TECHNICAL NOTE

Artificial Intelligence-Supported Applications in Radiotherapy Treatment Planning and Dose Optimization

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1. Introduction

In recent years, doctors and specialists working in radiotherapy are constantly looking for standardization, efficiency, and stability in the treatment of patients. Artificial intelligence is defined as a discipline based on mathematics, statistics, and computer science and contains methods that are capable of imitating human intelligence. Part of artificial intelligence is dedicated to a subset that can learn "how to do things". Using "deep learning", which includes complex models based on artificial neural networks, this department can learn and perform some human activities [1]. In the medical field, such methods have been used to enable the modeling of dose-response relationships by integrating medical images and clinical features. These methods have been used to identify tumor heterogeneity or evaluate the response of normal tissue to radiation [2].

Head and Neck Cancer (HNC) includes a diverse group of malignant tumors that involve the upper part of the digestive system, namely the lips, oral cavity, nasal cavity, larynx, nasopharynx, and paranasal sinuses [3]. Contouring is a stage of radiotherapy that uses MRI and CT images to determine the exact boundaries and locations of the tumor and accordingly determines the dose and volume of drugs. The location of vital structures and the volume of clinical targets present in HNC make this process challenging. Therefore, it is prone to errors and variations between operators [4]. This process requires a high level of radiation that is delivered to a relatively small and irregular area. In HNC, a large number of organs are at risk due to the complex anatomical structure of this region. So any damage to these organs, as a result of unwanted radiation, may lead to acute and late side effects such as dry mouth and dysphagia [5]. Using deep learning and examining data from medical sources, artificial intelligence plays different roles, such as planning the treatment plan, determining the exact borders of tumors with healthy tissues, calculating the amount of radiation dose and the amount of rest time between them [6].

Treatment plans planned by specialists may deviate from the actual value due to weight loss, tumor volume reduction, or inaccuracy in positioning. These changes are not considered in the initial planning scan and should be taken into account when evaluating the actual dose received by the patient. For this purpose, the use of artificial intelligence in the planning of the treatment causes the radiation to be proportional to the change in the size of the tumor and the anatomy of the normal tissue and reduces the dose to the sensitive structures of the body. This process is called "automated treatment planning". Automated treatment planning means any process that uses some form of artificial intelligence to automatically plan treatments with a more efficient goal (Figure 1).

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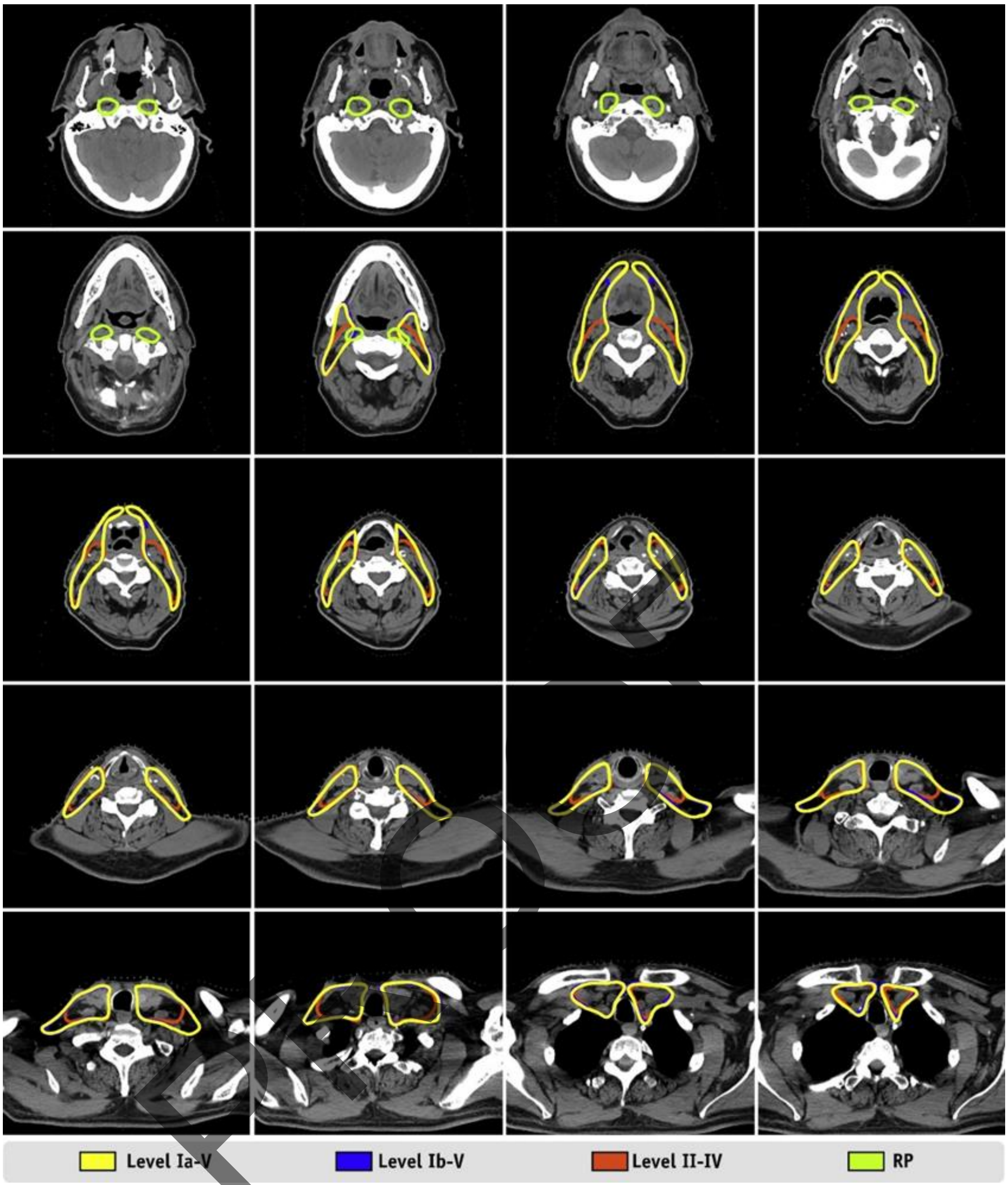

Figure 1. Selection of tumor areas and their staging by artificial intelligence

Artificial intelligence-based systems save time, resources, and costs. Also, using complex calculations, it increases the precision and accuracy of the amount of dose received by patients. However, its clinical implementation must be under the supervision of experts in this field and be approved by them [7].

2. Materials and Methods

The present study is in the form of a letter to the editor. To conduct this study, initially, published studies in reputable databases such as Pubmed, Web of Science, Scopus, and the Google Scholar search engine were reviewed using the keywords artificial intelligence, radiotherapy, head and neck cancer, in combination with machine learning, deep learning, and radiation dose, both individually and in combination, up to the year 2023. Additionally, a search for article sources was also conducted, and ultimately the studies were combined descriptively with each other.

3. Results

Our study results have shown that despite the increasing use of artificial intelligence in various stages of radiotherapy, there is a noticeable trend towards improvement. Utilizing these innovative methods can lead to a significant enhancement in treatment accuracy and efficiency. Moreover, the use of artificial intelligence systems can greatly improve the detection and treatment of cancerous diseases, especially HNC. Implementing these systems will result in increased precision in delineating boundaries and matching damaged and undamaged tissues during the contouring phase [8]. Artificial intelligence systems can automatically determine the appropriate treatment dose for each patient, which can lead to improved treatment outcomes due to the reduction of human errors. In this method, precise analysis of radiotherapy images by artificial intelligence systems will enhance the accuracy of delivering the proper dose to the patient. Furthermore, reducing the time required for treatment planning and dose adjustments through artificial intelligence algorithms is another advantage of this approach [4].

Some other benefits of using these systems instead of fully manual treatment methods include the possibility of more precise and faster treatment planning for delivering treatment plans to patients, increased confidence in results determined by artificial intelligence systems, cost reduction associated with dose adjustments, and precise treatment planning, the ability to utilize more complex data to improve treatment outcomes, and the potential for enhancing treatment outcome predictions and increasing treatment efficiency [9].

Despite the numerous advantages of artificial intelligence systems in radiotherapy, some individuals may have less trust in them due to a lack of transparency in their performance. In this regard, the need for proper training and implementation of artificial intelligence systems for use in radiotherapy is essential to maintain public trust. Additionally, neglect in updating and maintaining artificial intelligence systems may lead to a decrease in trust and suboptimal performance [10]. Following the challenges that arise in using artificial intelligence, maintaining sensitive patient information processed by these systems and preserving their privacy are unavoidable issues that can impact the perspectives of both physicians and patients towards these systems.

Based on our study results, it can be stated that the use of artificial intelligence in the treatment of malignant diseases such as HNC, alongside ensuring the security and privacy of patient data processed by artificial intelligence systems, can lead to a significant transformation in the field of radiotherapy. This transformation aims to provide precision and accuracy during treatment stages such as contouring and optimization of the received dose for patients.

4. Discussion

In recent years, there has been a noticeable expansion of studies related to the application of artificial intelligence in radiotherapy. Currently, recent studies have recognized the integration of traditional methods with artificial intelligence systems in the contouring stage as one of the best therapeutic options for achieving better efficiency [8].

One strategy utilizing Machine-Learning (ML), which includes models like support vector machines, is knowledge-based planning. In this approach, features like organ and target distances or the number of beams are input into an ML model that predicts characteristics of the dose distribution, such as Dose Volume Histograms (DVH) points. These predictions can then be utilized in an optimizer as objectives, enabling an automated process [9]. In more recent developments, Deep Learning (DL) methods, specifically utilizing U-nets, have been employed to predict an entire dose distribution instead of a restricted set of DVH points. This approach enables the optimizer to directly aim for achieving that specific dose distribution.

However, despite these advancements, there is still a generally negative perception from some patients and healthcare providers regarding the use of artificial intelligence in such healthcare practices, and there is not a clear consensus on its contribution to improving patient care and knowledge [10].

5. Conclusion

The integration of artificial intelligence in cancer radiotherapy, through machine-learning and deep learning methods, offers promising avenues for enhancing treatment planning and dose distribution prediction. While some challenges and concerns exist, such as negative perceptions from patients and healthcare providers, the potential benefits of optimizing treatment outcomes and efficiency cannot be overlooked. Continued research and development in this field hold the key to unlocking the full potential of AI in cancer radiotherapy.

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