International Journal of Medical Science in Clinical Research and Review
Online ISSN: 2581-8945
Available Online at http://www.ijmscrr.in Volume 7|Issue 03 (May-June) |2024 Page: 549-556

Review Paper

Advancements in Magnetic Resonance Imaging for Enhanced Diagnosis and Treatment of Brain Tumors: A Review

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Article Received: 16-April-2024, Revised: 06-May-2024, Accepted: 26-May-2024

ABSTRACT:
Magnetic Resonance Imaging (MRI) stands as a cornerstone in the diagnosis, treatment planning, and post-treatment monitoring of brain tumors, offering a non-invasive and detailed insight into the intricate landscape of the brain. In the realm of diagnosis, MRI's high-resolution imaging capability provides clinicians with precise information regarding tumor location, size, and morphology, facilitating accurate differentiation between various tumor types. Advanced MRI techniques such as diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), and magnetic resonance spectroscopy (MRS) offer additional dimensions by revealing tumor cellularity, vascularity, and metabolic characteristics, thus enhancing diagnostic accuracy. MRI plays a pivotal role in treatment planning by delineating tumor boundaries and their relationships with adjacent critical structures, guiding surgical interventions, radiation therapy, and chemotherapy protocols. Functional MRI (fMRI) aids in identifying eloquent brain regions, minimizing postoperative neurological deficits. Additionally, intraoperative MRI enables real-time assessment of tumor resection margins, optimizing surgical outcomes. Despite its indispensable role, MRI does have limitations, including challenges in distinguishing tumor recurrence from treatment-related changes and artifacts in certain brain regions. Nonetheless, ongoing advancements in MRI technology, including novel imaging sequences and contrast agents, hold promise for overcoming these limitations and further enhancing the accuracy and effectiveness of brain tumor management.

Keywords: Magnetic Resonance Imaging, Brain Imaging, Tumor, Segmentation, Brain Disease

INTRODUCTION:

The brain and spinal cord together comprise the central nervous system, which is the principal organ of the human nervous system. The cerebellum, brainstem, and cerebrum make up the brain. The majority of bodily functions are under its control[1]. It gathers, organizes, and processes sensory data before deciding what commands to send to the other parts of the body. The skull bones of the head both enclose and shield the brain. The two cerebral hemispheres make up the cerebrum, which makes up the majority of the human brain. Every hemisphere consists of an outer layer called the cerebral cortex made up of grey matter and an inner core made up of white matter[2]. The cortex is composed of two layers: the inner allocortex and the outer neocortex. The allocortex consists of three or four neuronal layers, whereas the neocortex contains six. The frontal, temporal, parietal, and occipital lobes are the four lobes that make up each hemisphere in the traditional division. The occipital lobe is devoted to vision, whereas the frontal lobe is linked to executive processes including planning, thinking, self-control, and abstract cognition[3]. The blood–brain barrier separates the brain from the bloodstream, suspends it in cerebrospinal fluid, and protects it from injury. The brain is still vulnerable to injury, illness, and infection, though. Trauma or a stroke, which is a decrease of blood supply, can both result in damage[4]. Degenerative conditions like Parkinson's disease, dementias like Alzheimer's disease, and multiple sclerosis can all affect the brain. Psychological disorders such as schizophrenia and severe depression are believed to be linked to abnormalities in the brain. Benign and malignant brain tumors can also develop there; these typically come from other parts of the body[5]. Neuroanatomy is the study of the structure of the brain; neuroscience is the study of its function. There are many methods for studying the brain. Other animal specimens that can be studied under a microscope have historically yielded a wealth of information. Studying the brain requires the use of medical imaging technologies like electroencephalography (EEG) recordings and functional neuroimaging[6]. The medical histories of

individuals who have suffered from brain injuries have shed light on how each brain region functions. Research in neuroscience has grown significantly, and it still continues. Three pairs of nerve tracts called cerebellar peduncles connect it to the brainstem. The midbrain is connected to the superior pair, the medulla is connected to the middle pair, and the pons is connected to the inferior pair[7]. The cerebellum is made up of a densely folded grey matter outer cortex and a white matter inner medulla. There is disagreement over the flocculonodular lobe's role in balance maintenance, however the anterior and posterior lobes of the cerebellum seem to be involved in the coordination and smoothing of complicated motor movements. The functions it includes are mainly:

MOTOR CONTROL:

Language, emotion, motor control, and reasoning are all influenced by the frontal lobe. It is home to the prefrontal cortex, which is in charge of higher order cognitive functioning, the motor cortex, which plans and coordinates movement, and Broca's area, which is crucial for language production[8]. The brain's motor system is in charge of creating and regulating movement. The brain sends signals through nerves to motor neurons in the body, which regulate muscle contraction. Movements from the brain are transmitted to the torso and limbs via the. The motor cortex, which is composed of three regions, generates gross movement, including walking and the movement of the arms and legs[9]. The main motor cortex is located in the precentral gyrus and comprises areas devoted to the movement of various body parts. The premotor region and the supplemental motor area are two additional areas that are prior to the primary motor cortex and are responsible for supporting and regulating these motions[10]. A motor homunculus has been used to illustrate how the hands and mouth have a significantly bigger area devoted to them than other body parts, allowing for finer movement. Motor cortex-generated impulses leave the medulla via the corticospinal tract and cross across (decussate) at the medullary pyramids. significantly bigger area devoted to them than other body parts, allowing for finer movement[11]. Motor cortex-generated impulses leave the medulla via the corticospinal tract and cross across (decussate) at the medullary pyramids.

SENSORY NERVE:

The receiving and processing of sensory data is a function of the sensory nerve system. This information is obtained at brain regions exposed to blood vessels, via spinal cord tracts, and through the cranial nerves[12]. Additionally, information from the five senses vision, smell, hearing, and taste—is received by and interpreted by the brain. Additionally, mixed motor and sensory inputs are incorporated. The brain gets information regarding temperature, vibration, pain, pressure, and delicate touch via the skin. The brain gets information regarding joint position from the joints. Situated in close proximity to the motor cortex, the sensory cortex also contains regions associated with feeling from other body parts[13]. A sensory receptor on the skin interprets a sensory input into a nerve signal, which travels through spinal cord tracts to ascend a sequence of neurons. The dorsal column–medial lemniscus pathway is responsible for transmitting information about joint position, vibration, and delicate touch[14]. The route fibers ascend the posterior region of the spinal cord and reach the posterior region of the medulla. There, they establish connections with second-order neurons, which subsequently transmit fibers across the midline.

REGULATION OF BRAIN:

The brain's autonomic activities involve homeostasis maintenance and the regulation, or rhythmic control, of breathing and heart rate. The medulla's vasomotor center affects blood pressure and heart rate by constricting arteries and veins somewhat while at rest[15]. It achieves this by acting on the vagus nerve, which affects the sympathetic and parasympathetic nervous systems. The respiratory centres in the medulla and pons are the primary brain regions that regulate breathing rate. By producing motor impulses that travel via the phrenic nerve, the spinal cord, and the diaphragm and other breathing muscles, the respiratory centers regulate breathing. This nerve, which is mixed, returns sensory data to the centers[16]. Baroreceptors in aortic bodies in the aortic arch produce information regarding blood pressure, which is then transmitted to the brain by the vagus nerve's afferent fibers. The carotid bodies, which are situated close to the carotid artery, provide information regarding variations in carotid sinus pressure. This information is transmitted by a nerve that connects to the glossopharyngeal nerve. This data ascends to the lone nucleus located in the medulla[17]. The vasomotor center receives signals from this location and modifies vein and artery constriction accordingly.

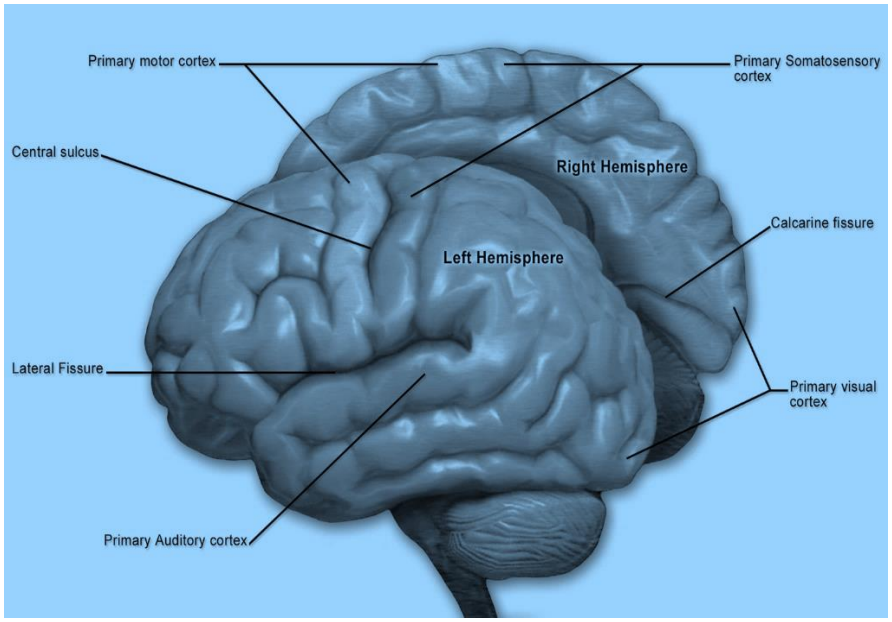

Figure 1: Showing Anatomy of Brain

When abnormal cells start to develop within the brain, a brain tumor happens. Malignant (cancerous) and benign (non-cancerous) tumours are the two primary categories of tumors. These can be further divided into two categories: brain metastasis tumours, which are secondary tumours that have typically spread from original tumours outside the brain, and primary tumours, which originate inside the brain[18]. Depending on the tumor's size and the affected brain region, all kinds of brain tumours can cause a variety of symptoms. When present, symptoms could include headaches, seizures, blurred vision, nausea, and mood swings. Additional symptoms include be trouble speaking, walking, feeling things, or even unconsciousness.

The majority of brain tumours have no known cause, yet radiation from CT scans may be responsible for up to 4% of brain malignancies. Uncommon risk factors include ionizing radiation, vinyl chloride exposure, Epstein-Barr virus, and genetic diseases such von Hippel-Lindau disease, neurofibromatosis, and tuberous sclerosis[19]. Research on the use of mobile phones has not clearly demonstrated a risk. Adults with primary tumours most commonly have meningiomas (typically benign) and astrocytomas, including glioblastomas. The most prevalent kind in children is malignant medulloblastoma. The diagnosis is typically made using magnetic resonance imaging (MRI) or computed tomography (CT) in addition to a medical evaluation[20]. A biopsy is then frequently used to confirm the outcome. The tumours are categorized into several severity grades based on the results. Medical imaging resonance plays a important role in diagnosis of the brain tumour.

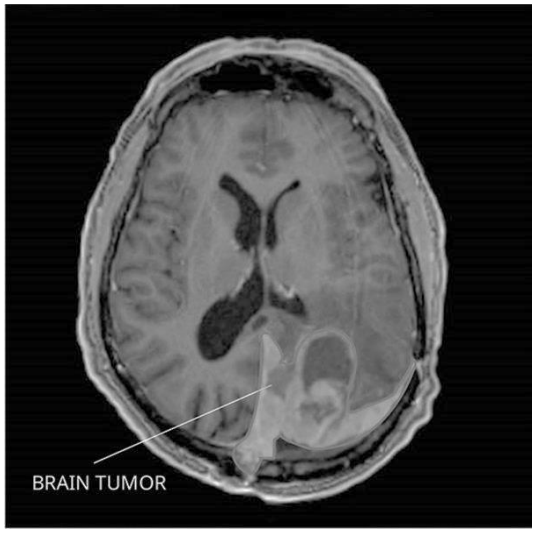

Figure 2: Showing tumour in axial section of brain

Type of Brain Tumor	Description
Gliomas	- Originate in the glial cells of the brain
	- Include astrocytomas, oligodendrogliomas, and glioblastomas
Meningiomas	- Arise from the meninges, the protective layers of the brain
	- Typically slow-growing and often benign
Pituitary adenomas	- Develop in the pituitary gland
	- Often benign and may not require treatment
Medulloblastomas	- Typically found in the cerebellum, especially in children
	- Fast-growing and malignant
Schwannomas	- Arise from Schwann cells, which produce the myelin sheath around nerves
	- Commonly found on the nerves of the head and neck
Craniopharyngiomas	- Develop near the pituitary gland and hypothalamus
	- Mostly benign but can cause significant symptoms
Ependymomas	- Arise from ependymal cells lining the ventricles of the brain
	- Can occur at any age and may be slow-growing or aggressive
Hemangioblastomas	- Typically found in the cerebellum or brainstem
	- Associated with Von Hippel-Lindau syndrome
Chordomas	- Rare tumors that develop from remnants of the notochord
	- Typically found at the base of the skull or in the spine
Oligodendrogliomas	- Arise from oligodendrocytes, a type of glial cell
	- Tend to grow slowly and may become malignant over time

Table 1: Showing different types of tumor and its description

Neoplasms frequently appear on MRI scans as variously colored masses, Benign brain tumors often show up on MRI they appear either hypodense or isointense (same intensity as brain tissue) on T1-weighted scans, or hyperintense (brighter than brain tissue) on T2-weighted MRI, although the appearance is variable[21]. The majority of malignant primary and metastatic brain tumours can show contrast agent uptake on MRI studies, sometimes in distinctive patterns. On T2-weighted scans, pressure zones where a tumour has compressed brain tissue also show up as hyperintense and may be indicative of a diffuse neoplasm because of their hazy contour[22]. A similar outcome can also be seen in cases of peritumoral edoema, or swelling surrounding the tumour. This is due to the fact that these tumours cause the BBB permeability to rise and interfere with its regular operation. Recent developments have expanded the use of MRI in giving physiological information that can support prognosis and diagnosis. The location and form of a brain tumour can be determined by MRI alone, but other MRI techniques like DWI, pMRI, fMRI, MRA, and MRS may also be employed. Physicians and surgeons use these imaging techniques to diagnose the type of tumour, schedule surgical procedures, and evaluate radiation and chemotherapy[23]. There are different type of MRI scan like.

Magnetic Resonance Spectroscopy (MRS) inspects metabolic or chemical changes within the tumour. Proton spectroscopy is the most frequent type of MRS, with frequencies measured in parts per million (ppm). Gliomas, or malignant brain tumours, have a different

spectrum than normal brain tissue, with higher choline levels and lower N-acetyl aspartate (NAA) signals. MRS can assist clinicians identify the type and aggressiveness of a brain tumour[24]. For example, benign brain tumours and meningiomas have elevated alanine levels. It can also aid to identify brain tumours from scar tissues or dead tissues induced by earlier radiation treatment, which do not have the same high choline levels as brain tumours, as well as tumor-mimicking lesions such abscesses or infarctions. Perfusion Magnetic Resonance Imaging (pMRI) evaluate the blood volume and flow of various brain regions, as well as brain tumours. To improve contrast during pMRI, a contrast agent, often gadopentetate dimeglumine (Gd-DTPA), is injected into the veins[25]. pMRI generates a cerebral blood volume map that demonstrates tumour vascularity and angiogenesis. Brain tumours require a bigger blood supply, resulting in a high cerebral blood volume on the pMRI map. The vascular morphology and degree of angiogenesis from pMRI aid in determining the grade and malignancy of brain tumours[26]. For brain tumour diagnosis, pMRI can help determine the optimum site for biopsy and reduce sample error. After therapy, pMRI can help evaluate whether the abnormal area is. **Magnetic Resonance Angiography (MRA)** examines the blood arteries in the brain. MRAs are often performed before surgery to help surgeons better comprehend the tumour vasculature. For example, one study found that surgeons could distinguish between benign and malignant brain tumours by analyzing the forms of blood veins taken from MRA[27]. Although not required, some MRA may inject the contrast agent, gadolinium, into the patient to obtain an improved image.

Functional MRI (fMRI):

fMRI is significant because the structure near the tumour distorts the surrounding regions, making it difficult to differentiate. Neurosurgeons would utilize fMRI to determine whether to undertake a resection, in which the tumour is surgically removed as much as feasible, a biopsy, in which a surgical sample is taken to offer a diagnosis,

The Preprocessing of MRI Images:

The MRI preprocessing procedures are presented prior to the brain tumour segmentation techniques as they have a direct bearing on the characteristics of the segmentation outcomes. Generally speaking, preprocessing of the raw MRI images is required to achieve the segmentation goals. These pre-processing techniques, which directly affect the outcomes of brain tumour segmentation, include de-noising, skull-stripping, intensity normalisation, etc. One common MRI preprocessing task is image de-noising[28]. It is challenging to accurately distinguish between brain tumour and normal brain tissues in regions of interest when analysing an MRI picture due to noise. Preprocessing an MRI image is therefore required in order to minimise noise and improve the contrast between different areas. Skull striping precision has been regarded as a crucial step in brain tumour segmentation, as it impacts the effectiveness of tumour detection, pre-surgical planning, cortical surface reconstruction, and brain morphometry. brain tumour segmentation techniques may be divided into several groups according to various ideas[29]. Based on the level of necessary human engagement, brain tumour segmentation techniques in clinics are often divided into three primary categories: completely automatic, semi-automated, and manual. as manual brain tumour segmentation aims to manually draw the boundaries of the brain tumour and paint the regions of anatomic structures with different label, brain tumour experts must be experts in both the information presented in the brain tumour images and some additional knowledge, such as anatomy. d. Manual segmentation is still often used in clinical trials nowadays[30]. Since more and more brain tumour photos are becoming available in the clinic, manually segmenting the various brain tumour locations will become a laborious and error-prone operation for the professionals, as well as provide rather subpar outcomes. To solve this issue, more sophisticated segmentation techniques like completely and semi-automated segmentation techniques are needed For semi-automatic brain tumor segmentation, it mainly consists of the user, interaction, and software computing. In the semi-automatic brain tumor methods, the user needs to input some parameters and is responsible for analyzing the visual information and providing feedback response for the software computing. The software computing is targeted at the realization of brain tumor segmentation algorithms. The interaction is in charge of adjusting segmentation information between the user and the software computing. Using a preset similarity criterion, neighbouring pixels with homogeneity attributes are combined to create disjoint sections in an image using region-based segmentation techniques. Typically employed in the brain tumour segmentation procedure, the region-growing and watershed segmentation approaches belong to the category of region-based methods. To extract a linked region of comparable pixels from an image, the simplest and most used region-bas segmentation technique is called region growing. Growing a region begins with at least one seed that is a part of the interest structure.

DISCUSSION:

In clinical practice, MRI-based brain tumour segmentation approaches have already demonstrated a great deal of promise for tumour detection and analysis. These techniques will surely continue to be improved in the future. More sophisticated MRI modalities including Magnetic Resonance Spectroscopy (MRS), Diffusion Tensor Imaging (DTI), and Perfusion Imaging (PI) are receiving more

attention in the segmentation of brain tumours as a result of the advancement of MRI methods. A team known as the Section of Biomedical Image Analysis (SBIA), for instance, has spent more than 15 years developing these modalities. The various regions of the brain tumour can be located using these methods. The advent of machine learning techniques has made it possible to separate brain tumours from normal tissues and MRS data[In addition to the advance to studies in the field, brain tumour automated segmentation technology may improve therapy choices and offer more accurate prognoses.

CONCLUSION:

We suggested an interactive segmentation technique that lets users segment brain tumours in MRIs rapidly and effectively. We suggested a novel approach that employs symmetry analysis of the previous knowledge in addition to the region's area and edge information, making it more consistent in pathological situations. Since a tumour is a rather broad notion in medicine, the suggested technique may have limits that manifest as soon as previously undetected patients exhibit pathologic tissue types that were not predicted by the discriminative model. Depending on the original tumour location, secondary tumours in particular may consist of a wide range of tissue types. When applied to many datasets with varying tumour sizes, intensities, and locations, it demonstrates that it has the ability to accurately and automatically identify a wide variety of brain tumour types. that it has the ability to accurately and automatically identify a wide variety of brain tumour types.

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