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A REVIEW ON RECENT ADVANCES IN BRAIN TUMOR AND MODERN TECHNOLOGIES

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ABSTRACT

Brain tumors occur when cells in the brain grow and multiply too quickly. Detecting these tumors early is very important because it can save many lives. Brain tumors can be grouped into different types based on where they start, how fast they grow, and how far they have developed. Correctly identifying the type of tumor is necessary for choosing the best treatment.Braintumor segmentation means marking the exact area where the tumor is located in brain images. Doctors can do this manually, but it requires a lot of expertise, and checking many images can be very slow and tiring. Because of this, automatic methods for identifying and separating tumor regions are needed to make diagnosis faster and more accurate.

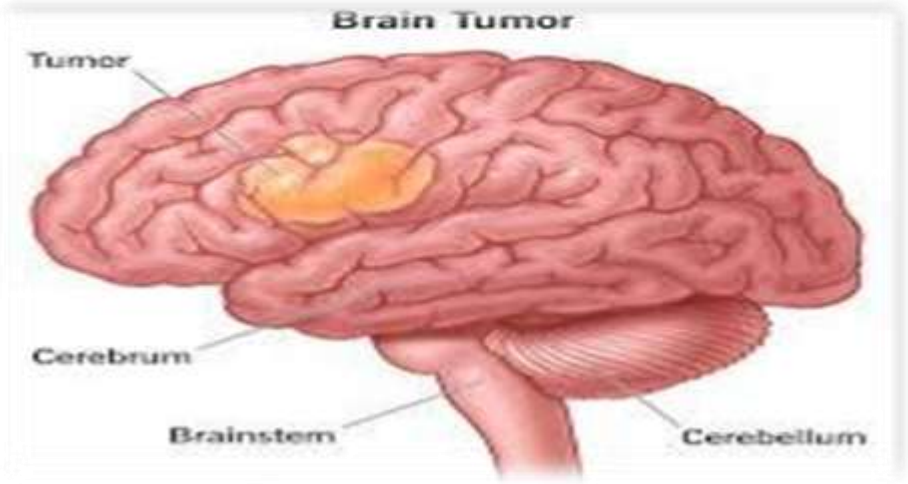
Brain imaging methods such as CT scans and MRI scans help detect tumors safely and quickly. Today, machine learning (ML) and artificial intelligence (AI) techniques are being used to automatically classify and segment brain tumors from these images. The quality of the segmentation method greatly affects how accurately tumors can be identified, which directly influences diagnosis and treatment decisions.

This review explains different types of brain tumors, available public datasets, image enhancement techniques, segmentation methods, feature extraction processes, and classification approaches. It also covers machine learning methods, deep learning models, and transfer learning techniques used for brain tumor detection. The goal of this study is to combine brain imaging technologies with computer-based methods to improve brain tumor analysis. It also highlights current challenges in these engineering methods and suggests future directions for better diagnosis systems.

INTRODUCTION

The human brain is the main control center of the body. It helps us think, speak, feel emotions, and respond to different environments. It is made up of three major tissues: cerebrospinal fluid (CSF), white matter (WM), and gray matter (GM). Gray matter contains nerve cells that control most brain activities, while white matter contains long nerve fibers that connect different brain regions. The two halves of the brain, the left and right hemispheres, are connected by a thick band of white-matter fibers called the corpus callosum. A brain tumor occurs when brain cells start growing in an abnormal auncontrolled Because the skull is a hard, fixed space, any unexpected growth can pupressure on the brain and affect how it functions. In some cases, the tumor can also spread to other parts of the body, causing even more serious problems. Fign.1 Affect of brain tumor

Fig no. 01 : View of Brain Tumors



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Detecting cancer early is very important because it allows doctors to plan effective treatments. Once cancerspreads, it becomes much harder to cure, and survival chances decrease. Early detection using fast and affordable diagnostic techniques could save many lives. Brain tumors can be diagnosed using either invasive or noninvasive methods. A biopsy is an invasive procedure in which a small sample of the tumor is removed and examined under a microscope. This method is considered the most accurate way to confirm cancer. Noninvasive methods include physical examinations and imaging techniques such as CT scans and MRI scans. Compared to a biopsy, these scans are faster and safer, and they help doctors detect brain abnormalities, monitor disease progression, and plan surgeries.

However, interpreting brain scan images can be challenging. The results depend heavily on the radiologist's experience, and different doctors may interpret the same image differently. To reduce errors, computer-aided diagnosis (CAD) systems are now being used. These systems provide computer-generated results that support radiologists in identifying abnormalities more accurately and in less time.Recent CAD systems use artificial intelligence techniques such as machine learning (ML) and deep learning (DL) to classify tissues and segment brain tumors automatically. Segmentation—the process of marking the exact tumor region in the image—is especially important. It helps determine which areas of the brain are affected. But segmenting tumors in MRI images is difficult because of noise, low contrast, unclear boundaries, and differences in tissue appearance.

Brain tumors vary greatly in size, shape, and location. Manual segmentation takes a lot of time and effort. Therefore, automatic and semi-automatic segmentation methods using AI have become essential tools in medical diagnosis. Before treatment such as surgery, radiation, or chemotherapy, doctors must precisely identify the tumor's size, shape, and location. This review examines different algorithms used to detect and segment brain tumors

TYPES OF BRAIN TUMORS

Brain tumors can be grouped based on:Where they start
(in the brain or in another part of the body)
They are mainly divided into two big categories:

1.Primary Brain Tumors

These tumors start inside the brain

A. Benign (Non-cancerous) Tumors

These tumors grow slowly and usually do not spread to other brain are

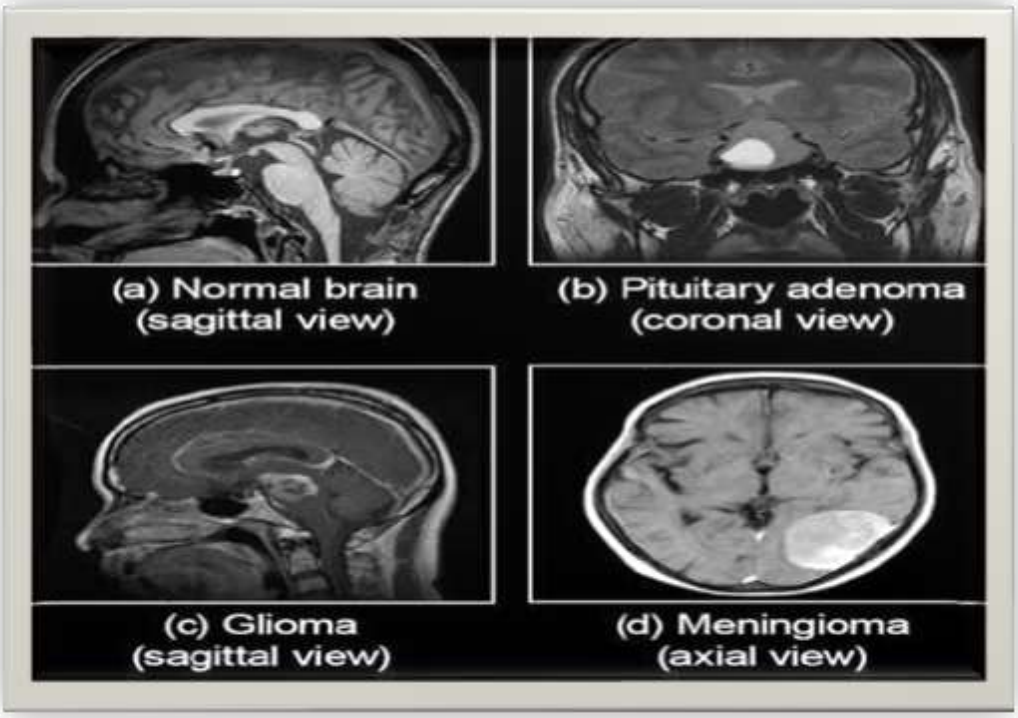

Fig no. 02 : Overview of Brain tumor tupes

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1.Meningioma
- Develops from the protective layers (meninges) around the brain.
- Usually slow-growing.

2.Pituitary Adenoma
- Starts in the pituitary gland.
- Can affect hormone levels.

3.Schwannoma (such as acoustic neuroma)
- Starts from Schwann cells that surround nerves.
- Can affect hearing and balance.

4.Craniopharyngioma
- Found near the pituitary gland.
- Common in children.

B. Malignant (Cancerous) Tumors

These tumors grow quickly and can invade nearby brain tissue.

1.Gliomas

These come from glial cells, which support the brain's nerve cells.

Gliomas are the most common type of brain tumor.

Types of gliomas:

Astrocytoma
- Comes from star-shaped cells called astrocytes.
- Can be slow-growing or very aggressive.

Glioblastoma (GBM)
- The most aggressive type of astrocytoma.
- Grows very fast and spreads easily.

Oligodendroglioma
- Comes from cells that make the myelin covering of nerves.
- Usually grows slower than GBM.

Ependymoma
- Begins in the cells lining the brain's ventricles (fluid-filled spaces).
- Seen in both children and adults.

1.Medulloblastoma
- Very fast-growing and cancerous.
- Common in children.
- Starts in the cerebellum (back part of the brain).

1.ineal Region Tumors
- Grow in or near the pineal gland.
- Examples: pineoblastoma, pineocytoma.

2) Secondary (Metastatic) Brain Tumors

These tumors do not start in the brain.They spread to the brain from cancers in other parts of the body.

Common cancers that spread to the brain:
- Lung cancer
- Breast cancer
- Melanoma (skin cancer)
- Kidney cancer
- Colon cancer

PATHOPHYSIOLOGY OF BRAIN TUMORS

The pathophysiology of a brain tumor means how it develops, grows, and affects the brain. It explains the biological changes that happen from the moment normal brain cells turn into tumor cells.

1. Abnormal Cell Growth Begins

A brain tumor starts when normal brain cells stop following the rules of cell growth.

This can happen because of:

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- DNA damage or mutations
- Genetic changes inherited or acquired
- Exposure to radiation
- Environmental factors
- Random cell errors during division
- Because of these changes, the cells:
- Do not stop dividing
- Do not die when they should
- Start growing too fast
- Become abnormal in shape and function

2. Formation of a Tumor Mass

As these abnormal cells keep multiplying, they form a lump (mass) of tissue.
This mass is called a tumor.Even if the tumor is non-cancerous, it still takes up space inside the skull.

3. Pressure Inside the Skull Increases

The skull is a closed, hard box.
There is no extra space, so when a tumor grows, it causes:
Increased intracranial pressure (ICP)
Compression of nearby brain tissue
Reduced blood supply to some areas
Swelling (edema) around the tumor
This pressure leads to symptoms such as:

- Headache
- Vomiting
- Vision changes
- Seizures
- Weakness or speech problems

4. Tumor Invades or Damages Brain Tissue

Cancerous (malignant) tumors often:
Grow very fast
Invade nearby healthy tissue
Destroy normal brain cells
Spread along white-matter tracts
This disrupts the brain's ability to control body functions like movement, speech, vision, and memory.

5. Tumor Creates Its Own Blood Supply (AngiogenesisTo grow larger, the tumor needs more oxygen and nutrients.

So it releases chemicals that cause new blood vessels to form around it.This process is called angiogenesis.
It helps the tumor grow even faster.

6. Brain Edema (Swelling) Develops

The tumor leaks abnormal chemicals that make nearby brain tissue swell.This is called vasogenicedema.
It increases pressure even more and worsens symptoms.

7. Secondary Changes Occur

As the tumor grows, it can cause:
Blockage of CSF flow, leading to hydrocephalus
Shifting of brain structures (midline shift)
Deterioration of nerve connections
Metabolic imbalance
In malignant tumors, cells may also spread within the brain or spinal cord (but usually not to distant organs).

CAUSES OF BRAIN TUMORS

Causes Brain tumors can happen for different reasons, but in many people the exact cause is not known. Most of the time, it happens because of a mix of genes and environment, not just one thing.

1. Genetic Causes (Family-Related)

Sometimes, people are born with certain genetic problems that can increase the chance of getting a brain tumor.
These conditions are rare.

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Examples:Neurofibromatosis
Li-Fraumeni syndrome
Von Hippel–Lindau disease
Tuberous sclerosis
But in most cases, brain tumors happen due to random changes in cells, not because of parents.

2. Radiation Exposure

Exposure to strong radiation, like radiation treatment given to the head (especially in childhood), can increase the risk of brain tumors.
But everyday things like:

- X-rays
- CT scans
- Airport scanners

Have very low radiation and are not known to cause brain tumors.

3. Weak Immune System

People whose immune system is very weak because of illness or medicines can develop certain rare types of brain tumors, like CNS lymphoma.

4. Environment and Lifestyle

Here, the research is not very clear.
Mobile phones: No strong proof that they cause brain tumors.
Chemicals (pesticides, petrol products): Some studies say yes, some say no — nothing confirmed.
Smoking and alcohol: Not strongly linked to brain tumors.

5. Age and Sex

Some brain tumors are more common in children, others in adults.
Some types happen slightly more in men, and some in women.

ADVANCES OF BRAIN TUMORS

Doctors choose the treatment based on where the tumor is, how big it is, what type it is, and the patient's health.Modern medical science has many new advanced methods.

✅ 1. Surgery (Modern Techniques)

- Microsurgery: Surgery done with a microscope to remove the tumor safely.
- Neuronavigation: Works like a GPS for the brain, helping doctors find the exact tumor spot.
- Awake Brain Surgery: Patient stays awake so doctors can protect speech and movement areas.
- Endoscopic Surgery: Uses a small camera inside the brain; only a small cut is needed.

✅ 2. Radiation Therapy

- Stereotactic Radiosurgery (Gamma Knife, CyberKnife):Very accurate radiation that hits only the tumor, without cutting the head.
- Proton Beam Therapy:Very safe for children; affects only the tumor, not healthy tissue.
- IMRT:Shapes radiation beams to fit the tumor's shape exactly.

✅ 3. Chemotherapy

Medicines that kill cancer cells.
Types:

- Tablets/Oral chemo (like Temozolomide)
- Targeted chemo – attacks the tumor cells more directly, with fewer side effects

✅ 4. Targeted Therapy

Medicines that attack specific parts of cancer cells.
Examples:

1. Bevacizumab – stops the tumor from getting blood supply
2. EGFR inhibitors – useful for certain tumor types

✅ 5. Immunotherapy

Helps the body's immune system fight the tumor.
Includes:

- Checkpoint inhibitors

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- Cancer vaccines
- CAR-T therapy (still in testing stages)

✅ 6. Tumor Treating Fields (TTF)
A wearable device that uses gentle electrical fields to slow down tumor growth.
Commonly used for glioblastoma.

✅ 7. Clinical Trials
Patients can get new experimental treatments that are still being studied.

PRECAUTION FOR BRAIN TUMORS PATIENTS
These help keep the patient safe and comfortable.

- 1. Regular Check-ups
  - Do MRI/CT on time
  - Tell the doctor if any new problem appears
- 2. Avoid Stress & Heavy Work
  - No heavy lifting
  - Avoid tiring activities
  - Rest is very important
- 3. Healthy Diet
  - Eat fruits and vegetables
  - Eat protein-rich foods (eggs, pulses, milk, chicken)
  - Avoid junk food and too much sugar
- 4. Prevent Seizures
  - Take seizure medicines every day
  - Avoid bright flashing lights
  - Sleep properly
- 5. Protect From Infections
  If immunity is low:
  - Avoid crowds
  - Wash hands often
  - Avoid contact with sick people
- 6. No Alcohol & Smoking

These slow down recovery and may affect medicines.

- 7. Mental Health Care
  - Talk to a counselor
  - Do meditation
  - Stay close to supportive people
- 8. Stay Safe at Home
  - Walk slowly
  - Avoid wet/slippery floors
  - Have someone nearby if you feel dizzy
- 9. Follow Doctor's Instructions
  - Take medicines on time
  - Never change medicine dose yourself

 # ARTIFICIAL INTELLIGENCE (AI) IN BRAIN TUMOR
•AI helps doctors:
- Detect tumors faster
- Predict tumor growth
- Plan safer surgeries
- Personalize treatment

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• Robotic Surgery
- Robots help surgeons perform very precise and steady movements during brain surgery.

MODERN TECHNOLOGY AND AI TECHNOLOGY:

The some modern technologies are including in the brain tumors

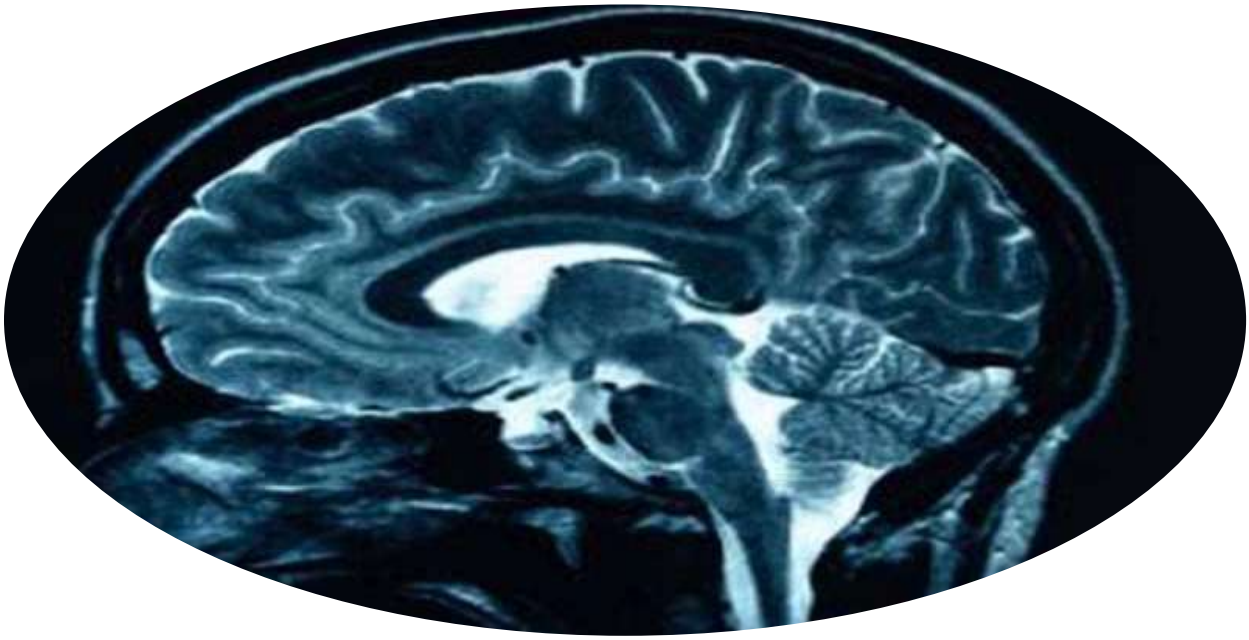

Fig no. 2 MRI SCAN

✅ MRI Scan

- Takes clear pictures of the brain to show where the tumor is.

✅ fMRI Scan

- Shows which part of the brain is used for speaking, moving, thinking — helps doctors avoid these areas during surgery.

✅ DTI Scan

- Shows important brain wires (nerve pathways) so doctors don't damage them.

✅ PET Scan

- Shows how active or aggressive the tumor is.

2. Modern Surgery Tools

⭐ Neuronavigation (Brain GPS)

Works like Google Maps inside the brain.
Helps surgeons reach the tumor safely.

⭐ Intraoperative MRI (iMRI)

MRI machine used during surgery to check if the tumor is fully removed.

⭐ Awake Brain Surgery

Patient is awake so doctors can protect speech and movement areas.

⭐ Laser Therapy (LITT)

A small laser heats and destroys the tumor — no big cut needed.

⭐ Endoscopic Surgery

Uses a thin tube with a camera to remove deep tumors with tiny cuts.

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3.Radiation Technologies

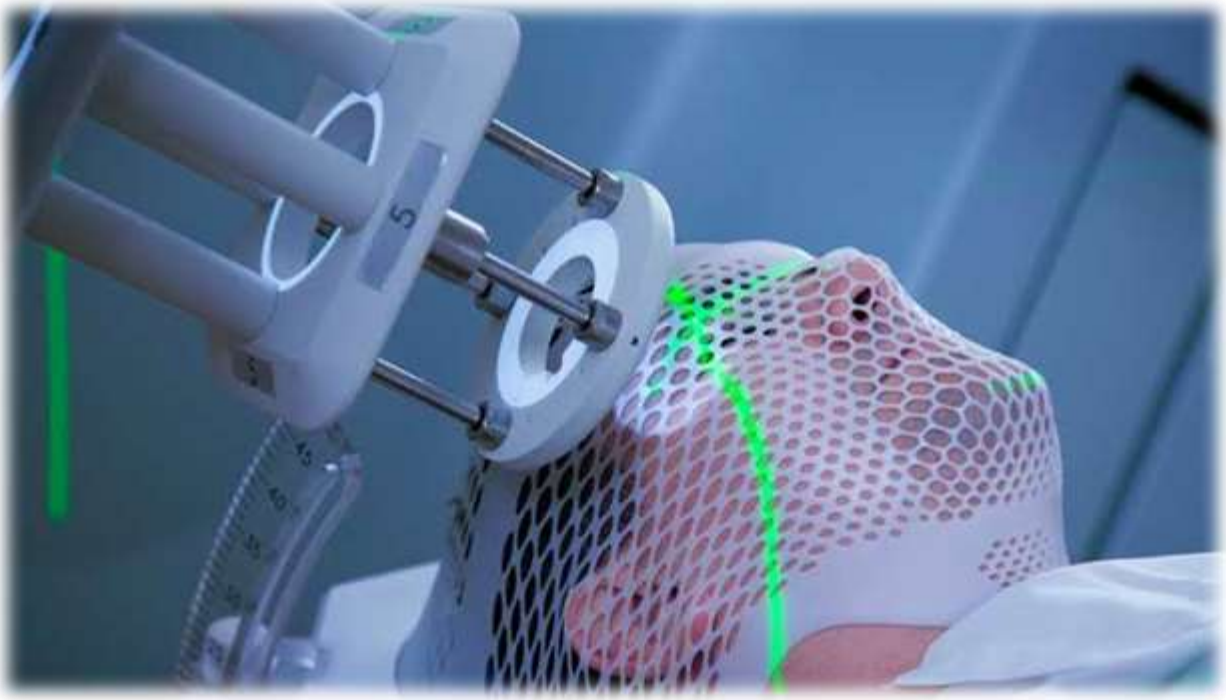

Fig no. 03 : Radiation Therapy

🎯 Gamma Knife
A very focused beam of radiation kills the tumor without surgery.
🎯 CyberKnife
A robot gives precise radiation, even to hard-to-reach tumors.
🎯 Proton Therapy
Uses proton beams that stop exactly at the tumor and avoid healthy tissue.

4. Modern Medicines

💉 Targeted Therapy
Medicines that attack only tumor cells, not healthy cells.
💉 Immunotherapy
Helps the body's own immune system fight the tumor.
💉 Tumor Treating Fields (TTF)
A cap worn on the head that uses electrical waves to slow tumor growth.

5. AI and Computer Technology

🤖 Artificial Intelligence (AI)
Helps doctors read MRI scans faster and more accurately.

WHATS A NEW (2023–2025)

1. Next-gen immunotherapy (CAR-T and multi-target strategies).

Early-phase trials and conference reports show CAR-T approaches are being engineered for dual/multi-antigen targeting, improved persistence, and locoregional delivery (to bypass the blood–brain barrier). Results are mixed but promising for slowing tumor growth in some patients and informing better designs.

2. Tumor-Treating Fields (TTFields) & electric-field therapies getting refined.

Non-invasive alternating-electric-field therapy continues to be optimized (new devices, expanded indications, combination trials with chemo/immuno), and recent reviews report continuing evidence for clinical benefit and better quality-of-life data.

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3. Precision genomics & single-cell / spatial omics are transforming biologytargets.Single-cell and spatial transcriptomics have revealed tumor cell states, lineage relationships and microenvironment features that explain therapy resistance and suggest new, targetable cell populations. This is accelerating rational combination therapies and biomarker development.
4. New targeted drugs and regulatory movement for rare CNS tumors.

There have been recent FDA actions addressing rare brain tumors — e.g., approvals and orphan designations for therapies targeting molecularly defined tumors (diffuse midline glioma with H3 K27M mutation among updates reported in 2025). This marks important progress for previously untreatable subtypes.

5. Novel delivery methods (nasal, locoregional, implants) and device-based strategies.

Work on bypassing the blood-brain barrier — intranasal delivery, convection-enhanced delivery, and implantable/BCI-associated devices for local therapy or monitoringadvancing in preclinical and early clinical work. These aim to get therapies into the tumor while reducing systemic toxicity.

6. linical-trial activity and combination strategies.

There's a robust pipeline of clinical trials testing combinations (CAR-T + checkpoint blockade, TTFields + chemo, epigenetic drugs + radiation) — the field is moving away from single-agent expectations to rational combos based on tumor biology.

CONCLUSION

In the past few years the field of brain-tumor research has moved from descriptive pathology toward a molecularly driven, multimodal treatment paradigm. The 2021 WHO CNS classification and subsequent molecular studies have redefined glioma taxonomy and enabled more accurate prognostication and targeted trial design. Advances in diagnostics — including high-resolution functional imaging and ctDNA-based liquid biopsy from CSF — are improving noninvasivetumor characterization and real-time monitoring of treatment response. On the therapeutic front, Tumor-Treating Fields and novel targeted and immunotherapeutic strategies (including CAR-T approaches and combination immunotherapies) have shown clinically meaningful benefits for selected patients while highlighting the need to overcome intratumoral heterogeneity and the immunosuppressive microenvironment. Importantly, progress in patient-derived models, biomarker-driven trials, and adaptive trial designs is accelerating translation of laboratory findings into personalized therapies. Looking forward, the greatest opportunities lie in integrating multimodal molecular diagnostics with rational combination therapies and delivery strategies that circumvent the blood–brain barrier, along with rigorous biomarker-guided clinical trials to convert incremental gains into durable outcomes for patients. Continued cross-disciplinary efforts — combining genomics, advanced imaging, bioengineering, and immunology — will be essential to translate recent advances into substantially improved survival and quality of life.

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