

Brain Tumors

Brain tumors can affect people of all ages.¹ Unfortunately, the incidence of brain tumors is on the rise for all age groups, especially older adults.² Therapists who work with patients with brain tumors could benefit from knowing the pathophysiology and clinical presentation of brain tumors. The purposes of this update are to relate recent classification systems to the traditional classifications of brain tumors and to examine current neuroimaging techniques. Given the scope of this article, only the most common types of brain tumors are discussed.

Classification of Brain Tumors

Brain tumors may be benign or malignant, or primary or metastatic. The term “benign” may imply that a complete cure is possible, but this is not always true.^{3,4} A benign tumor can be life threatening if it is very large or if it results in increased intracranial pressure,^{3,4} cerebral edema,⁴ or herniation syndromes³ such as a transtentorial herniation, especially if it is located in a critical area of the brain such as the pons or medulla. In contrast, malignant brain tumors are potentially life threatening.³ Primary brain tumors, which originate directly from cells in the brain, rarely spread outside of the central nervous system.⁵ Metastatic brain tumors originate from tissues outside of the brain.⁵ Kernahan and Ringretz independently developed 2 different classification scales for brain tumors based on the degree of malignancy.^{6–8} Brain tumors are graded from I (“least malignant”) through IV (“most malignant”) on the Kernahan scale.⁷ The Ringretz scale is a similar 3-grade scale that combines Kernahan scale grades III and IV into Ringretz scale grade III.⁸

The World Health Organization (WHO) has developed the most commonly used classification system for brain tumors (Tab. 1).⁶ The WHO system is based on the similarity of tumor cells to normal cells, rate of tumor growth, presence of necrotic cells in the center of the tumor, presence of definitive tumor margins, and vascularity.⁹ Grade I tumors are the most discrete in nature, grow slowly, and are often cured with surgery alone. Grade II tumors also grow slowly, but they have the ability to invade adjacent normal tissue and

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may recur with higher grades of malignancy. Grade III tumors have actively reproducing abnormal cells that can infiltrate adjacent cells. Grade IV tumors are the most malignant, with rapid proliferation and infiltration to adjacent tissue.⁶ New blood vessels are produced in these tumors to maintain their rapid growth.⁹ Grade IV tumors also have a central area of necrosis.⁶

Common Types of Brain Tumors

A complete discussion of each type of tumor is beyond the scope of this article; therefore, pathophysiology of the most common types of brain tumors encountered by physical therapists will be discussed.¹⁰ Pilocytic astrocytomas (grade I) and low-grade astrocytomas (grade II) are benign tumors that often form cysts or are enclosed in a cyst.^{3,6} Astrocytomas arise from astrocytes, cells that play a role in nutrition and various cleanup functions within the central nervous system.¹¹ Grade I and II astrocytomas usually occur in the third or fourth decade of life.^{3,4} They are most often located in the frontal lobe of the brain, but may also be found in the basal ganglia and temporal, parietal, or occipital lobes. Although grade I and II astrocytomas are slow growing, they may become very large and progress to a higher grade over time.³ Shinoda et al¹² reported that patients with a grade II astrocytoma have a 5-year survival rate of 66%. For patients with untreated low-grade astrocytomas, the

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10-year survival rate is 11%.³ Two probable causes of death in patients with low-grade astrocytoma are tumor recurrence with malignant transformation or continual progression of the grade II tumor.¹² The most positive prognostic factors for patients with astrocytomas include an age of less than 40 years, a preoperative and postoperative functional level of 70% or more on the Karnofsky Performance Status Scale (KPS) (Tab. 2),¹³ tumor location, greater extent of surgical removal, and uniform blood vessel size in the histological specimen.^{12,14}

Glioblastoma multiforme is the most common adult brain neoplasm¹⁵ and occurs most frequently in the fifth and sixth decades of life.^{3,15} Glioblastoma multiforme is classified as a grade IV astrocytoma.^{3,6} It is a rapidly growing, highly malignant tumor that is identified by the presence of dead tumor cells.^{3,16} Men are affected more frequently than women.¹⁵ Glioblastoma multiforme is frequently found in the frontal lobe and may spread through the corpus callosum to the adjacent side of the brain.¹⁵ Glioblastoma multiforme may also occur in the temporal, parietal, or occipital lobes,¹⁵ with rare occurrence in the cerebellum, brain stem, and spinal cord.³ Resio and DeVroom¹⁷ reported that surgery, combined

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Table 1.World Health Organization Grading System (Malignancy Scale) for Central Nervous System Tumors^a

Tumor Group	Tumor Type	Grade I	Grade II	Grade III	Grade IV
Astrocytic tumors	Subependymal giant cell	*			
	Pilocytic	*			
	Low grade		*		
	Pleomorphic xanthoastrocytoma		*	*	
	Anaplastic Glioblastoma			*	*
Oligodendrogliomas	Low grade		*		
	Anaplastic			*	
Cranial and spinal nerve tumors	Schwannoma	*			
	Malignant peripheral nerve sheath tumor			*	*
Meningeal tumors	Meningioma	*			
	Atypical meningioma		*		
	Papillary meningioma		*	*	
	Hemangiopericytoma		*	*	
	Anaplastic meningioma			*	

^a Reprinted from Kleihues et al⁶ with permission.**Table 2.**The Karnofsky Performance Scale Used in Oncology to Assess a Patient's Level of Function^a

Condition	Percentage	Comments
A: Able to carry on normal activity and to work. No special care is needed	100	Normal, no complaints, no evidence of disease.
	90	Able to carry on normal activity, minor signs or symptoms of disease.
	80	Normal activity with effort, some signs or symptoms of disease.
B: Unable to work. Able to live at home, care for most personal needs. A varying degree of assistance is needed.	70	Cares for self. Unable to carry on normal activity or to do active work.
	60	Requires occasional assistance, but is able to care for most of his/her needs.
	50	Requires considerable assistance and frequent medical care.
C: Unable to care for self. Requires equivalent of institutional or hospital care. Disease may be progressing rapidly.	40	Disabled, requires special care and assistance.
	30	Severely disabled, hospitalization is indicated although death not imminent.
	20	Hospitalization necessary, very sick, active supportive treatment necessary.
	10	Moribund, fatal processes progressing rapidly.
	0	Dead

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with radiation therapy, is the treatment of choice for glioblastoma multiforme. The duration of survival for individuals with glioblastoma multiforme is 12 to 18 months following diagnosis.¹⁷

Oligodendrogliomas are primary brain tumors that arise from oligodendrocytes, the cells in the central nervous system that produce myelin.³ Oligodendrogliomas are primarily found in the frontal lobes and are common in the third and fourth decades of life. The boundaries of this type of tumor are often undefined, and the tumor may show calcification.¹⁵ Oligodendrogliomas can reach a large size before becoming symptomatic,⁴ with seizures and chronic headaches as common first signs.¹⁵ Partial excision combined with radiation therapy is used to treat oligodendrogliomas. The survival duration for this type of tumor ranges from 5 to 7 years with partial excision, and possibly 10 years with complete resection.¹⁵

Meningiomas are slow-growing, encapsulated, highly vascular, benign intracranial tumors.^{15,18,19} They originate in the tissues that surround the brain and spinal cord, specifically in the arachnoid granulations.¹⁸ Meningiomas comprise approximately 20% of all intracranial tumors in adults.¹ Although most meningiomas are considered benign, some may become malignant.²⁰ Meningiomas are com-

monly seen in individuals between the third and sixth decades of life²¹ and are more common in women than men by a 2:1 ratio.²² Treatment techniques consist of surgery, radiation, and chemotherapy.¹⁹ Most meningi-

omas are benign tumors located in the arachnoid layer,³ and as a result, they can be completely resected, making surgery the treatment of choice.^{19,21} Prognostic factors that may indicate a more favorable outcome for people with meningiomas include age younger than 60 years, no evidence of an increase in intracranial pressure, complete resection of the tumor, and an absence of atypical histologic features.¹

Vestibular schwannomas, formerly called acoustic neuromas,¹ are benign, slow-growing tumors that are intracranial or located on peripheral nerves.²³ Vestibular schwannomas originate from Schwann cells,²⁴ the cells in the peripheral nervous system that produce myelin.¹¹ They account for 10% of all intracranial tumors in adults and are most likely to occur in the third or fourth decade of life. Vestibular schwannomas, just inside the internal auditory meatus, most often originate on the vestibular portion of the vestibulocochlear nerve.^{23,25} As the tumor grows, it migrates toward the cerebellopontine angle. In the early stages of the tumor, there may be few or no symptoms, but as the tumor begins to grow more rapidly, symptoms appear due to compression of the vestibulocochlear nerve.²³ As a result, vestibular schwannomas are a common cause of sudden hearing loss.²⁶ In later stages, cranial nerves V (trigeminal) and VII (facial) also may become involved.^{23,25} The most common intervention for this type of tumor is surgery.²³ In some cases, surgery may cause deafness, facial weakness, or paralysis.²⁷ The prognosis for patients with vestibular schwannomas is favorable if complete excision is possible. If the tumor is left untreated, brain-stem compression may eventually cause death.²³

Metastatic brain tumors are intracranial tumors that originate from tissues outside of the brain⁵ and can occur as single or multiple tumors.¹ The most common source of metastatic brain tumors is lung cancer, with breast cancer being the second most common source.¹ The cancer cells spread to the brain through the cardiovascular system. Metastatic brain tumors occur in 20% to 40% of people with a primary cancer.⁵ The occurrence of metastatic brain tumors is increasing as the success of treating primary cancers advances, resulting in individuals living longer with time to develop metastases to the brain.¹ The metastatic tumors are normally fast growing.²⁸ Treatment includes the use of chemotherapy, radiation therapy, and surgery, with corticosteroids used to manage swelling and inflammation.^{5,28} Radiation therapy is commonly used in cases of multiple metastases.¹⁵ Treatment will rarely cure a metastatic tumor. Treatment may help reduce the symptoms and increase the quality of life and length of survival for the individual.²⁷ Prognosis is most favorable for people who are younger than 50 years of age, have only one brain metastasis, and have no uncontrolled systemic diseases. The prognosis is also favorable when there is complete

resection and no increase in intracranial pressure and when the primary cancer is correctly identified.¹

Etiology

There are several theories about the causes of brain tumors. Head trauma was once thought to initiate the development of meningiomas.^{22,29} However, in a study of 2,953 patients, Annegers et al³⁰ found no correlation between a previous head injury and an increased chance of acquiring a brain tumor. Some meningiomas have been associated with heredity.²² In a study of 154 individuals from 72 families, Grossman et al³¹ reported the largest series of primary brain tumors in family members without a known hereditary syndrome. Based on the occurrence of brain tumors in spouses, environmental factors are also associated with the etiology of astrocytomas.³¹ Possible sources of environmental risk factors for brain tumors include ionizing radiation,^{22,29} chemical agents such as petrochemicals and organic solvents,³² and viruses.²² Ron et al³³ found that 86% of a sample of Israeli adults who received ionizing radiation as children for treatment of tinea capitis developed meningiomas. A source of ionizing radiation to the head is dental radiographs, which are associated with an increased risk of subtentorial intracranial meningiomas, but not supratentorial brain tumors.³⁴ Certain polyoma viruses and several types of adenoviruses have been implicated as a cause of central nervous system tumors in laboratory animals, but research in humans has been inconclusive.²² Brain tumors may also be a result of metastasis from other primary cancers.⁵

Clinical Presentation

People with brain tumors may have a variety of signs, symptoms, and impairments. Symptoms of primary brain tumors depend on the location, type, and rate of growth of the tumor.² Tumors can cause symptoms directly, from invasion or compression of an area of the brain, or indirectly, by causing an increase in intracranial pressure.¹⁹ The enlargement of a tumor in a contained space leads to increased pressure throughout the entire cranial vault.¹ As a result, 65% of patients complain of headaches, 30% report visual symptoms such as blurred vision or an expanded blind spot, and 10% experience nausea and vomiting.¹ Tumors that compress brain tissue for long periods can lead to partial or generalized seizures.¹

Symptoms may also be related to the tissue being compressed or invaded (Tab. 3). Pressure on the sensory cortex or parietal lobes can lead to a loss of the ability to process complex sensory input and can result in astereognosis, agraphesthesia, or difficulties with tactile localization and two-point discrimination.^{15,35} Compression of the sensory cortex or parietal lobes may result in a loss of word recognition and language comprehension because the parietal association cortex is responsible for

Table 3.Clinical Symptoms of Brain Tumors^{1,2,15,21,34}

Associated Symptoms	Anatomic Region				
	Parietal Lobe	Frontal Lobe	Temporal Lobe	Occipital Lobe	Cerebellum
Motor		Spasticity Ataxia of the contralateral side Urinary incontinence or retention Loss of strength Hemiparesis Seizures	Seizures		Dysmetria Ataxic gait Intention tremor Nystagmus Dysidiadokinesia
Sensory/perceptual	Loss of ability to process complex sensory input Astereognosis Agraphesthesia Difficulty with tactile localization Difficulty with two-point discrimination		Contralateral hemianopsia	Visual field deficits Inability to recognize faces or colors Inability to focus on objects	
Cognitive/affective	Loss of word recognition and language comprehension	Changes in mental status Changes in personality Social inappropriateness Obscenity Lack of concern Lack of judgment Failure of memory Poor attention span Dysphasia or aphasia	Loss of consciousness	Alexia	

integrating both visual and auditory input.³⁵ Frontal lobe tumors are common² and can lead to changes in mental status and personality.¹ Tumors localized in the prefrontal area may result in social inappropriateness, obscenity, lack of concern, lack of judgment, failure of memory, and poor attention span.^{15,35} Other frontal lobe signs include spasticity, ataxia of the contralateral side, and urinary incontinence or retention.³⁵ Pressure in the frontal lobe of the dominant hemisphere can influence Broca's area^{1,35} and can lead to the loss of expressive speech or motor dysphasia.¹⁵ A tumor on the dominant side at Wernicke's area could result in dysphasia or aphasia.³⁵ A tumor over the motor cortex can cause a loss of strength or hemiparesis and may lead to partial, Jacksonian, or generalized seizures.¹⁵ Tumors in the temporal lobes can result in partial complex seizures, losses of consciousness, and contralateral hemianopsia.^{4,15} Occipital lobe tumors may result in visual field deficits or visual disturbances, such as the inability to recognize faces or colors, an inability to focus on objects, and alexia. Tumors also can affect cranial nerves and their function.³⁵ Cerebellar tumors may lead to dysmetria, ataxic gait patterning, intention tremor, nystagmus, and dysidiadochokinesia.^{1,15} A tumor near the brain stem can cause changes in consciousness¹ and inefficient respiration, which can progress to death.¹⁹

Use of Neuroimaging in Diagnosis and Surgery

A neurologic examination can assist in differential diagnosis of brain tumors. Diagnostic tools can provide specific and accurate information of the location, size, and characteristics of a tumor.¹⁹ Imaging techniques, such as computed tomography (CT), magnetic resonance imaging (MRI), and angiography are often used to assist in making a diagnosis.¹

Computed tomography can be used to distinguish between many soft tissues^{35,36} and can indicate the location, density, and borders of the tumor, as well as the presence of edema.^{19,21} Although MRI is more frequently used to diagnose brain tumors, CT scans are still used when an MRI is unavailable or too costly.³⁶ Computed tomography scans are diagnostic in 95% of patients with meningiomas.²¹ They are also a much faster imaging technique than an MRI.³⁶ The CT scan can be completed quickly, whereas the MRI requires the patient to lie still for an extended period of time.

Magnetic resonance imaging has a much finer resolution than CT,² and thus is the method of choice for diagnosing brain tumors.^{28,36} Magnetic resonance imaging is also a preferred technique because it does not use

ionizing radiation, has greater tissue contrast resolution than CT, and has not been shown to produce side effects. Magnetic resonance imaging gives more information about the characteristics of the tumor than CT scans and can better diagnose metastatic tumors.³⁶

Angiography is another form of imaging³⁶ that is primarily used to diagnose and map vascularized tumors.¹ It is helpful in providing surgeons with information on the blood supply to the tumor and the location of the brain tumor in relation to the blood supply of the brain.³⁶

Although CT scans, MRI, and angiography provide detailed anatomical images, it is believed that functional changes in tumor cells precede changes in the anatomical structure.³⁷ The word “functional” in this context refers to cellular metabolism. Functional imaging techniques can be used to diagnose brain tumors or to assess the effectiveness of medical treatment. These techniques also are used to more quickly differentiate between thriving and injured tumor cells after treatment.³⁷ Functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and magnetic resonance spectroscopy (MRS) are imaging tools that assist with presurgical functional mapping.³⁸ They may be combined with CT scans and MRI to create a multifaceted image showing the anatomical and metabolic aspects of the brain. This provides for a more thorough evaluation and aids physicians as they formulate a diagnosis and determine the most appropriate form of treatment.³⁹

Functional MRI takes a rapid succession of scans that can detect small changes in the level of oxygen consumption and blood flow that take place in the areas of the brain that are active. This information helps surgeons modify their approach to minimize patient risk.³⁸ Positron emission tomography is an imaging technique that detects the metabolic activity of structures. In the brain, PET detects the differing levels of glucose uptake that occur in brain tissue, brain tumors, and necrotic tissue. Brain tumors have a higher level of glucose uptake than brain tissue, whereas necrotic tissue has little to no glucose uptake.³⁹ Magnetic resonance spectroscopy is also an imaging technique that detects metabolic changes. Magnetic resonance spectroscopy is noninvasive and does not require contrast agents or labeled tracers. An advantage that MRS has over PET is that it does not utilize high-energy radiation.³⁷

Brain tumors that were once thought to be inoperable are now being resected using image-guided surgery. Surgeons are able to remove brain tumors more effectively and safely due to advances in computer technology and intraoperative imaging.³⁸ Ram³⁸ described 4 image-guided surgical techniques: neurosurgical navigation, intraoperative MRI, intracranial endoscopy, and intraoperative brain mapping with awake craniotomy.

In neurosurgical navigation, surgeons know at any given time the coordinates of the operating tools in the brain. Cameras calculate the position of probes in the brain and display it on a computerized anatomical model. Using intraoperative MRI, surgeons are able to determine when the brain tumor has been completely excised. The surgery takes place in the MRI so that new scans can be taken throughout surgery. Intracranial endoscopy is a minimally invasive technique used with patients whose brain tumors are within or next to the ventricular system. The entry location of the endoscope is small; therefore, recovery time is minimized. Intraoperative brain mapping with awake craniotomy is performed using a local anesthetic only so that the patient can communicate during surgery. The cortex is stimulated with an electrode to detect areas of language and motor function. The surgeon can then protect those areas during surgery, thereby helping to prevent postoperative neurological deficits and decrease recovery time.³⁸

Rehabilitation Considerations

Physical therapists encounter patients with brain tumors in many different practice settings, including acute care, subacute care, outpatient clinics, and rehabilitation facilities. Special considerations need to be observed when a patient is being seen shortly after surgery. Postoperatively, a patient may experience increased intracranial pressure, which precludes positions that inhibit proper cerebrospinal fluid movement.³ Avoiding activities that result in a Valsalva maneuver also helps in preventing an increase in intracranial pressure.³ A patient who is experiencing increased intracranial pressure may exhibit signs such as a decreased level of consciousness, speech or visual problems, headaches, seizures, vomiting, or respiratory changes.³

When designing the rehabilitation plan and establishing goals for people with brain tumors, the Dietz classification of phases of care for patients with cancer may be helpful.⁴⁰ The Dietz classification involves 4 phases of care: preventative, restorative, supportive, and palliative.⁴¹ The preventative phase of rehabilitation emphasizes early intervention and education to prevent or slow down further development of the tumor and its effects.⁴² In the restorative phase of rehabilitation, patients are expected to return to their prior level of function or to functional independence.⁴¹ Goals are directed toward restoration of function and productivity in the workplace.⁴³ The focus of the supportive phase of rehabilitation is self-care activities such as dressing, grooming, bathing, eating, and toileting.^{42,43} Palliative rehabilitation, according to Dietz,⁴¹ is indicated for patients in the terminal stage who have rapidly progressing tumors where function continues to decline. The primary goal of this phase is to help the patient remain comfortable and preserve independence as long as possible.⁴⁰ An additional goal is to involve the family in assisting the patient.⁴⁰

Summary

This update has provided an overview of the pathophysiology and clinical presentation of brain tumors. The focus has been on providing information on classification scales, neuroimaging techniques, and surgical methods. The new WHO classification of brain tumors has incorporated assessment of additional characteristics beyond malignancy in order to categorize different types of brain tumors. Recent advances in neuroimaging have changed the diagnostic and treatment capabilities in the assessment of patients with brain tumors.

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