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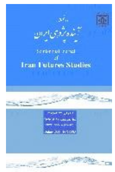

Identifying trends in the use of artificial intelligence in new treatment techniques with linear accelerators and brachytherapy: A case study of the use of U network

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Abstract

Introduction: Medical physics specialists face problems due to the complexity and time-consuming design of radiation therapy. Various studies have pointed out the importance and role of artificial intelligence in radiation therapy and accelerating and improving its quality. This research examines and analyzes the possibility of using the U network to improve the design of radiation therapy as a technique to modify radiation therapy with a future-oriented approach.

Methods: To achieve this research goal, trend analysis has been used as one of the main methods of future research. The development path of the U network was examined in authoritative articles, and then by extrapolating the future development path, the application of this technique in radiation therapy was investigated. According to Prisma 2020 guidelines, study selection processes, screening, and inclusion and exclusion criteria were defined.

Findings: Among the 28 articles studied, 20 articles were selected for further evaluation. The evaluation of the trend of U network strategies in different fields of radiotherapy showed that the use of U network will lead to better performance than traditional methods and more effectiveness and reduction of human error in radiotherapy treatment design.

Conclusion: Considering the future trends of the use of the U network in different fields of radiotherapy and the growth of the statistics of articles in this field, which shows the increasing interest in the research and development of artificial intelligence technologies, it is expected that in the future, by solving the existing challenges, the development of the application of artificial intelligence technologies in the Radiation therapy centers, reducing treatment costs and improving the treatment process in the field of radiation therapy.

Keywords: Radiation therapy, U network, Trend analysis, Treatment design, Treatment Process

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Introduction

Foresight, as a scientific and practical field, examines future trends and predicts possible developments in various areas (Moradi H et al.; 1384). This science helps us to envision a brighter future by better understanding today's changes (Minaei H et al.; 1397). In the medical field, foresight holds special significance as it studies and predicts technological, social, and economic transformations related to health and treatment. This domain enables researchers to make better decisions by accurately identifying existing trends and recognizing future challenges and opportunities, thus facilitating the improvement of medical services. Rapid advancements in information technology and artificial intelligence have created fundamental changes in the diagnosis and treatment of diseases, potentially leading to reduced costs and improved quality of life for patients (Garson and Levin 2001).

Identifying trends is an important tool for forecasting future developments. Researchers collect historical data and identify existing trends, analyzing patterns to recognize influential events in these trends (Gordon 2010). In the context of cancer diagnosis and treatment, there are multiple challenges that artificial intelligence has significantly improved in diagnostic processes.

The use of artificial intelligence and deep learning technology in medicine has brought about notable transformations, particularly in disease diagnosis through precise analysis of medical images (Stahl BC et al., 2023). Deep neural networks like U-Net are designed for processing medical images and are applied in early disease detection (Ozaltin O et al., 2023). Despite these advancements, challenges such as algorithm accuracy and privacy issues persist (Siddique and Chow 2020, Shur, Doran et al. 2021). This research aims to understand the capabilities of artificial intelligence in modern radiotherapy techniques and analyze its evolving trends.

Methodology

The present research is a foresight study aimed at identifying the trends in the application of the U-Net network in various radiotherapy fields. The research method is a case study based on trend identification techniques. Case studies are common in qualitative research, where the researcher gathers firsthand information about the topic and derives analytical, perceptual, and classification descriptions from the collected data. A trend consists of a series of logically related events, allowing the researcher to predict related events, analyze others' actions, and envision future scenarios.

The literature review involved searching for articles in three databases: Google Scholar, PubMed, and ScienceDirect, using various keyword combinations

related to U-Net and radiotherapy. Twenty-three articles meeting the criteria were selected and classified based on the type of radiotherapy for clarity in analysis. Each study's data included authors, publication year, study objectives, methodology, and main findings (advantages and limitations).
This research provides a comprehensive examination of U-Net's use in radiotherapy, following PRISMA guidelines as a minimum evidence-based standard for reporting systematic reviews and meta-analyses. PRISMA focuses on evaluating intervention effects but can also serve as a basis for systematic reporting.

Results

In the article screening process, three articles identified as critiques or letters to the editor were removed initially. Subsequently, three additional articles that did not focus on the research objective and U-Net methodology were excluded after reviewing titles and abstracts. Ultimately, 20 articles were selected for review after a thorough examination of 22 articles, with two being discarded due to the absence of case studies or dataset descriptions.
The number of articles on AI applications in radiotherapy increased significantly from 2019 to 2023, with the highest number of articles (17,600 or 27%) published in 2023. This reflects growing interest in AI's potential to improve treatment accuracy and efficiency. The review also highlights an increase in articles specifically related to U-Net applications in radiotherapy, with the number rising from 648 in 2019 to 2,760 in 2023. The study categorizes six types of radiotherapy: brachytherapy, intensity-modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT), stereotactic radiosurgery (SRS), targeted radionuclide therapy (TRT), and proton therapy. The various strategies of the U-Net model for different types of radiotherapy are summarized as follows:

1. Providing a deep learning-based system for high-dose brachytherapy
2. Automatic segmentation and reconstruction of the applicator
3. Reducing treatment planning time
4. Reducing errors
5. Increasing accuracy
6. Creating personalized brachytherapy conditions

U-Net Strategies for Enhancing IMRT Techniques:

1. Dose prediction
2. Dose verification
3. Beam angle optimization
4. Potential for online techniques
5. Accurate predictions

6. High speed
7. Error reduction
8. Creating personalized treatment conditions

U-Net Strategies for Enhancing SRS Techniques:

1. Tumor identification and separation
2. Prediction of dose during the procedure
3. Reducing time requirements
4. Potential for developing high-quality treatment plans

U-Net Strategies for Enhancing VMAT Techniques:

1. Dose distribution prediction
2. Achieving high accuracy
3. Reducing treatment design time
4. Generating pseudo-CT images
5. Predicting dose maps

U-Net Strategies for Enhancing TRT Techniques:

1. Automatic characterization of lesions
2. Excellent potential for use in real-time clinical settings

U-Net Strategies for Enhancing Proton Therapy Techniques:

1. Proton dose calculation
2. Increasing accuracy
3. Reducing treatment planning time
4. Improving image quality
5. Creating suitable treatment plans

For brachytherapy, strategies include deep learning systems for high-dose treatments and automatic segmentation. For IMRT, strategies encompass dose prediction and optimization. SRS strategies focus on tumor identification and treatment planning. VMAT strategies involve dose distribution prediction and accuracy enhancement. TRT emphasizes automatic lesion characterization, while proton therapy strategies include dose calculation and improved treatment planning. Overall, U-Net demonstrates significant potential in advancing radiotherapy techniques across multiple modalities.

Future trends in U-Net applications in radiotherapy are anticipated as follows:

Brachytherapy: Increased accuracy in automatic applicator reconstruction and enhanced individualized dosimetry using deep learning will reduce

treatment planning time. Improved digitalization of needles and advancements in MR-IGABT imaging techniques are expected.
IMRT: Deep learning will optimize beam angles, develop online techniques for real-time dose prediction, and integrate physician preferences into dose forecasting. Enhanced accuracy for complex configurations and improved dose verification tools are anticipated.
SRS: Enhanced accuracy in identifying small tumors is expected, along with reduced false-positive rates compared to human assessments. AI decision support systems will be developed, improving dose prediction for gamma knife procedures.
VMAT: Predictive capabilities for various doses will expand, with increased accuracy and comprehensive treatment planning based on predicted dose distributions. Enhanced data diversity and GPU performance will reduce processing times.
TRT: Automatic lesion characterization in PET/CT will improve, with advancements in radionuclide dosimetry. The adoption of deep learning algorithms in clinical practice is expected to accelerate, enhancing detection and segmentation speed and accuracy.

Conclusions

The use of U-Net in radiotherapy presents both advantages and limitations that must be considered for effective implementation. U-Net can enhance various stages of the radiotherapy process:

1. Treatment Planning: By analyzing pre-treatment images, U-Net aids in identifying regions and fine-tuning radiation doses.
2 .Treatment Monitoring: It tracks changes in treatment areas, facilitating dynamic adjustments.
3. Post-Treatment Evaluation: U-Net provides detailed analyses of changes after treatment, aiding decisions for supplementary therapies.
4. Increased Accuracy and Efficiency: Improved precision and reduced errors in dose delivery can lower patient costs.

Despite its benefits, challenges such as data limitations and model generalization hinder the clinical application of deep learning approaches like U-Net. Future research should focus on data acquisition mechanisms in clinical settings. Additionally, the memory-intensive nature of U-Net, especially with 3D models, complicates implementation; thus, most studies have concentrated on 2D structures. However, 3D analysis could significantly enhance understanding, particularly in cancer diagnosis.
Future studies should evaluate the practical reduction of treatment costs using U-Net and report relevant statistics to persuade healthcare facilities to adopt this method. Enhancements to U-Net can further improve diagnostic and

treatment quality. This article assesses various applications of U-Net in radiotherapy, helping specialists focus on existing challenges.
Collaboration between radiation oncologists and AI experts will facilitate better identification of challenges and solutions in radiotherapy. Furthermore, training programs for healthcare professionals on intelligent technologies are essential for raising awareness about AI's potential in clinical settings. This study enables the selection of appropriate solutions for existing challenges and the development of current algorithms in radiotherapy.

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