ADVANCES IN ARTIFICIAL INTELLIGENCE FOR BRAIN TUMOR DIAGNOSIS, PROGNOSIS AND PREDICTIVE TREATMENT

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I. ABSTRACT

This paper explores the latest developments in the application of artificial intelligence (AI) in neuro-oncology, with a focus on gliomas, a class of brain tumors that pose a serious threat to world health. AI has revolutionized the treatment of brain tumors by leveraging genetic, histopathological, and imaging technologies for effective diagnosis, classification, outcome prediction, and treatment planning. When it comes to accuracy and specificity, AI models beat human judgments in all areas of managing malignant brain tumors, including diagnosis, prognosis, and therapy. This paper discusses AI methods, emphasizing their contemporary applications, ranging from deep learning to conventional machine learning.

Keywords: Artificial Intelligence, Brain Tumor, diagnosis, prognosis.

II. INTRODUCTION

Even though they are rare, brain tumors represent a major global health concern, with about 250,000 new cases reported year. In 2022, there were over 96,000 cases of brain tumors reported in the US alone, with about 26,600 of those cases being malignant. The most common kind of brain tumor to be identified is glioblastoma, which has a particularly dismal prognosis—just 7% of patients survive the tumor five years after diagnosis. This emphasizes the critical need for better ways to identify brain tumors, treat them, and predict how they will progress (1).

In neuro-oncology, artificial intelligence (AI) is a promising technique that is now tackling issues at different phases of therapeutic care. AI shows promise in brain tumor management in diagnosis, prognosis, and treatment planning by improving and speeding up MRI imaging, spotting anomalies, streamlining processes, giving precise measurements, analyzing large amounts of medical imaging data, and seeing patterns that are difficult for human observers to notice. By offering comprehensive image analysis for diagnostics, tumor grading, prognosis determination, and treatment response assessment, it has greatly advanced the area. Artificial Intelligence (AI) is essential in clinical neuroimaging for tasks including tumor kind and boundary identification, pre-treatment planning optimization, and post-treatment response evaluation (2).

Growing research has been done on incorporating AI tools into workflows related to pathology and radiology, which may lead to breakthroughs in neuro-oncology. Artificial Intelligence (AI) provides a complete framework for brain tumor analysis, encompassing computer vision (CV), deep learning (DL), and machine learning (ML) approaches. These techniques are then integrated with computational biology.

AI makes use of a variety of data types, such as radiomics from tumor cells, clinical data, and imaging data from CT and MRI scans. In neuroimaging, pre- and post-contrast T1-weighted, T2-weighted, diffusion-weighted (DWI), susceptibility-weighted imaging (SWI), fluid-attenuated inversion recovery (FLAIR), and T1-weighted imaging are frequently used. In specialist institutes, MR spectroscopy and perfusion imaging are also utilized. There are various systems being investigated to forecast IDH and other mutations based on radiomics data from MRI perfusion scans or 18F-FET PET/CT scans. These systems include Terahertz spectroscopy and deep learning imaging signatures (DLIS).

III. Advancements in AI-assisted preparation for accurate brain tumor diagnosis

The difficulties of navigating brain anatomy and tumor variability have been solved in brain tumor analysis by AI, which has also greatly improved preprocessing procedures that are essential for precise diagnosis, prognosis, and treatment planning shown in fig.1. AI-powered techniques, like those included in the BrainNet viewer, address problems with spatial consistency by correcting distortions and aberrations in MRI images. More accurate tumor localization and segmentation are made possible by this adjustment, which is essential for efficient brain tumor investigation.

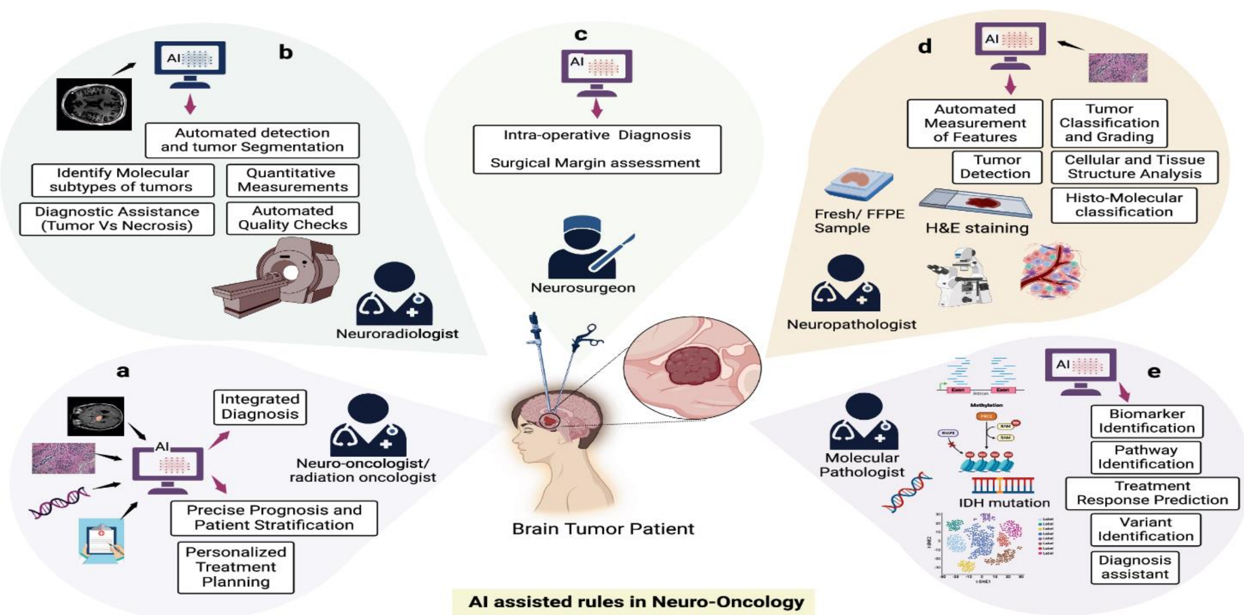

Fig 1. AI-empowered multidisciplinary brain tumor management.

IV. AI for diagnosing Brain Tumors

Identification and characterization of abnormal growths or masses inside the brain are necessary for the diagnosis of brain tumors. A variety of pathological, clinical, and medical imaging techniques are used to ascertain the kind, location, and characteristics of the tumor. Classifying brain tumors is essential for diagnosis, prognosis, and treatment planning since they differ according to their origin, location, histology, malignancy, and patient age. There are several kinds of these tumors, and each one has unique cellular origins and histological characteristics.

While most current studies seek to construct prediction, models trained using imaging data, pathology data, or both data modalities combined, AI can be useful at all stages of tumor diagnosis. Potential exists for the use of AI models in brain tumor diagnosis, especially when it comes to utilizing quantitative image analysis techniques to differentiate between gliomas and isolated brain metastases. Pathologic tests offer a more detailed look at the tumor's cellular and molecular characteristics, while neuroimaging offers a unique view into the full, unmodified tumor. As a fundamental component of artificial intelligence, machine learning (ML) is advancing the field of brain tumor diagnostics by improving tumor type distinction, speeding up image analysis, improving accuracy, and enabling early detection. Recent advancements in DL, ML, and CV have the potential to resolve issues and enhance patient care in the diagnosis of brain tumors.

V. AI in the Prognosis of Brain Tumors

In neuro-oncology, prognosis is calculating the rate at which a patient's disease will progress while taking treatment strategy, disease stage, and location into account. Progression-free survival (PFS) and overall survival (OS) are important parameters that help determine prognosis and direct treatment. Artificial Intelligence is a key factor in improving prognostic capacities in brain tumor treatment. By using features taken from pre-treatment imaging data, ML and DL algorithms are being used more and more to forecast OS and PFS. Prominent research indicates that radiomic characteristics from T1 and FLAIR MRI scans of individuals with glioblastoma, as well as T1, T2, and FLAIR scans from patients without treatment, hold great promise for predicting PFS and OS. When paired with clinical characteristics in glioblastoma patients, the AI models perform better than standard clinical factors. Surprisingly, models built using T2-weighted MRI and radiomic characteristics from peritumoral edema show correlations with molecular subtype, site of recurrence, and survival outcomes, particularly in patients with glioma and glioblastoma. Tumor identification and recurrence location prediction are done using DL-based models, sometimes even ahead of radiologists. These models demonstrate AI's remarkable forecasting powers by utilizing a variety of imaging techniques.

VI. AI in Brain Tumor Therapeutic management

AI has been applied to improve treatment response evaluation and planning for brain tumors, in addition to enhancing diagnostic and prognostic skills. It helps in the detection and characterization of brain tumors, which changes treatment strategies and improves accuracy. It helps medical professionals choose the best course of action for each patient. This complex procedure uses a variety of methods, such as imaging, clinical evaluations, biopsies, and molecular analysis, to accurately identify the presence, kind, location, and extent of tumors.

Because AI-based techniques are so good at predicting therapeutic responses, treatment planning for a wide range of tumors can be improved. AI's effectiveness is demonstrated by novel approaches, such as forecasting responses to radiation therapy using predictive models based on pre-treatment ADC maps and using radiomic features from contrast-enhanced T1 and FLASH scan to predict responses to gamma knife radiosurgery for metastatic brain tumors. Across multicenter patient populations, integrated models that integrate radiomics and clinical characteristics efficiently evaluate the effects of radiation therapy on patients with brain metastases from primary breast and lungs cancer.

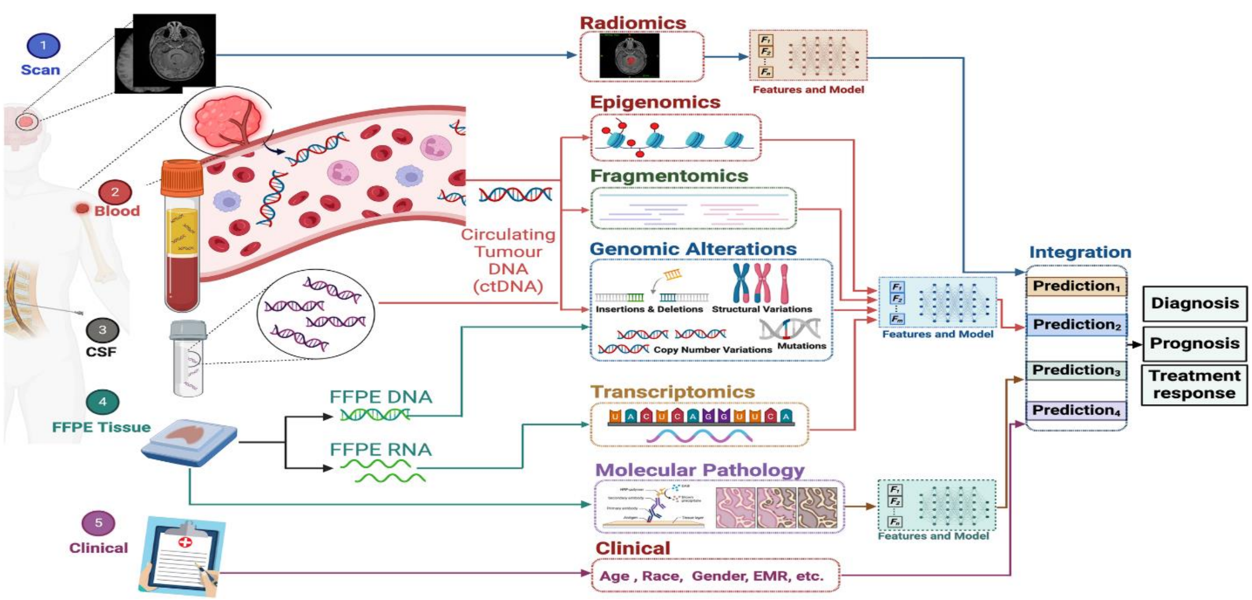

Fig.2: Multimodal integration for enhanced diagnosis, prognosis, and treatment response prediction in brain tumors.

VII. Multimodal integration

Although they come with time and cost challenges, multimodal imaging modalities like MRI, CT, and PET add a rich layer to the integrative tapestry. Multimodal imaging greatly improves diagnostic accuracy when combined with clinical expertise and other diagnostic data. AI-enabled genomics and radiomics integration emerges as a transformative force in the study and treatment of brain cancers shown in figure 2.

CONCLUSION

This study looked at the revolutionary uses of AI in brain tumor treatment, such as CV, ML, and DL. When it comes to diagnosis, prognosis, and treatment planning, AI's ability to identify and categorize brain tumors from medical images holds great potential. AI is vital to treatment planning, optimization, and response prediction, enabling tailored suggestions and real-time tracking.

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