-mediable condition**: The extent of data linkage and the level of detail required for certain AI/ML use cases can raise concerns about the potential for re-identification of input data. Patients' confidence in the effectiveness of anonymization means that significant effort would be needed to provide a clear and thorough explanation, ensuring valid consent is obtained for the use of their data.
- Concerns about AI/ML use remain, including the need to retain human involvement and **equity in care**. Additionally, there is a strong emphasis on ensuring that healthcare access remains equitable for all, regardless of socio-economic status, location, or other potential barriers, to prevent disparities in the treatment and care patients receive.