Pilocytic Astrocytoma and Medical Imaging: A Case Report

Abstract

Brain tumors are becoming more and more prevalent. Medical imaging plays a major role in the detection, treatment and follow up care of such tumors. Thanks to the advancement of technology and the increase in knowledge of human anatomy and pathology, prognosis for many of these tumors has increased. However, there are still many limitations and risks associated with treatment. This case report follows a young female and her experience as she underwent multiple forms of testing to eventually be diagnosed with a pilocytic astrocytoma. The treatment methods and follow up care plan are also included. In addition, an upcoming form of surgery is presented to demonstrate an alternative way in treating tumors within the brain.

Introduction

A brain tumor, often referred to as a mass, consists of a group of abnormal cells that have developed within the brain. These masses are dangerous for multiple reasons, including directly destroying brain cells, as well as indirectly, when the mass grows in size. This puts pressure on different parts of the brain, causing swelling and an increase in pressure to occur within the cranium. A brain tumor is classified based on three different aspects; 1) whether it is cancerous, 2) the specific site and 3) the type of tissue involved. Most tumors today are classified based on the World Health Organization, or WHO, classification system. This system grades tumors based on their growth rates. The Grades range from I-IV with I being the least malignant. The main factor in classifying brain tumors is the tissue in which the mass arises from.

Within the brain are supportive cells called astrocytes. These cells, which get their name from their star like shape are what give rise to astrocytoma’s. Pilocytic astrocytoma’s (PA) are a low grade glioma and are the most common type of brain tumor seen in children. PA’s account “for more than half of all primary central nervous system malignancies.” This specific type of tumor is generally considered to be the most benign tumor of the astrocytoma classification and is graded by WHO as Grade I. Although this is one specific type of brain tumor, there are many generalized symptoms that could potentially be a result of any kind of tumor.

Additionally, there are many possible symptoms that can occur as a result of a brain tumor. However, just because a patient presents with some of these symptoms does not mean
that they have a tumor, nor does the lack of these symptoms mean they do not have one. A headache can be an indicator when it follows certain patterns. For example, headaches that grow worse with exercise, changes in body position or that occur while sleeping and are accompanied by another symptom such as vomiting are all possible symptoms. Headaches that are present in the morning but that are relieved within a few hours can also be a symptom. Many other mental changes and general symptoms have been connected with the presence of a brain tumor. Some of these include:

- Changes in personality and behavior.
- Inability to concentrate.
- Memory loss.
- Problems with reasoning.
- Gradual loss of movement or feeling in an arm or leg.
- Hearing loss with or without dizziness.
- Speech difficulty.
- Unexpected vision problem, including vision loss in one or both eyes, or double vision.
- Problems with balance.
- Weakness.
- Numbness.¹

Any number or combination of the above symptoms can occur at any point in a brain tumor patient. Some of these symptoms depend on the location within the brain.

**Brain Anatomy**

The brain has a high moisture content and is made up of 85 percent water and the average adult brain weighs over 1300 grams. There are three main parts that make up the brain. The cerebrum is the largest section and makes up most of the interior skull. In the posterior-inferior region of the skull is where the second part of the brain, the cerebellum, is located. The part of the brain that transitions into the spinal cord is known as the brainstem. It is the smallest portion.⁴⁻⁵

The cerebrum can be divided into right and left hemispheres and both hemisphere can be further divided into four lobes each. The lobes are frontal, parietal, temporal and occipital. The superficial layer of the brain is called gray matter which completely covers the deeper layer, also
known as white matter. Gray matter is also referred to as the cerebral cortex and “contains specialized regions of the brain involved in muscle control, sensory perceptions, such as seeing and hearing, memory, emotions and speech.” These specialized regions can be seen with their paired function (see Figure 1). The basal ganglia, or white matter helps relay sensory information between the body and the cerebral cortex. The white matter also helps regulate the unconscious functions of the body.

**Case Report**

An 11-year-old female was evaluated by her school counselor after her parents expressed concerns over her cognitive performance. Reasons for her parents’ concerns included short term memory loss and confusion. The patient’s mother reported having to spend countless hours each night reviewing the same information repeatedly, in order to complete that day’s homework assignments. Following the counselors evaluation, the patient was referred to a neuropsychologist. Extensive testing was done to identify cognitive strengths and weaknesses, and to establish a baseline in order to monitor ongoing neurodevelopmental progression. Prior to this testing, other indications for slow developmental progression were also of concern. As a child the patient took longer than other children to learn certain skills and processes. Until she was in the fourth grade the patient was unable to ride a bike-something that many other kids could do by seven or eight years of age. The patient was also delayed in learning motor skills that involved the use of her hands-such as coloring, writing, and the use of scissors. After the neuropsychologist’s testing, many of his results were consistent with the parents’ observations, as well as that of the counselors. However, there were also many variations between the two tests, some of which the neuropsychologist was very interested in. Test results showed that the most disruptions in the patient’s auditory language processing and the degree of the patient’s memory difficulties were suggestive of a seizure disorder. Due to this last finding, following the neuropsychologist’s evaluation, the patient underwent multiple electroencephalogram’s.

**EEG**

An electroencephalogram, also referred to as an EEG, is a test in which the electrical activity occurring in the brain is measured and recorded. EEG’s are performed by attaching electrodes all over the patients scalp. As the electrodes receive the electrical signals being
relayed throughout the brain, they send them to a machine via wires. The machine then changes the signal into patterns that appear as wavy lines on a monitor. The results can be printed on paper as well. An electroencephalogram not only monitors brain activity but can also help diagnose certain health conditions such as:

- Seizures.
- Brain diseases.
- Head injuries.
- Tumors.
- Infections.
- Periods of memory loss.
- Changes in body chemistry which can affect the brain.
- Fainting spells
- Confusion.  

During the patients’ EEG’s, various activities were performed, such as flashing lights in her face in hopes of causing a seizure. This was done in order to graph the abnormal brain pattern that would be the result. The patient’s EEG report was in the normal range. However, the recommendation was made to consider ongoing monitoring of possible seizure activity and if there should ever be such activity to follow it up with more aggressive medical testing. This was recommended because EEG’s are not 100 percent reliable and do not catch all seizure activity.

As is the case with many medical investigative tools, such as an EEG, errors do occur because of multiple factors and therefore are not completely reliable. “For example, the sensitivity of a single standard EEG in epilepsy is therefore relatively low (50%), but can be increased to more than 90% by repeated recordings, although it may not reach 100%.”

This can be due to equipment failures, but can also be attributed to patient or technologist influences. Also, depending on the size and location within the brain, seizure activity may not be picked up through the skull and brain tissue by the superficially located electrodes.

After three months of undergoing numerous EEG’s that did not show any seizure activity, the patient was referred to a neurologist who ordered a Magnetic Resonance scan of the brain.

**Diagnosis via MRI**
Magnetic Resonance, MR, is unlike many other diagnostic imaging tools because x-rays are not produced in order to obtain images. Instead, a superconducting magnet is used in order to create a very strong magnetic field. This causes the water molecules in the patient’s body to align with the superconducting magnet. Radiofrequency waves are directed at these water molecules. As the molecules relax back into alignment, energy is released that can be detected and measured. A computer then processes this information into either a 3-D or 2-D format for display. The different tissues, such as bone, fluid-filled spaces and soft tissue are differentiated from one another by their water content. A contrast agent known as gadolinium is often used in MR imaging because of its ability to enhance certain types of tissues. “When injected into the body, gadolinium contrast medium makes certain tissues, abnormalities or disease processes more clearly visible on a magnetic resonance imaging (MRI) scans.” This ability to view abnormal tissue is due to interstitial leakage of the gadolinium that occurs as a result of disruption of the blood-brain barrier that is often related to tumors. MRI is also great in the visualization of tumors because of the different imaging sequences that can be used to differentiate normal brain tissue from abnormal brain tissue. Two sequences in particular that allows visualization of edema and nonenhancing portions, which as a result helps assess the degree of mass effect are T2-weighted and fluid-attenuated inversion recovery, or FLAIR, images.

Case Study Continues

The patient received an MR scan of the brain and gadolinium was used to enhance any abnormal tissue. This scan demonstrated a three cm mass that was predominantly found within the white matter but also extended into the gray matter some. It was located in the posterior left frontal lobe and no surrounding edema or enhancement was seen (see Figure 2). The radiologist who read the scan saw no reason to be concerned so the patient went home and back to regular life. Three weeks later the patient received another MR scan of the brain after experiencing a grand mal seizure. This type of seizure is also called a tonic-clonic seizure and is characterized by a sudden loss of consciousness as well as muscular stiffening of the full body.

The second MR showed minimal changes in the size of the mass. However some faint enhancement of the septa lying within the mass, as well as some fluid-containing areas were demonstrated. The scan was sent to a neurosurgeon for further consultation who upon seeing the
mass, which he described as mostly benign, immediately decided that the patient needed to be treated.

**Treatment**

The main approach for treating a pilocytic astrocytoma is surgery. Depending on the situation, radiation can also accompany surgical resection. Generally speaking, the radiation approach is not taken unless some of the tumor cannot be removed. Although surgery is the best form of treatment as of today, there are many risks associated with such surgery. Since the brain is a complex structure and each cell that makes it up is very specialized, cutting into it is not an easy task. Before surgically removing a mass located in the brain, the risks and benefits have to be reviewed and a plan of action mapped out. Krieg SM et al.\(^{12}\) state that “resection of such highly eloquent gliomas always involves a compromise between the extent of resection and the preservation of motor or language function.”\(^{12}(p.51)\)

The neurosurgeon who performed the surgery to remove the tumor from the patient’s brain was well aware of the risks associated. As plans were being made, the neurosurgeon told the patient’s parents that there was a chance that following the surgery, the patient would not be able to speak intelligently. This was due to the fact that the mass was located in and near the language part of the frontal lobe and the surrounding tissue would more than likely be affected to some extent by the procedure. To remove this mass that had infiltrated the posterior left frontal lobe of the patients’ brain, a craniotomy was performed.

Prior to undergoing surgery, part of the patient’s head was shaved and prepped. During the craniotomy, part of the skull was removed from the surface in order to allow access to the region of interest—in this case the posterior left frontal lobe. As the surgeon slowly resected the abnormal tissue, he was careful to minimize unnecessary damage to surrounding tissue. This was done by using lasers and small instruments as the surgeons “hands” for the procedure. Due to the fact there were parts that projected into the gray matter, he was not able to remove all of the mass without risking more serious damage and side effects as a result. This type of incomplete resection is fairly common. “Gliomas, invade and infiltrate the normal brain and therefore, they cannot be completely removed or ablated without associated injury of normal tissue and related functional damage.”\(^{13}(p.257)\) Therefore the neurosurgeon had no choice but to leave some of the tumor intact. Once he removed as much as he possibly felt he could, the part of the skull that was
removed was placed back into place and fastened down by small metal plates. The patient was able to go home five days after her operation.

**Follow-up Care**

In all cases in which surgical resection of a pilocytic astrocytoma occur, follow up care is vital. One thing that is required is a post-operative MRI. This is done in order to determine the full extent of surgical resection and to detect residual disease. This exam should be performed within 72 hours so that any residual tumor can be distinguished from inflammatory changes that occur from surgery.\(^{14}\) In some cases a CT instead of an MRI is performed. This was the case for this 11-year-old patient because of the metal plates that were placed in her skull following the craniotomy.

The main reason for continual follow up care is to make sure the resected tumor does not return, nor the residual section increase in size. Following the operation, the neurosurgeon gave three possibilities for what could happen with the fragments of tumor remaining in the gray matter. The first possibility was for it to stay dormant. The second was for it to grow back rapidly and turn malignant. The third and most likely was for it to grow back gradually and in the patient’s later 20’s have to be removed again. Over the past 11 years the patient has undergone numerous CT exams in order to track the tumors growth. In the first year following the craniotomy, the patient received a CT scan every three months. The timing between scans was then increased to six months until the patient turned 18. Now a CT is performed every five years to track any change in the brain tumor. As of five years ago, no change has occurred. Conversely, immediately following surgery the patient experienced a few short-term as well as long-term side effects resulting from the procedure.

**Patient’s Outcomes**

Even though there was the risk that the patient would be unable to speak intelligently following the craniotomy, the patient has shown no signs of such damage as a result. However, it did take the patient several days to regain movement and control of her whole right side and she even had to retrain herself to eat and do other such tasks. Even though she was able to gain most of this control back quickly, she had some other difficulties that took longer to overcome. For example, when the patient walked down the halls at school, she would find herself bumping into
the lockers on her left due to the lack of help the left side of her body was receiving from the right. In addition, one thing that the patient still experiences is trouble with her memory function, but has since learned to organize and cope with it. Her memory also seems to be better the more actively she is using and exercising her brain. Unfortunately, many other cases have not had such great outcomes. Reasons for negative outcomes include incomplete surgical resection of the brain tumor, inability to remove at all due to the location of the mass within the brain, or because of damage to surrounding brain tissue sustained during such invasive procedures. As a result, different approaches for treating brain tumors are constantly being sought after.

**Ultrasound Surgery**

One potential approach that is now gaining recognition in the medical world is called Ultrasound surgery. There are many other names for this method including MRI-guided Focused Ultrasound. As the last name implies, this method brings two known technologies together in order to create a completely non-invasive approach to removing tumors. The idea of using focused ultrasound in this way is not new. In fact, for over six decades, this form of thermal ablation has been tested in search of a noninvasive approach to treating brain tumors. During focused ultrasound, an ultrasound beam is focused deep within the soft brain tissue, resulting in localized heating. This can be done without damaging the surrounding tissue because of how the ultrasound waves are focused. However, it wasn’t until MRI came into the equation that it really became possible. With the feedback that MR provides, both anatomically and physiologically, a completely noninvasive procedure can be performed. This is possible because the MRI “allows for exquisite targeting and feedback control of the procedure with quantitative temperature imaging.”

In 2011, ultrasound surgery was demonstrated by Yoav Medan, a medical inventor and the Chief Systems Architect at InSightec Ltd. in Israel. In this demonstration, a tissue-mimicking phantom was used to show how Ultrasound can be changed, focused, shaped and altered in order to create a lesion in one specific spot, at a specific frequency without damaging surrounding tissue. How this type of surgery would work in a clinical setting goes as follows. First, the patient would be placed on a MR table and a transducer would be attached to the patient. Next, the physician would take a regular MR scan, then from that scan set safety limits and select a point to target. Following this targeting, he would then apply low energy ultrasound, which is
termed “sonicate.” The energy that is applied at this point elevates the temperature of the tissue by just a few degrees. MR then allows the physician to measure the temperature changes in real time. After verification that the right tissue is being targeted a second boost of energy is applied to ablate the tissue. This ablation occurs as the temperature rises between 55 and 60 degrees C for more than a second. This temperature change is enough to destroy the proteins of the cells within the targeted tissue and therefore destroy the tissue as a whole.

**Conclusion**

After significant neurological testing and medical imaging exams, an 11-year-old female, was diagnosed with a 3 cm pilocytic astrocytoma residing in her posterior left frontal lobe. The patient was referred to multiple health professionals after parents’ concerns with the patient’s memory function and slow developmental progression. Tests and exams were ordered to help with the diagnosis. Medical imaging played an enormous role in the diagnosis, treatment and follow up care in this case. After diagnosis, a treatment plan was chosen in which the patient was taken to surgery to undergo a craniotomy for removal of the mass. Because of the location, not all of the abnormal tumor was able to be removed. This is not uncommon and other methods of treating such brain tumors are being researched and tested to reduce the occurrence of such incomplete resection and to hopefully minimize the risks associated with today’s method of treatment.

Once such method is ultrasound surgery is one method that is being highly tested in hopes of applying its many benefits to patients. If Ultrasound Surgery can be implemented clinically for brain tumor ablation, it would make a huge step forward in treating patients presenting with brain tumors. There are many benefits that this form of treatment would provide. First, by removing brain masses in such a noninvasive method, there is no risk of motor or language function loss. Also, tumors of any size, type and in any location can be treated. Lastly, because of the lack of ionizing radiation involved in Ultrasound and MRI, the patient receives no radiation which is a huge benefit in and of itself.
References


Figures and Captions

Figure 2. Brain mass in a 11-year-old female. A. T2 FLAIR Sagittal image depicting 3 cm brain mass (black dashed line). B. Transverse image depicting brain mass in left posterior frontal lobe. C. Coronal image of the 3 cm Pilocytic Astrocytoma located in the patients left posterior frontal lobe (white line). D. Coronal T2-weighted image of left posterior frontal lobe mass. Images used by permission from the patient’s family.