Posterior Fossa Craniotomy for the Removal of a Brain Tumor
Rainbow Babies and Children's Hospital
Cleveland, OH
August 31, 2006

00:00:16
ANNOUNCER: Today, surgeons at Rainbow Babies and Children's Hospital in Cleveland, Ohio, will demonstrate the removal of a brain tumor in a 6-year-old girl. This procedure is a posterior fossa craniotomy for the removal of a fourth-ventricular brain tumor, the most common of childhood brain tumor. During this program, doctors will discuss this case as well as new treatment strategies at the brain tumor center at Rainbow Babies and Children's Hospital. For more than a century, Rainbow Babies has been dedicated solely to the care of children and is one of the most renowned pediatric medical centers in the world. You may send your questions to the surgeons at any time during the webcast. Just click the MDirectAccess button on the screen.
00:01:03
ALAN COHEN, MD: Good evening. Welcome to Rainbow Babies and Children's Hospital in Cleveland, Ohio. I'm Dr. Al Cohen, the chief of pediatric neurosurgery, and with me tonight is my colleague, Dr. John Letterio, who is chief of the division of pediatric hematology oncology, and we're going to discuss a posterior fossa craniotomy for a brain tumor in a young child. We will discuss our experience with the surgical management of brain tumors at Rainbow Babies and Children's Hospital and with the management of brain tumors in general at the brain tumor center here at Rainbow. Brain tumors have achieved a dubious distinction; with the advances in treatment of leukemia, brain cancer is now the number-one cause of cancer death in children, and our efforts at the brain tumor center are directed toward changing that statistic. There are about 2,000 newly diagnosed cases of pediatric brain tumors in the United States each year, and most of those brain tumors occur in the posterior fossa, at the base of the skull. And so, if we can go to the slides, I'll show -- The case here is a 6-year-old African-American girl who presented to us with a two-month history of episodic headache and vomiting, and she had about one week of a gait unsteadiness. John, headache, as you know, is a pretty nonspecific sign. It occurs fairly frequently in kids.
00:02:22
JOHN LETTERIO, MD: I think that's an important point for people to remember is that many of the symptoms that patients present with as initial symptoms for brain tumors can often be considered symptoms for other very benign conditions, and I think it's important to realize that many of these cases will present over several months or weeks' period of time not as an acute problem.
00:02:42
ALAN COHEN, MD: Kids get headaches for a number of reasons. Kids can get migraine, there can be a number of causes of headaches, but there are some factors, as in this child's case, when the headaches occur in the morning, that raises a red flag for the possibility of increased intracranial pressure. Or if the headaches occur frequently and increase in severity, especially with vomiting that's increasing in severity. But headaches occur for many reasons and so does vomiting. And in fact, some cases that we see were initially misdiagnosed as child-- with psychological problems or child with gastroent--

gastrointestinal problems. But ultimately this child came to our attention because of progressive headache and the unsteady gait, and on the examination, we found bilateral pappiledema and truncal ataxia. Pappiledema is swelling of the optic disc, and it's a sign of increased intracranial pressure; when we look in the eye and the back of the retina, we can diagnose that. And truncal ataxia is unsteadiness of gait. So this picture of the history and the examinations suggests a mass in the posterior fossa of the brain. And again, this is the most common site of tumors in children. And so the child underwent examination with C.T. and M.R.I., and that demonstrated a large fourth-ventricular brain tumor with hydrocephalus, or water on the brain. And cerebellar tonsillar herniation: the cerebellum, the balance part of the brain, had its tip pushed down beneath the base of the skull. Now, if we can look at the images here, this is a C.T. scan, it's a non-contrast scan, and the bone here around this is white, the brain is gray, the cerebro-spinal fluid is black or dark, and this is the tumor. This is like taking a slice of bread, cutting through the head in slices, and anteriorly, or the front, is here, and posteriorly is here. So this is the posterior fossa and the area of the fourth ventricle. And this is where the tumor is growing. It's a large mass that you can see filling the fourth ventricle and causing problems both by causing increased mass effect by the tumor itself and also by causing hydrocephalus. If you think of this as blocking the drain in the sink, there's a backup of water in the head. Can we go to the next picture? And this is an M.R.I., a more accurate image of the brain, a magnetic resonance image. Again, in the same kind of plane. Here's the eyeballs in the front, and this is the tumor. You can see it a little bit more accurately, filling the fourth ventricle. This is a fluid-filled space at the base of the brain. It's causing mass effect and hydrocephalus. Here is a T-2 weighted image. You can see the eyeballs again anteriorly, and this heterogeneous signal of a very large mass in the fourth ventricular chamber. And if we go to the next image, this is a sagittal view, and you can recognize the nose and the mouth here. This is the front of the brain and the back. Here is the large tumor, filling the rhomboid fossa, the fourth ventricle, pushing on the brain stem, pushing the cerebellar tonsils outside the base of the skull through the foramen magnum, causing tonsillar herniation and causing this backup of water on the brain. Normally, there is fluid in the cerebral ventricles; there are four ventricular chambers, but here the tumor is blocking the egress, so there's a backup of the water on the brain, and this is what we call noncommunication hydrocephalus. The problem in this case then is caused by the tumor itself, which creates mass effect inside the skull, the brain is inside the rigid skull and has no room, so if there's a mass there, it's there at the expense of the normal brain, and this causes also symptoms because of the hydrocephalus, the increased fluid causing increased intracranial pressure. And there's one final view, this is a coronal view. Here are the ventricles. We're looking at the patient face-on. Here are the ears, and this is the large, enhancing fourth-ventricular mass with noncommunicating hydrocephalus. So we have a problem now of a young child with increased intracranial pressure from a posterior fossa fourth-ventricular brain tumor and hydrocephalus. And the plan of attack then is first to place the patient on intravenous dexamethasone, which is a steroid, to try to control pressure and swelling. And then we need to -- to operate on the child for two reasons: one is to make a tissue diagnosis to find out what this is, and two to decrease the mass effect and de-bulk as much of the tumor as we safely can.

00:07:04

JOHN LETTERIO, MD: And I think that brings an important point to light. These imaging modalities that we have are very good at identifying the presence of the tumor, but they can't distinguish between the variety of tumors that can present in the posterior fossa. And I think getting an accurate diagnosis is really important in terms of defining the -- the approach to the management of the patient.

00:07:25

ALAN COHEN, MD: And we have other, more sensitive techniques: P.E.T. scans, we have N.M.R. spectroscopy in attempts to get a more accurate view of what type of tumor we're dealing with. The three big players in pediatric posterior fossa tumors are astrocytoma, medulloblastoma, and ependymoma. Astrocytoma comes from the star-shaped astrocytes supporting cells in the brain. And a posterior fossa cerebellar astrocytoma is actually a benign tumor. If we can operate and remove the tumor, the child is cured. Medulloblastoma and ependymoma are malignant primary brain tumors that usually require surgery and a comb-- combination of adjuvant therapy, or assisted therapy, with chemotherapy and radiation. But we often can't make a diagnosis exactly of what type of tumor we're dealing with preoperatively, and that's one of the things that we're working with in the lab to try to find better imaging techniques and optical techniques to ensure a better diagnosis. In any event, our surgical strategy is the same: to make a diagnosis and de-bulk as much of the tumor as we safely can. The problem is, though, that before opening the posterior fossa, we need to treat the hydrocephalus because if we were to open the brain with this much mass effect, the brain would come herniating out of the head. So the first technique is to place a ventricular catheter through a small, little opening in the skull, and this is a safety valve to let some of the fluid out. And then we turn the patient prone and we do a posterior fossa craniotomy for tumor. And what we're going to see when we go to the O.R. here is the approach for a posterior fossa craniotomy for tumor. The posterior fossa is the small portion of the base of the skull that houses the cerebellum and the brain stem and the fourth ventricle. And the fourth ventricle is a small, irregular-shaped rhomboid fossa. It's sort of diamond-shaped. It's mysterious, it sits housed just behind the brain stem, just underneath the cerebellum, and it can be the source of several tumors that can fill the fourth ventricle and cause hydrocephalus and increased intracranial pressure. The technique that we're going to use in today's case is a midline posterior fossa craniotomy. We'll make an incision at the base of the skull, work through the soft tissue, remove bone, and then go in, separate the leaves of the cerebellum and work in the fourth ventricle to take out the tumor. So this will be the position, the patient will be prone, and now I think we can go to the operating room, and we'll demonstrate the surgical approach. Here we have the patient prone under general endotrachial anesthesia, and the patient has received intravenous dexamethasone steroids and antibiotics, and you can see we're incising the midline. We're standing at the patient's head looking down. We've infiltrated the scalp with a solution of xylocaine, with epinephrine, to control the bleeding, and we'll use a bipolar coagulator here to stop some of the scalp bleeding. The scalp is very vascular, it tends to heal well, and we try to use the bipolar to control the bleeding. If we can stay in the midline, through the ligamentum nuchae, then we can minimize the bleeding in the operation. So the initial exposure then is to open through the soft tissues down to the midline and expose the occipital bone at the base of the skull and the upper part of the spine. Now we're using a monopolar coagulator, and we're undermining the skin edges at the top. And the reason we do that is so that we can open the fascia, the soft tissue, in a y-shaped fashion. Here we can see the occipital bone, and this is the monopolar coagulator, and now we're looking down at the upper part of the spine, and we're taking the muscle off the arch of the axis, the C2 cervical vertebra and the atlas right here, C1. And we expose the upper cervical spine, the arch of C1 and C2, because this is a low situated tumor and we need to have better access low down. So as you see, we're opening this area and exposing the base of the skull and the upper portion of the cervical spine in preparation for doing the posterior fossa craniotomy.

00:11:31

This y-shaped opening in the fascia is done so that we can create a water-tight closure. When we close the wound, the cerebro-spinal fluid often wants to leak through the stitch holes, and we use a lot of measures to control all the soft tissues to keep the cerebro-spinal fluid within the head. This -- the forceps now are outlining the proposed site of the posterior fossa craniotomy, where we'll remove the bone flap, and that's the arch of C1, the atlas, which we will also remove to facilitate the exposure of this tumor. That's the foramen

magnum, the base of the skull, that will be the inferior bottom margin of the tumor exposure. Again, we're standing at the head of the bed.
00:12:15
JOHN LETTERIO, MD: So it's important to monitor bleeding during the procedure. Are there other things that are important to follow in this patient during this part of the procedure?
00:12:22
ALAN COHEN, MD: Well, we monitor bleeding and we work closely with the ped-- pediatric anesthesiologist. Again, we've got a ventricular drain in place to take out the overflow of cerebro-spinal fluid so that once we take the bone off, when we open the dura, or the linings of the brain, we don't have increased intracranial pressure. And that's one of the things that we can tell sometimes preoperatively, the type of tumor. When we look at an M.R.I., is it a medulloblastoma, an ependymoma, an astrocytoma? Medulloblastomas are a very vascular tumor and we're prepared for blood loss. And even though there are different surgical strategies in dealing with each of the tumors, even with a vascular tumor, we have a blood conservation center here, and we attempt to do all posterior fossa brain tumors -- and all brain tumors in children whenever possible -- without the need for a blood transfusion. So now we can go back to the O.R., and we have exposed the occipital bone and the upper part of the spine, and we're doing a craniotomy. And this is a high-speed drill, and we're drilling a hole in the bone. This has a clutch so that it won't plunge, and you can see the bone dust here. We're going to actually take the bone dust and save that for use at the end of the operation. Hopefully this will have growth factors that'll help regenerate the bone flap. We actually put the bone back with titanium plates and screws and ultimately, nature helps diffuse the bone. But the way we do this is -- you can see, we're using an instrument to strip the dura. We've made a hole in the bone, and we're going to make another one in the other side, and that's the top of the exposure. And here we have the high-speed drill again with a clutch so that it won't plunge. As soon as it goes through the inner table of the bone, the drill will stop spinning. And that marks the upper extent of the craniotomy, the top of the exposure, and then inferiorly, at the bottom, is the foramen magnum, which nature has given us for the opening, and we strip that. And then we'll use -- again, we're taking the bone dust here -- then we'll use a -- a high-speed drill with a foot plate -- power tools again -- to elevate the bone flap, a bilateral posterior fossa craniotomy. And the upper margin of that exposure, here we're stripping the dura again from the undersurface of the bone. The dura, or the protective mother, the "dura mater," is the thick lining of the brain, and that's directly underneath the bone. And so our job here, to get to the tumor, we have to go layer by layer through the skin and the soft tissue. Now we're going to take the bone off. And the way we do that is using this craniotome with a foot plate and the technique is to make lateral cuts, the cuts on the side, from top down as we outlined there first, and then we do the top cut across the midline last. And the reason that we do that is because the most dangerous cut is the one on the top because that sits just directly underneath the transverse sinuses, the big veins that drain the brain and the midline, where the transverse sinuses come together -- And here, this is the drill with the footplate -- where the transverse sinuses come together is the torcular herophili, a confluence of the sinuses. So our feeling is, if there is ever going to be an injury to those vessels, we want to have everything else ready so that we can get the bone flap off quickly. So the technique coming across the top is, we go almost halfway and then stop, and we're working, again, just underneath the big venous sinuses, and then we start on the other side and go almost halfway. We've already made the lateral cuts on the side, so if there were any trouble from bleeding now, when this bone flap comes off, we can take care of it because we can get the bone flap off quickly. The order that we make the cuts is quite important in terms of doing a posterior fossa craniotomy. A craniotomy is an opening in the bone where we replace the bone at the end of the procedure, and in many places, a craniectomy is done, where the bone is removed but not replaced because the bone is irregular, and sometimes it's difficult. But with the advances in these power tools, it's not

too difficult to get the bone off, and we like to replace the bone at the end of the operation. It's more physiologic, it's more anatomic, it reduces the pain, and if we ever were to have to operate again, it gives a barrier of protection. That's the bone plate that's come off. A posterior fossa craniotomy bilaterally down to the foramen magnum, and we'll also remove the posterior arch of C1, and now we're looking at the dura, the linings of the brain. And so we've got now the soft tissue open and the bone flap off. We're irrigating now with some warm Ringer's solution to control bleeding. We wax the edges of the bone to control bleeding, and we've opened the ventricular drain now to reduce the pressure, and you can see we're feeling the two cerebellar hemispheres under the bone to make sure there's not too much tension. The brain is now relaxed, and that's a combination of the anesthesia and the external ventricular drain that we have as a safety valve for the procedure.
00:17:14
JOHN LETTERIO, MD: So, Al, is this the first point at which in the surgery you can begin to visualize the actual tumor there in the posterior fossa?
00:17:23
ALAN COHEN, MD: Right. Well, at this point, we've still got the dura between us and the tumor. We've got the bone off, we know where the tumor is, it's in the midline. One of the reasons that these tumors can be misdiagnosed is because the fourth ventricle is a potential space, and these tumors can actually sometimes get to a pretty big size before they create symptoms. So we don't see the tumor yet; we're going to see the tumor once we open the dura, and that's what we're going to do next. So we can go back to the O.R. now. The bone is off. Again, the patient is in the prone position, face down. We're standing at the top of the head and looking down. And this is the dura over the two cerebellar hemispheres. And you can see what we're doing is we're incising the dura with a number-15 blade, and you can see we're doing this slowly and repetitively because we don't want to plunge into the brain. You can see that it's soft because the brain is relaxed here. We're irrigating. There is some pleading coming from the edges of the dura, and we can control that with bipolar coagulation, but in fact, in some cases, we can control that just with a little hemostat, with a forcep; we grab it and can slow the bleeding down. Or stop the bleeding. And what we're doing, you can see, is we're not opening in the midline. We're opening off to the side. Here's a little dental instrument that we put under the dura, and we're cutting over this groove. We can do this or we can use scissors, but instead of opening in the midline, we're opening on the side. This is on the patient's right side, on your left because we're standing at the head of the bed. And the reason that we're doing it this way is because, unlike the skin opening and the soft tissue opening where we really want to be in the midline to prevent bleeding, in the dura, especially in children, we want to be away from the midline because the midline in the dura has a big occipital sinus. And sometimes in young children, the whole dura can be a big venous lake, and if we were to open cavalierly right down the middle, in a linear fashion, we could get tremendous hemorrhaging. By opening on the side, in a sort of y-shaped fashion, we can avoid the majority of bleeding along the midline occipital sinus. And when we do have bleeding, we can control that with little silver clips, which we can remove at the end of the operation when we close the dura. So the procedure now is to start on one side, then on another. And now we've got the dura open. We're looking from the top down, and that's the inferior, the bottom end. And you can see the brain stem down there at the tip of the forceps, and the dura is opened and retracted, and we're looking from the top down at the cerebellum and the brain stem. And there's this little sheer, thin membrane which is the arachnoid, which is a thin lining of the brain underneath the dura. And under the arachnoid is the clear cerebro-spinal fluid. You can see some of it there. It looks like water. At this point, we still haven't seen the tumor yet. The tumor is right down there. It's between the two cerebellar tonsils, and we're opening the arachnoid, letting some of the fluid out. And this is causing further relaxation of the brain. That's the area where we're going to see the tumor. Now, the tum-- and this is the brain stem. Again, looking from the top down, these are automatic retractors that are elevating the cerebellar tonsils, and we

gently pull them out of the way. And by dissecting in the area of the cerebello-medullary fissure on each side, right where the tip of the forceps is, you can see the tip of the tumor at the bottom end of the fourth ventricle. Really, it's up underneath the brain, and so the problem with this case, with posterior fossa tumors, is it's a big tumor but it's hidden from us by the cerebellum, so we see only the tip of the iceberg. That's the tumor right at the tip of the forceps there. And we could easily take out the cerebellum and have good exposure, but that would cause an unacceptable neurological deficit, so the trick is to work in a small area and enucleate the tumor, to expose as much of the tumor as we safely can. That's the tumor, filling the inferior, or the bottom part, of the fourth ventricle. And then work from the inside out. What we try to do is to place a Cottonoid, one of these little white paddies that you see there, underneath the tumor between the tumor and the fourth ventricle floor. And the reason for doing that is the floor of the fourth ventricle is the brain stem, and all the cranial nerve nuclei that are very important there can't be injured, so the brain stem is very unforgiving. Here we're looking from the side and we're placing a Cottonoid up along the floor of the fourth ventricle to try and protect it. These are the automatic retractors maintaining the exposure, and right next to the forceps you can see a little red vessel, that's the P.I.C.A., or the posterior inferior cerebellar artery, a branch of the vertebral artery. There are important cranial nerves and vessels here that need to be preserved, but the real technique is to use these retractors to pull the cerebellum apart, expose the tip of the tumor, and then work within the tumor, enucleate it, and take it out in a piecemeal fashion. Here we're looking from the side. We've looked from the top before, and we have the mobility to work on the side of the head and the top of the head and move around from side to side to make this exposure easier at all angles. We have a superior, inferior, and lateral pulls of the tumor that we need to have exposed in order to facilitate the dissection.
00:22:30
JOHN LETTERIO, MD: And one of the things that you mentioned is that these posterior fossa tumors tend to be relatively large. One of the things that distinguishes Rainbow is the minimally invasive neurosurgery programs that you're developing, and I wonder, in these tumors, is there a role for the minimally invasive approach and what's happening in that area?
00:22:50
ALAN COHEN, MD: So minimally invasive neurosurgery is attractive because nobody really wants to have a maximally invasive neurosurgery, and minimally invasive neurosurgery is applicable for a number of tumors. What we can do using endoscopes, the same technology that general surgeons use to take out the gall bladder, we have small endoscopes that we can use through various approaches. And sometimes we can biopsy tumors, and sometimes we can treat hydrocephalus with an endoscopic third ventriculostomy to basically make a trap door in the ventricle to avoid the need for a ventricular shunt. For a large tumor like this, though, the standard treatment would be a posterior fossa craniotomy for tumor. And before we go on, there's a PowerPoint picture here that I can show. This was the exposure here, and this is what we were seeing looking down as we've taken the bone off. The posterior fossa craniotomy, we're looking at the two cerebellar hemispheres, and that's the dura. Then we opened that dura in the Y-shaped fashion to prevent the bleeding from that vascular midline occipital sinus, and once we do that, this was the exposure. And that's the exposure you saw before while we were working, the two cerebellar hemispheres. And at the top of the screen, that V-shaped area is the tip of the tumor that's projecting in between the two cerebellar tonsils down at the base of the -- of the brain. So now we can go back to the O.R., and we've got the tumor exposed. We're seeing the tip of the iceberg. These are our retractors. This is a suction catheter. And again, what makes this challenging is, it's a very big tumor, but we're only able to see a small portion of it at any given time. And this is called a buddy automatic retractor system, and we have a bipolar forceps here. We're coagulating the tumor, and we have a suction catheter. We use a variety of techniques, but the basic message here is that we're taking the tumor out in a piecemeal fashion rather

than try to take this out as one big specimen, which would cause unacceptable neurologic deficit; we're going to work within it and use the bipolar to control bleeding, suction to keep the field dry, and then we'll take -- here's a piece of tumor being delivered like a baby here. But you can see that it comes out in pieces. What was difficult about this case is that it was somewhat vascular but it was also very firm, and so we had to take this out in pieces. Sometimes tumors are vascular, and they can be challenging, but they're soft and so they can be rapidly removed. When a tumor is firm, we have to take it out piecemeal and avoid causing a traction injury to the brain or the brain stem from where the tumor is attached. So the challenge here is to work within the tumor through this small exposure at the surface, where it presents in the vallecula between the two cerebellar tonsils, and we're working in this tumor in the fourth ventricle. You can see the retractors, and we're just going to go in and out and control the bleeding and take this out in a piecemeal fashion. This is why brain surgery is sometimes measured by the calendar, not the clock, because we go slowly and carefully, and this is a procedure that took several hours.
00:25:55
JOHN LETTERIO, MD: Al, what are the major limitations for your ability to actually visualize the margins of tumors in this sort of resection?
00:26:02
ALAN COHEN, MD: Well, that's one of the challenges. And sometimes we can't, especially in tumors that come from the brain. They don't have a capsule around them, and so it's difficult to distinguish the margins. Sometimes we tell a difference by the texture of the tumor. Here is a specimen that we're going to send off to Pathology, and in this case, we send the tumor for a frozen section. This looked like it was going to be a malignant medulloblastoma on the basis of the clinical history, and it turned out that it was a juvenile pilocytic astrocytoma. So the good news in a case like this is that's a benign tumor and that surgery alone, in this case, is curative. This is a patient who wouldn't need adjuvant or assistive therapy with chemotherapy or radiation. But the challenge is it was a firm and difficult and stuck tumor, and it took quite a while to take out piecemeal.
00:26:45
JOHN LETTERIO, MD: In cases like this, are there intraoperative imaging tools that you can use that would enable you to do better resection?
00:26:52
ALAN COHEN, MD: I think intraoperative imaging tools are the challenge of the future, and using optical guidance and dyes that may be taken up by the tumor and not the brain would allow us to tailor the resection and go after what's tumor and leave the brain, remove the tumor. So I think that's stuff that we're working on in the laboratory here and as an advance for the future. Now, we have the tumor being debulked, and the tumor is in the fourth ventricle. At this point, after doing a good part of the debulking of the tumor, we bring in the operating microscope. And we can go back to the operating room using a surgical microscope that gives us magnification. And we're looking down now, and the problem here is that this tumor arose from the cerebellum, the balance area of the brain, but also from the brainstem itself. And the principle is that we can take the tumor out down to the brainstem, but we don't want to go into the brainstem because, again, of the problem of neurologic deficit. There is some bleeding coming from the tumor here and we have a micro paddie on this. We use a variety of hemostatic agents—Gelfoam, Avitene—to help stop the bleeding. A little bit of pressure and some warm irrigation that usually stops the bleeding. And we need to keep a clean field when we're working under the operating microscope because things are magnified. This is actually a small portion of the operative field that we're seeing, and a little bit of pressure that will stop the bleeding. And what we're going to do here is remove the residual tumor down to the floor of the fourth ventricle. Now we're looking from the anatomic position, so up is up. It would be as if we were looking at the back of the patient's head. The two retractors on the side are pulling the cerebellar tonsils apart, and the tumor has largely been removed. We're looking down

at the fourth ventricle now. Again, superior is up in your field and inferior, the patient's legs, are down at the bottom. Same exposure. And you can see the white brainstem down at the bottom, and we're suctioning some of this fluid. Now this is the cerebrospinal fluid, and the fact that that's in the wound tells us that we have unblocked the hydrocephalus, that the fluid is coming through the aqueduct of Silvius from the third ventricle, and the tumor had been blocking that, but this fluid comes in now. So we've treated the hydrocephalus both with the ventricular drain, which is a temporizing measure, and with the tumor resection. Now this probe is showing you the floor of the fourth ventricle, and that's the area on the right side where the tumor was stuck to the floor of the fourth ventricle, where there's a little bit of char on it. And again, cerebrospinal fluid coming through the aqueduct of Silvius down into the fourth ventricle. The bottom of the fourth ventricle is the obex, this little v-shaped area at the bottom aspect of your screen. And the retractors--we're gently retracting the cerebellar tonsils to maintain the exposure. The operating microscope allows us to do things that we couldn't have done before. We can see under magnification and work on small vessels. And the idea again is to remove as much tumor as is safely possible. And we try to do the same operation in every case. Whatever the tumor is, the thing that makes the biggest difference in the outcome is the extent of surgical resection. So whether this is a benign or a malignant tumor, we will try to take everything out. But in some cases, where tumor is attached to eloquent neural structure, there's surgical judgment involved and we have to know when to stop. And the principle when we're dealing with the floor of the fourth ventricle is to shave the tumor down to the brainstem and then stop. And we use intraoperative monitoring of the cranial nerves to help make the operation safer. We can monitor the brainstem auditory and vocal responses and the facial nerve. And again, when these potentials give us abnormal signals, it tells us to back off, you're tugging too hard. Again, anything that we can do to make the procedure safer is something that we try to do in the operating room. Here is the view again from the top down, looking at the floor of the fourth ventricle, with the bulk of the tumor removed there. There's a small portion right there where the suction catheter is that's stuck to the floor of the fourth ventricle. We're irrigating with some saline solution, and we'll go back and try to shave that piece of the tumor down as close to the brainstem as we can. The brain is now relaxed and pulsatile, and the increased pressure has been taken care of.
00:31:11
JOHN LETTERIO, MD: Now how much do you worry about seizures during these procedures? Is this an issue with posterior fossa tumors or primarily an issue with tumors that occur elsewhere in the brain?
00:31:21
ALAN COHEN, MD: So, in addition to causing mass effect and increased intracranial pressure, some tumors can cause seizures by irritating the cortex, and those tumors often come to neurosurgical and neurological attention at an earlier time. They can be diagnosed, especially if they're in an eloquent area of the modus strip [?], when they're still at a small size. But posterior fossa tumors don't cause seizures. They cause increased pressure. The cerebellum does not cause epilepsy, and so we can get by without using anti-epileptic medication for these lesions. There are cases where tumor resection itself can be curative in terms of treating epilepsy, and we have an epilepsy center here where we do work in that area. But in posterior fossa tumors, really we want to get rid of the mass effect. We don't have to worry about seizures. Now we can go back to the operating room and we've got the tumor largely debulked. And we're looking down at the floor of the fourth ventricle. Here's the retractors. Again, we're in the anatomic position, so it's as if we're looking at the back of a patient's head. Up is up on your screen, left is left, and right is right. And here we're using a bipolar coagulator to shrink down a residual piece of tumor that's coming out of the floor of the fourth ventricle. And we're going to do this carefully. We're irrigating so the bipolar forceps don't stick to this, because if they stick, then when we try to take them off it can cause bleeding. We don't want to tug on the brainstem, and so we're sort of

walking on eggshells here. Again, this is a slow, tedious procedure, but the idea is to take out the bad stuff and save the good stuff. Or the principle of neurosurgery is like the bank robber's credo, which is get in, get the money, and get out. And that's what we're trying to do, but we're trying to do it really with a light touch here, because the brainstem is an unforgiving structure and we really not only don't want to injure it, but we don't want to even cause swelling because swelling, or edema, in the brainstem can cause secondary neurological compromise. What we're doing is shrinking this down, and you can see the cerebrospinal fluid coming down through the top through the aqueduct of Silvius, which has been unblocked. This is as if we took a ball out of the drain in the sink. And we've treated the hydrocephalus. At the bottom end of the screen on your right, you can see a loop of the posterior inferior cerebellar artery. That's a branch of the vertebral artery that has to be preserved. And again, that floor of the fourth ventricle that has the important cranial nerve nuclei. Again, here's we're coagulating the tip of the tumor and then we'll take microscissors, cut this down, and serially shave it down to just leave nothing but the floor of the fourth ventricle.

00:33:48

JOHN LETTERIO, MD: Although it's relatively rare, these posterior fossa tumors do have the potential to seed the spinal column. Do you worry about—is there a risk of that happening during the procedure? Are there things that you need to do before the surgery to define whether or not that's happened?

00:34:03

ALAN COHEN, MD:

Well, there are some types of oncologic operations where we actually try to do an en bloc reception to try to prevent any seeding anywhere. That is not possible in the fourth ventricle because, as I said, we have to work from the inside out. And you're right, some of these tumors can seed the neuraxis. They can seed the subarachnoid space. Sometimes we see in malignant tumors some sugarcoating over the surface of the brain. By the way, the tumor is out and we're looking at the fourth ventricle. But because the tumor is exposed to the cerebrospinal fluid pathways, there is an incidence of seeding the spinal cord. And so what we do is we image the spinal cord preoperatively with an MRI to be certain that there's no disease. Because after surgery, there can be some blood products that may change the way the image looks. But spinal seeding is something that's a significant concern in malignant posterior fossa tumors. Those are the two cerebellar tonsils at the bottom. And we see some cerebrospinal fluid welling down from the aqueduct of Silvius, which has been unblocked above. The tumor is shaved down to the floor of the fourth ventricle. This was a tough tumor because it was vascular and firm. And again, the trick was that we were not taking it out through the major exposure of showing the whole tumor equator. We were just showing the tip of the iceberg and working from inside out. But knowing where this was and seeing it on the MRI allows us to do this. Here we're on the side with the same view. The top of the head is to the right, the bottom is to the left. We're showing the cerebellar tonsils and brainstem there. Here's the fourth ventricle and where the tumor was—the tumor was actually largely under both of those cerebellar hemispheres. We could only pull them apart so much without creating too much swelling, but that's outlining where the tumor was underneath. Now that that's been removed, the CSF pathways, the cerebrospinal fluid pathways, are open. And although there is a ventricular drain, we will ultimately be able to remove that. What we do is we leave the ventricular drain in place for several days postoperatively and then slowly elevate it, wean it, so that we make the patient use his/her own CSF reabsorptive pathways and can remove it. And about a third of the cases we need to proceed with a ventricular shunt to treat hydrocephalus. But most often, we can rid the patient of the need for this ventricular drain and ventricular shunt. We're coagulating the surface of the cerebellum here, the peel [?] surface, to prevent any bleeding. We'll control the bleeding, and then we'll proceed with the closure of the brain in layers.

00:36:18
JOHN LETTERIO, MD: Aside from the size of the tumor, Al, are there other things related to the surgery itself that have an impact on recovery, an ultimate recovery from the surgery?
00:36:29
ALAN COHEN, MD: Well, certainly the location is one. And this is a tumor that's in the fourth ventricle. It depends what the tumor is attached to. When the tumor is attached to the cerebellum, we can work more safely in taking the tumor attachment. When the tumor is attached to the floor of the fourth ventricle, as in the case with ependymomas, or in this case, with an astrocytoma, we have to be much more careful because we can't violate the floor of the fourth ventricle. So location and consistency of the tumor are factors. Bleeding is a factor in young children. A highly vascular tumor is something that we have to prepare for. And as I said, one of the ways we do that in a blood conservation program is to medicate the patient preoperatively to prepare for blood loss. But still, even with vascular tumors, in most cases we can remove the posterior fossa fourth ventricular tumors without the need for a blood transfusion.
00:37:17
JOHN LETTERIO, MD: And we'd like to encourage anybody who's watching online to send in their questions by email if they'd like to have us address any of their questions.
00:37:24
ALAN COHEN, MD: So while you're working on your questions, we'll go back to the operating room. And now we have the tumor out, and we're looking down on the operative bed from the top down now. We're standing at the top of the head. And the challenge here is to close the linings of the brain. We've opened the dura, remember, in a y-shaped fashion. And the dura, the dura mater, or the protective mother, is a fibrous lining of the brain, and we need to close that so we can keep the cerebrospinal fluid inside the head. And the problem is, if we try to close the dura primarily—we're stitching it here—it won't close, because whatever happens, it always shrinks. We can keep it moist, but it always shrinks. Here's the bone flap that we're going to later place. And the way we close the dura is to use a dural graft, and there are a variety of tissues that can be used. In this case, we're using bovine pericardium. It's a treated tissue, and it's a fibrous area that we can use in a sort of chevron shape. It's a triangular shape, and that allows us to close the dura under tension. We're irrigating here. We're going to fill the intradural compartment with saline, but we're using running sutures up each side and along the top to reconstitute the normal anatomy. This is important to do to prevent infection because if we leak cerebrospinal fluid through the stitchholes, and the CSF often wants to leak out of these stitchholes, if the fluid can leak out through the skin, then the germs on the skin can go in, and that can cause infection—meningitis, ventriculitis. So we take a fair amount of time doing a watertight closure, and we can prove that it's watertight by asking the anesthesiologists to do a Valsalva maneuver. They increase the pressure and we can make sure that there's no fluid leaking from the wound. If we see something leaking, we can oversew that with a stitch or two. And once we close the dura and prove that it's a watertight closure, we replace the bone flap. As I say, we like to do a posterior fossa craniotomy. A craniotomy means we remove the bone and then we replace it. And what we're using here are microtitanium plates, and these are small, very sturdy plates and screws. These are dog bone-shaped plates. We have a variety of different sizes with some very interesting names. But what we do is, we put these plates into the bone, and then we put the bone into the skull, and we screw it back together. And that gives us an immediate stabilization. Here we're replacing the bulk lab [?]. And then over time we put the bone dust back and nature will then get a fibrous union and heal the bone itself. We like to put the bone back because it restores normal anatomy. I think it reduces the incidence of pain, and I think it protects the wound. And again, if the surgery were ever needed again, it gives us a layer of protection. That's the graft there of bovine pericardium. We're pointing out the exposure. And we'll irrigate the wound with antibiotic solution. We use intravenous

antibiotics and then irrigation antibiotics. And now we're replacing the bone flap. And we have these titanium plates and screws that go into the skull, and we'll fix the bone. They're made of titanium, they're very lightweight, very small, they don't set off any radar devices in an airport, but it restores normal anatomy. And we have a variety of creative shapes and sizes of these bone screws and plates to allow us to put the bone back together.

00:40:44

JOHN LETTERIO, MD: Are there other important things to consider in the immediate post-op recovery period. Are there things that you watch for?

00:40:50

ALAN COHEN, MD: Yeah, we're always worried about protecting the brain. The brain is unforgiving, and so the major concerns are to prevent infection of hemorrhage. We spend a good deal of time with the bipolar forceps to stop any bleeding. We use intravenous antibiotics to prevent infection, and we use steroids to try and prevent brain swelling. And then we have this ventricular drain that's in place to protect the wound. Here we're screwing the titanium plates and screws in to close the exposure. And we monitor the patient in the pediatric intensive care unit. So this is a multidisciplinary team that's working to take care of the patient with the neurosurgeon—the neurologist, the oncologist, the nursing staff, therapists—but we're walking through a minefield and we're looking for problems every step of the way. And here we're putting the final touches on the bone flap. And you can see at the top of the exposure we have this little fascial sling that we're going to use again to prevent CSF leakage or cerebrospinal fluid leakage. We're trying to get a watertight closure to keep the CSF or cerebrospinal fluid in the head.

00:41:59

JOHN LETTERIO, MD: So I think this case really illustrates how complicated brain tumors are and how dependent we are, both as physicians and these patients, on a very concerted, coordinated effort by a number of specialists who focus on the care of patients with brain tumors. I think it requires the input of specialists like neurosurgeons, neuroradiologists, neurooncologists, radiation therapists, and folks who are involved in both the treatment and recovery of children who—

00:42:30

ALAN COHEN, MD: That's right. This is something that—you know, a neurosurgeon would like to take credit for anything that goes well, but it is a multi-disciplinary effort, and this is something that could not be done without a multidisciplinary team, without a brain tumor center. While we talked, there's one more piece of the operation that we can show while we're speaking, and we can go back to the operating room. We've got the bone on right now and we need to put the patient back together. So this is the bread and butter part of the operation, but we're closing the muscle and the fascia and the soft tissue and the skin. And we do that in layers, and you'll see. We're in the top of the head, and the principle is to do this in layers, to keep the cerebrospinal fluid inside the head, to keep the good stuff in and the bad stuff out. And so we do a layered closure—we're using Vicryl sutures, which are absorbable sutures. We do this in layers because it's just the simple principle: the more barriers we have, the more chance we have of keeping the cerebrospinal fluid inside the patient. And here we're closing the muscle and then the fascia. We do this with interrupted sutures, so if one breaks, we don't lose the whole suture line. We start from one end and work upward, and we do this in layers.

00:43:42

JOHN LETTERIO, MD: So while you're looking at the surgery, actually we've had some questions come in, and one relates exactly to what you're talking about here, and it comes from—the question is how long do brain surgeries like this generally take?

00:43:56

ALAN COHEN, MD: And again, some people joke that brain surgery is measured by the calendar, not the clock. It's not something that's rushed, and, in fact, brain surgery—even a quick operation is done not because the surgeon is operating quickly but because the

surgeon uses economy of movement, trying to anticipate the next movement, trying to understand what to do before a problem happens. A lot of surgery really is done in the planning stages. It's like what Yogi Berra said about baseball is that 90% mental, the other half is physical. And sort of the same thing is true in brain surgery. A lot of this is in the planning stage. But brain surgery is not quick, and this operation took six hours. And it's a long time—when you're doing the case, you don't really think about the time, but in fact, it's not something you want to rush, especially at the point where we're working on the brainstem. There are certain parts of the operation that can be done fairly quickly and routinely, but we gear up as we work towards the microscope where we're working under high magnification by the brainstem, and that's something that really needs to be done slowly and carefully. And here we're using sutures to close as we're getting closer to the skin. Now we're in the subcutaneous tissue, and what we do here is we invert the stitch, so we do your side, the left first, and then the right, the patient's right first, and then left, and the reason we're doing that is to bury the knot so that it won't be seen or felt under the skin. These are absorbable sutures, and they give us some stabilization, and then over a period of a few months, these things reabsorb and go away. After this layer, we have only one layer left, and that's the skin. We use a running suture there. And then what we'll do is after the wound is closed, we'll dress the wound sterilely and then we'll release the patient and turn the patient from the prone to the supine position, from face-down to face-up, and then we excavate the patient. We take the breathing tube out and wake the patient up. We like to do that in the operating room to make sure that there's no neurological deficit. If there's a problem, we like to know about it right away. So we actually reverse the anesthesia on the OR table, and then we move the patient to the PCU, the Pediatric Intensive Care Unit, and we'll recover the patient there. We have an external ventricular drain that protects the wound. We use intravenous steroids and antibiotics, and our procedure is to obtain an MRI scan the next morning to see the extent of the tumor resection and to make sure there are no other unanticipated problems with the brain. And then what we do is over a period of several days is we gradually wean the external ventricular drain by raising the bag, forcing the patient's own cerebrospinal fluid pathways to open and handle this. And over a period of several days, we remove the drain, and about two-thirds of the case, we're able to keep the patient shunt-free, and about one-third of the patients require a ventricular shunt for hydrocephalus.
00:46:43
JOHN LETTERIO, MD: A couple of the questions that have come in relate specifically to the surgical procedures. One is, "What is the temperature of the instrument that you use for coagulation?" And the other is, "Are the inner stitches taken out or are they just left in?"
00:46:57
ALAN COHEN, MD: So the temperature, we use different techniques for coagulating, but the temperature's quite hot. If you felt it on your hand, you would burn yourself. As we're insulating, we don't feel that. We actually in some cases use lasers, high focused energy sources, to control the bleeding. So there's a very high energy field, and because it's hot, that's why you saw we were irrigating because we don't want to transmit that heat to the brain or to the brainstem itself. In regard to the second question, the sutures that we use in the deep layer, most of those are absorbable. The sutures that we used to close the dura were a permanent suture—that will stay in. The other sutures in the soft tissue and the muscle were absorbable, and we don't have to go in and take those out. And in some cases, even in the skin, we use absorbable sutures so that we don't have to take those out. They absorb over time.
00:47:42
JOHN LETTERIO, MD: One of the questions that has come in is actually a very common question and one that presents a concern to most folks, and that is what causes a brain tumor like this. What would make a child of this age actually develop a tumor like this, and I think the important point to remember is that in the majority of cases, these are

spontaneous. There is no known genetic basis or cause for these brain tumors to develop. There are some genetic syndromes, like neurofibromatosis or tubular sclerosis, where we know there is a higher incidence or predisposition to develop brain tumors, but by and large, for most of the brain tumors that develop in the pediatric population, it's not because of an exposure to something that might induce the cancer or because of something that may have happened. In general, these are spontaneous, and we really don't know the basis for the development of these tumors. It's an intense area of interest for the research that's going on, both at our institution and at other places that focus on brain tumors.
00:48:34
ALAN COHEN, MD: And that's one of the things that we have in our Brain Tumor Center is the ability to have a tissue bank, and we take the tissue from the tumor and we store it, and this way we can work with and we can look at genetic factors that may be involved in the diagnosis of tumors somewhere down the road. Things that we don't understand now we may understand later.
00:48:51
JOHN LETTERIO, MD: And that represents one of the unique aspects of a center for brain tumors. It brings together the expertise of neuropathologists, biologists who are interested in the behavior of these tumors, who want to focus on the development of tools that would allow us to better diagnose the actual type of tumor that may be present in the posterior fossa, and enhance our ability both to make the diagnose and follow for recurrence of these tumors. In addition, we have another question here that asks, "Is it possible for these tumors to grow back?" And that's always a concern for us with brain tumors. As Al mentioned, our approach to these tumors is always to get maximal surgical resection. Outcome and survival is clearly linked to how effective we are in terms of our surgical resection. They can grow back in the original spot of the tumor. Certainly local recurrence or regrowth of these tumors represents the greatest risk. They rarely metastasize or develop outside of the brain, but they can recur at sites adjacent to or in other sites close to where the original tumor was in the brain.
00:49:52
ALAN COHEN, MD: And again, the singlemost important factor in determining the outcome of a child with a brain tumor is the extent of surgical resections, so we will attempt to get a growth total resection in every case. We want to make a diagnosis and we want to remove the tumor, but we want to remove as much as the tumor as is safely possible. So if we have a malignant brain tumor, we'll try to get it all, but if it's stuck to cranial nerves or to an eloquent area of the brain, we'll take as much as we safely can. And that's where agimen [?] therapy comes in. That's where we have Dr. Jacobsen and our clinical hematology oncology division, Dr. Kinsella in our radiation oncology group. And we have a tumor board that meets and we try to find the best available therapy. And this is a multidisciplinary and sometimes a multi-institutional process where we consult our colleagues across the country to try to find the best available therapy.
00:50:41
JOHN LETTERIO, MD: And one of the questions did ask, "What are the approaches in management of these patients if there is tumor left behind?" In some cases with pilocytic astrocytoma, patients even with minimal residual disease can go for a great length of time without regrowth or progression of the tumor. And in younger patients, it's important to consider the potential side effects of radiation therapy. And the timing of the administration of these additional modalities of therapy is—we have to consider both the age of the patient and other important factors. In many cases, the use of chemotherapy, for example, in young children that would allow us to delay the administration of radiation therapy would allow for normal development of the brain and prohibit or prevent some of the side effects that we often will see with radiation therapy.
00:51:26

ALAN COHEN, MD: And the biology of brain tumors that affect children is very different from the biology of those tumors affecting adults, precisely for those reasons. Radiation is something that will stun the growth of tumors, but it's something that we can't use in the young child under the age of 2 or 3. It can have irreversible effects, deleterious effects on the nervous system, so sometimes we work with chemotherapeutic protocols to delay the timing and put off as long as we can the need for radiation therapy, which is safer to give at an older age.
00:51:55
JOHN LETTERIO, MD: So in most instances, we'll follow these patients with serial MRIs or CAT scans, evaluate whether or not there's any regrowth of the tumor using those imaging modalities. At the same time, we're evaluating the patient's recovery and development of symptoms that might give us an indication that tumors could be recurring.
00:52:12
ALAN COHEN, MD: We do follow the patient with surveillance imaging and really become a member of the patient's family. It's a very unique experience in pediatric surgery and neuro-oncology because we're dealing with not an instance of surgery. For the surgeon, this is a routine instance of our daily routine, but for the patient it's a life-changing event. This is health versus disease, life versus death, and it's very, very interesting that the whole healthcare team becomes members of the patient's family.
00:52:42
JOHN LETTERIO, MD: One of the questions that came through, Al, actually is related to the actual approach to performing the videotaping of the procedure. Where are the cameras placed and how do you get the images that you've taken during the surgery procedure?
00:52:56
ALAN COHEN, MD: Well, that can be done in a variety of different ways, and in this case, some of the cameras were off to the side and other cameras were through the microscope. So it was a little more difficult to see the beginning because it was an oblique angle. Sometimes we actually can place cameras in our headlights or from the ceiling. When we were working under magnification, we record digitally. We do this for teaching purposes and you are able to see through the microscope what we saw through the microscope.
00:53:23
JOHN LETTERIO, MD: One of the questions that we've received asked specifically about the kinds of therapies that are used to treat these tumors. If surgical resection is not complete, there are a number of chemotherapy drugs that we've used to treat these tumors. Many of them act by inhibiting the growth of these tumor cells, and they can have the same effect on normal cells. In general, the various types of chemotherapy that we use for treatment of these tumors attack different components of the cellular machinery that are required for their growth and our best results are usually seen by combining drugs that have different mechanisms of activity. But at this point, the optimal therapy for these brain tumors really involves complete surgical resection, and we employ these other modalities when we've not been able to do that effectively.
00:54:09
ALAN COHEN, MD: The other thing that we do with our tumor board at the brain tumor center is now that we're having better results, we have a Lance Armstrong Brain Tumor or Tumor Survival Center here—cancer survival—and we're dealing with issues that we didn't deal with before. Now that children are surviving cancer, we have issues of the child and family to deal with in the long term.
00:54:29
JOHN LETTERIO, MD: So I don't think we have any additional questions that have come in.
00:54:36
ALAN COHEN, MD: So that is posterior fossa craniotomy for tumor. Again, the posterior cranial fossa is the most common site of brain tumors in childhood. There are about 2,000 newly diagnosed brain tumors in the United States each year, and the optimal care of these

children is in a multi-disciplinary fashion with input from multiple services. I want to thank you for coming here to Rainbow Babies and Children's Hospital in Cleveland, Ohio tonight. I'm Dr. Alan Cohen, and on behalf of my colleague Dr. John Letterio and the staff at Rainbow, I want to wish you all a good night and thanks for tuning in.
00:55:20
ANNOUNCER: Thank you for watching this demonstration of a posterior fossa craniotomy for brain tumor from Rainbow Babies and Children's Hospital in Cleveland, Ohio. If you would like to obtain more information, make an appointment or a referral, please click the buttons on the screen.
00:56:02
END