Closure of Dural Defects After Tumor Resection: Effective Use of Sealants and Collagen Duraplasty

Oregon Health and Science University
Portland, OR
April 20, 2011

Good afternoon and welcome to Portland, Oregon. My name is Nicholas Coppa and I'm an assistant professor of neurological surgery at Oregon Health and Science University. I'm also a member of the division of skull base surgery. And today I have the opportunity to spend some time with the chief of our division, Dr. Johnny Delashaw. Dr. Delashaw has a lot of experience with complex cranial surgery. I think he's accumulated almost 20 years of experience at this point, if not more. And we hope today to learn some important aspects of reconstruction in dural closure with complex cranial surgery for tumor resection. Dr. Delashaw, thank you very much for being here with us today.

Thank you, Dr. Coppa. That was a great introduction. I'm here today to show you a couple of case examples of skull base surgery. The first example will be that of an acoustic neuroma, also known as an acoustic schwannoma. It's a complex tumor dealing around behind the ear that deals with hearing and balance. And we'll show a video of that surgery. It's obviously an edited video. It's short so that we can get to the point and show some basics about that surgery. And then we'll talk about some reconstructive techniques on how to close the covering of the brain called the dura in this location.

We'll have a second video, if time permits, that will show a tumor located in the right frontal region. It's a primary brain tumor. It's a tumor that actually recurred, we had operated on it years ago. And in this patient, we'll show you the surgery and then we'll show you how we closed the covering of the brain, the dura, and that location, too.

During this hour we'd like to discuss about closure and reconstruction, we'd like to discuss about dural sealants and about the use of collagen compounds used to close the covering of the brain, the dura.

Dr. Delashaw, before we get into closing the dura, why don't you share with our viewers your perspective of what skull base surgery is or what's considered complex cranial surgery and maybe why reconstruction is so important?

Thank you. That's a great question. You know, skull base surgery is a term used to comprise a lot of different problems. Some of those problems deal with very large tumors involving the face that extend into the brain that evolve and erode the covering of the brain, and spinal fluid can leak out through the nose or through the ear, it can involve the eyes, vision, and the nerves that allow the face to move and swallow. These kinds of tumors can be very complex and the surgery itself, you have to know your anatomy, you have to be very careful, and there's a high risk of having complications.

The other kinds of skull base surgery that we think about are those of ruptured aneurisms or other kinds of vascular problems where there's bleeding in the brain and the result can be morbidity or death. These are the kinds of pathology that we see in complex cranial surgery, also known as skull base surgery. We're not really going to talk about all those problems today. We're just going to talk about two of them. One is a primary brain tumor which will be our second video, and the other is a more complex skull base tumor called an "acoustic neuroma."

Why don't we advance to our first slide and begin to talk a little bit and introduce concepts of dural closure.

Okay. Let's do that. You know, CSF leaks are a potential complication following dural closure, really of any cranial surgery. Also, if we open the dura in spine surgery, and even when we don't open the dura in spine surgery, when there's an inadvertent tear in the dura when we remove bone. This results in a negative impact in the post-operative morbidity, patient quality of life, and hospital economics when we have a cerebrospinal fluid leak. Although hemostatic agents and adhesives have been previously used for dural sealing, DuraSeal sealant, which we're going to talk about today, is the only FDA-approved product for intraoperative dural sealing. It is indicated as an adjunctive suture repair for the dura.

The ideal dural sealant for CSF leaks, I think, would be one that's effective in forming a strong seal adherent, very strong seal to bring the tissues of the dura together to seal that crack, that area that we've opened. We want it biocompatible. We want it not derived from human or animal products just because we're worried about other diseases related to that. We want it to be absorbable. Hopefully we want it to disappear. We want it to be easy to prepare and use, so there's a quick assembly for the surgeons and the nurses, there's fast polymerization so it sets up quickly, it's easily visible so we know where the sealants been applied, and it allows such an irrigation after the application so the sealant won't disappear with that. We also worry about cost. We want it to be cost effective. Obviously, if the sealant is extremely costly, it will be very difficult for us to get the hospital to want to use it because it will make the procedure just too expensive.

Polyethylene glycol, also known as PEG, is a highly acceptable polymer used in many different products. It's used in pharmaceuticals like children's cough medicine. It's used in many injectibles. Actually, it's used in antacids, and eye drops. DuraSeal uses the polyethylene glycol as its "supplimer" (PH). And this is how it works, it's a polyethylene glycol hydrogel. It has basically a syringe of a blue compound, which is the polyethylene glycol, and then it has a clear compound in the other part of the syringe, which is some amino acids and proteins. When they're injected and they come together they form this gel. This gel forms over just a few seconds, usually around three seconds, and then it seals over the crack of the dura and stays there for many days to weeks. In actuality, it probably is still there even at six weeks after application. This is how DuraSeal works.

DuraSeal is interesting in that it has some burst pressure properties, too. If we look at other agents that have been used to seal the dura, DuraSeal is far more effective in keeping the burst pressure from breaking through. If you look at this graph on this slide that I'm showing you, the blue is DuraSeal, and the amount of burst pressure it takes, the amount of pressure it takes to burst through this sealant is far greater than that of its competitors, Evicel and Tisseel. DuraSeal seems to be a much better product for the use of dural sealants and closure.

DuraSeal can be used with collagen duraplasty. For those that I'm not sure – I'm not sure who the audience is, but for those who don't understand what collagen duraplasty is, that's the use of a compound that mimics the covering of the brain, the covering of the brain is called dura. The collagen duraplasty is using some artificial substance made of collagen that we use to lay over the surface of the brain and hopefully suture it to the dura to seal the area that we've been operating on, or at least to re-approximate the edges.

What we can see here in this slide, there's a picture of a craniotomy, and we have the dura open on the left, and you can see the brain with the dura open around it. A piece of collagen, artificial dura, it's called DuraGen in this particular case, made by Integra, is placed over the normal dura and it's allowed to depose the dura very closely. Now I personally like to use suture, but we definitely want those compounds to be as close to the original dura as possible. Then what you can do is you can place DuraSeal, that's this blue glue that you can see down on the bottom slide there, and you can place it over the entire area, most importantly to place it over the edges of the collagen duraplasty, the DuraGen, place it over the edges and over the human dura so as to add as a sealant. Remember, DuraSeal is an adjunct to getting the tissues close together.

So I think what I'd like to do is talk a little bit about the first operation and show you this operation. Before I do that, let's talk about the surgical strategies of closure in what we call the "infratentorial space." Now

the infratentorial space is the area where the brainstem and the cerebellum sit, they sit just behind the ear, and they're separated by the rest of the brain by what's called the "tentorium." So infratentorial is below the tent – below the tentorium. Where – we'll talk a little bit later about supratentorial which is above the tent.

So for the infratentorial area, gravity really wants to push out spinal fluid out the hole. So I think it's real important that when we close the dura, close the covering of the brain in this location, that we get the materials, the collagen duraplasty, to be re-approximated tightly to the human dura. So there I advocate use of suture. It's real important, I think, to meticulously close the dura with suture. Then, remember, suture is not watertight, and gravity still wants to push fluid out through the suture holes and through this space where the suture has not completely closed the dura. There's where I use DuraSealant DuraGen – I mean DuraSeal, I use DuraSeal there to cover the edges, and usually I just cover the entire duraplasty that we've done. So from that, that's what we use for infratentorial. I think what we should do is go through to our first case.

Okay. First case is an acoustic neuroma. I think we have a slide that gives – elaborates your history. It's a 49-year-old woman who presented with progressive hearing loss and vertigo. The neurological exam was normal with the exception of hearing loss in the right ear, and that was documented with an audiogram, as well as clinical examination. An MRI scan was done and showed an enhancing mass in the internal auditory canal in the cerebellopontine angle. And radiographically, this was most consistent with vestibular schwannoma. We do have an MRI of that. This is a T2 sequence. And you can see -- I don't have a pointer, so it's hard for me to – for those who aren't familiar with looking at these types of images, but what we're looking at here is a slice through the posterior fossa or the cerebellum at the level of the brainstem. And you can see off on the left side, right about 9:00, there's a lesion in the internal auditory canal heading toward the middle ear. Would you like to comment on the MRI at all, Dr. Delashaw?

Sure. So for some of the audience, I know the audience – it depends upon who the audience is, but for some of the audience, this is a slice called an "axial view." It's as if we took a slice right through the ears, right through this nose here, and we're looking at the back end of the brain. The white area of the brain, the real bright white is cerebral spinal fluid, and the gray is brain. But on the patient's right side, it's actually on the left screen. It's interesting how doctors like to put right and left a little different. But R – if you can look on this slide, R is for right, L is for left.

On the right side there's a mass there that's about a centimeter-and-a-half mass, and it's fairly homogeneous in consistency. If we gave contrast, which we're not looking at on this particular one, it would turn bright white, it would show up really bright white. And this mass is located in the area of the temporal bone called the "interacoustic canal," and that area is where the balance nerve, the hearing nerve, and the facial nerve, the facial nerve is the nerve that deals with motor function of the face, they all run together through this bony canal. And this tumor is consuming the canal, and actually has enlarged the canal, and it's classic for what we call an "acoustic neuroma," another name for it is an "acoustic schwannoma," and another name for it is a "vestibular schwannomas" or vestibular neurilemmoma, they're all the same. Now it's a tumor of Schwann cells. And the Schwann cells are cells that really are supposed to support the nerve rather than become a big ball and cause compression. But what it's done here in this patient, it's caused compression and it's causing her to lose hearing in that particular ear.

Let's imagine for a moment that I was a patient and I had an acoustic neuroma, and you were going to consent me for surgery, what would you say some of the potential complications could be operating on a lesion such as this?

Well there are a number of complications. First of all, if the patient has hearing, and one of the complications that incur with surgery is we would try to preserve hearing with this removal of this tumor because, remember, the tumor is of the balance nerve. The hearing nerve is opposed with it, but it's really of the balance nerve. But the hearing nerve is a very, very sensitive nerve, and any kind of manipulation can result in hearing loss, so one of the complications would be that of hearing loss. And with this size of tumor, if a patient has normal hearing, what I would counsel them in is they have a pretty

significant chance of losing hearing, probably anywhere from 40 to 50% chance of losing hearing with this size of tumor. The other complication is there's a nerve there, as I told you before, called the facial nerve, and the facial nerve deals with our ability to smile and close our eyes. It's motor function. And on the right side there would be a risk of injuring that nerve and having permanent weakness in the face.

Now here at OHSU we do a lot of acoustic surgery and our results are really as good as anyone in the world, probably better than most in the world, and we publish that. So even though we have very good results, I would still counsel the patient of facial nerve injury. The other complications that occur have to do with cerebral spinal fluid leak. And there, when we go through this video at the end, we'll show you some techniques on how to prevent a cerebral spinal fluid leak after this surgery.

Why don't we queue the first video and then we can also talk and comment as the video is rolling. Again, this is of a right-sided acoustic neuroma. Looking at this, what type of position do you like to use, Dr. Delashaw, when operating on a tumor of this size?

Well, you know, there are basically two ways to approach this. We're doing what's called a "retrosig craniectomy" to remove this tumor. There are a number of approaches to remove this tumor. The retrosig approach is one I like to use. It's an incision made just behind the ear. I like to use a little C-shaped incision. If we look on the left, the very far left, would be the top of the head, and the very far right would be the bottom of the head. And what we've done is we've made a hole just behind the ear. We're now opening up the covering of the brain, called the dura, and reflecting it forward towards the ear. And you can see sort of these yellow, brown stripes there, and that's the balance part of the brain called the cerebellum. So we've already made our hole, and we're opening the dura to come down to find the tumor. And there you can see it there. We just lifted up the dura to see the brain.

So the cerebellum here, you can see, is protruding out through the dural opening. Is there anything that you can do to relax the brain prior to opening the dura?

Well it's interesting, I've been at this for 20 years and things have changed over time. We can drain CSF with surgery just by coming down around the edge of the cerebellum, finding cerebral spinal fluid pockets, and drain it. But, clearly, good anesthesia is very helpful in reducing brain tension. Now here on the video we've already come around the cerebellum, we've not gone through any brain, and we're down along near the edge of the temporal bone. The temporal bone would be at the top of the screen here.

I'm taking a knife and I'm cutting right through the tumor and I'm taking a biopsy to send it to our pathologist to be sure that that's the tumor that it is. And it looks classic for an acoustic neuroma. Then what we need to do is not only do we want to know that it's an acoustic neuroma, but we also want to expose the entire tumor. So we're taking a drill and drilling out part of the temporal bone. We've drilled that out. And now we've kind of switched gears on our camera, and now when you look to the right, that's the end of the tumor on the temporal bone, and to the left is the tumor within the brain. We're drilling out the canal there so as we can get exposure from both ends of the tumor so then we can begin to dissect the tumor away from the cranial nerves.

Now one of the things I would like to say is it's important that on this drilling that we get a real nice exposure. We do this with lots of irrigation. We do this with what's called a "diamond bit drill." It drills the bone away very slowly. At the end we're going to want to close that area with some fat graft because in that area where we drilled there can be little micro air cells that can ultimately result in a spinal fluid leak.

So here we can see kind of the whole surgical exposure. You've de-bulked some of the central component of the tumor to reduce its mass. And you're operating on the side closest to the brainstem. Is that your usual strategy when you're taking out these tumors?

Yes. I want to preserve hearing, so I'm going to dissect the tumor away from the brainstem towards the temporal bone. So medial to lateral is very important if we're going to try to preserve hearing, which we're trying to do here. Now earlier in the video you saw the sort of bent, black probe. That's called a "Prass Probe," and that probe we actually are stimulating the brainstem looking for the facial nerve because we

want to preserve the facial nerve. It will actually put a little current in the nerves, and have electrodes in the face, and if there's some twitching in the face we'll get an audio sound telling us that we are on the facial nerve.

So here we are in the video. There's some bleeding here. The tumor obviously has some blood vessels to it. And we're slowly debulking the tumor, but continually taking the tumor from brainstem to temporal bone, medial to lateral.

I wanted to comment a little bit on the bleeding. I mean this is not terribly bloody. But can you comment on the importance of using bipolar cautery, keeping it at a minimum and how it can be dangerous potentially?

You know, experience is the most important thing in surgery, but also being able to see is important, and we're very fortunate we have micro-instruments that allow us to achieve hemostasis most of the time. And what Dr. Coppa is talking about is what's called a "bipolar," which is a forceps with electricity on the tips, and that can actually burn very, very delicately areas that are bleeding. And when you heat that up, it can stop the bleeding. It allows us to heat that up and stop the bleeding without injuring the important structures around it. So we're constantly doing that to stop the bleeding so we can see because we want to be able to see the hearing nerve, we want to be able to see the facial nerve and the motor nerve so that we can preserve that. And as you can see, even though we used the bipolar cautery at times, it continues to ooze and we have to keep coming back and stopping the bleeding. We use some irrigation here. The irrigation also helps clear the debris and allows us to see the structures.

This is a little instrument we're using right now, it looks like a little angled instrument. It's called a "Jimmy dissector." It looks like a little hockey stick. And what we're doing is we're separating the tumor, which is closest to us on the camera, from the important nerve structures, which is anterior to us or in front of -- behind us in the camera shot. And here we are just cutting carefully with micro-scissors tumor right around the facial nerve and the hearing nerve as we move from the brainstem side to the temporal bone side, and attempting not only to preserve facial nerve function, but attempting to preserve hearing.

And at this point, is that the facial nerve that we're looking at right there?

That is the facial nerve. See there's a little blood on it. I got the sucker right on it. We actually got the probe -- the probe is on it. We're stimulating it and being careful to be sure that it's still anatomically intact and also functional by being to stimulate and hearing that it's twitching in the face.

So really the two components of this surgery, you remove the bulk of the tumor in the cerebellopontine angle, and now kind of the second part is you're going after the component in the internal auditory canal which is what we're looking at here.

Right. We want to be real careful because we're getting very close to what's called the "fundus of the IAC," and that's where the facial nerve and the hearing nerve come very close together up into the temporal bone. We have to be very careful as to remove the tumor without injuring those nerves. And we're right at the very distal end of the tumor here. And we're using that Jimmy dissector to try to tease the tumor away from the nerves and bring it out through that bone drilling. You see that bone drilling hole there, it's probably got some little micro air cells. So at the end of this surgery, when we've got the whole tumor out, which is right here, this nerve is stimulating with the facial nerve probe here called the "Prass Probe," we'll take some fat and we'll lay it right in that bone, and it's amazing how well that fat will just kind of stick to the bone and reduce our incidence of cerebral spinal fluid leak coming from that bony area.

Here we are, we're still working. We've got most of the tumor out. We're just double-checking, making sure that if there's any tumor right there at the fundus. And we're looking now at the facial nerve and the area of bone we've drilled out in that retrosigmoid approach. The little gray structure you see to the left is the brain retractor supporting the brain so that we can get good visualization of the tumor removal. So here we are. We've removed the tumor now. We're going to put some bone wax, which is some -- it

used to be made out of beeswax, but it's not anymore, and we're going to put that over the bony area to help seal those holes. And then we're going to take a piece of fat, as we talked about earlier, and lay it in there. This fat's taken from the abdomen, just a small piece of fat. It's interesting, most of my patients always ask if they can take more, but I only take a little bit. It's really quite small. And we'll lay it in there. And then we'll remove the retractor. And then we'll begin to start our drill closure.

So you can see that there's also some greenish-brown material there, that's hemostatic agents that are used called "SurgiSeal" that is used to help achieve hemostasis. So we've done that, and now we're taking the dura and we're going to re-approximate it and try to get closure to prevent a cerebral spinal fluid leak from the wound itself.

What's your opinion on dural openings as far as semilunar, kind of x-shaped? To me it seems inevitably the dura is going to shrink to some degree after a relatively long operation. And what's your opinion on that?

Well there are many ways to open the dura in this particular location. Now, close to the ear is a big vein called the sigmoid sinus, and some people like to open the dura right behind the sigmoid sinus. That's so the dura covers most of the brain during the surgery and is a protectant.

And that structure in this video would be underneath that patty or that piece of material with the blue stripe.

Correct. And some people like to open the dura a little bit away. Me, I kind of like -- I used to like to open the dura just near where that patty is, but it gets to be harder to close at the end. And so I've gone back to opening the dura in a couple different triangles called a "cruciate incision" because I think it's ultimately easier to close at the end and I don't have to worry about bleeding from that vein. But, you know, I don't think it really matters. The important thing on this is that when you're closing the dura in this infratentorial area, that you try to get a very good approximation of the dura, and that requires suture, and many times it requires a compliment of some kind of duraplasty, either a bovine pericardium, or either a collagen matrix, which we like to use more of because the collagen matrix is synthetic and doesn't have any kind of animal or human products.

So here we are, we are closing the dura now. We're actually using a compound here. This is actually, I think, bovine pericardium, to be honest with you, and it's called "Liadura" [PH]. And we couldn't get the dura completely closed. It shrank a little bit, as Dr. Coppa has mentioned, and so we're bringing the dural edges together with suture.

I noticed the sutures are Prolene. Do you think there's a difference if you use Prolene versus a Nurolon suture?

I do. I use Nurolon a lot, but when I really want to get a good dural closure I like Prolene. The Prolene, the needle, and the suture are about the same size. With Nurolon, the suture is not as big as the needle, so when you put the suture through, the Nurolon goes through a bigger hole and it can leak more. So here we're using Prolene. We get a real nice dural closure, but we're not going to be done just with that. We really want to prevent a leak, so one is we've gone through some bone, we're going to put some wax along the bone edges. The wax along the bone edges is also to prevent spinal fluid from getting into what's called the "mastoid air cells" and down through the ear. And then we're going to coat this with the dural sealant. And the dural sealant we like to use is DuraSeal because it lasts longer than the others and it's so much easier to apply.

So here we are, we're applying it now. We spray it on. It's blue. It's easy to see. And we spray it over the entire defect. We don't worry too much about the thickness. We like it about one to two-millimeters in thickness. Here we are spraying it again. And that is sufficient to bring the edges together and prevent a CSF leak. And you can see it. It's blue. You can see where you apply it. So it's a real nice product. It takes just seconds for it to work. And then we can go ahead and finish our closure with reconstruction of the skull.

I noticed that I think one of the pearls of application of the DuraSeal is not really to get the tip very close to the surface you're trying to spray, but rather keep it, you know, at least several inches away and that allows a better application.

I think that's right, Dr. Coppa. You know, it's almost like spray paint. If you get the spray can too close to the wall it gets all drippy and clots into little chunks. But if you stand back a little bit and spray it you get a much more even flow. And what's interesting about the DuraSeal application product that they have now is you can spray it, you can stop, and you can re-spray it again, and it doesn't necessarily clog up right at the tip. They used to have problems with that, but now they've got that figured out, and it makes it even easier to use.

We didn't have this in the video, but once the DuraSeal is on do you just close the scalp or other -- what do you do about the bony defect?

That's a great question. The old days, being 20 years ago, we'd just close the scalp, because these holes are not that big. But what we found was people have headaches. They have headaches right around that defect. And what we found is that if we have something over that defect, they don't have the headaches that we were experiencing. So these days we either cut the bone out and put the bone back in, or we use a bone paste, a bone cement that hardens very, very quickly and prevents the dura from being attached to the muscle. So we actually reconstruct the skull and it keeps patients from having headaches, and they're much happier with their postoperative outcome.

We just got two questions in from our audience, and I think both of these actually bring up two very important points. I'm going to paraphrase the first question. So in your experience, utilizing the DuraSeal with a collagen duraplasty, not just on the native dura, do you think that's really best practice as what you've demonstrated in this video?

You know, the important thing here is when you're in the infratentorial space, gravity really wants to get that spinal fluid out because, remember, the dura is like a sac. So it's real important we get good apposition of tissues. So the kinds of tissues that I would use are I would use something to get the dura together, and that could either be bovine pericardium, which is an animal product and a lot of people don't like to use that, or an artificial dural covering such as DuraGen or one of the other company's materials. But I would definitely use something to get it close together, put sutures in it if possible, get it very close and opposed together with suture, and then I would apply a dural sealant. I think you're going to have less complications that way, and the patient's going to be happier because they're going to be in the hospital for a shorter period of time.

The next question actually kind of parleys on that. Application of the DuraSeal, do you think it's better to apply it just over the suture line or should you apply it over the entire dural surface?

Well that's a great question. The question, I think, is it's very important if you're dealing with the spine. And, remember, DuraSeal is also approved for spinal dural areas. But for the brain there's lots of space, and I typically just spray it over the entire area. It's most important to be over the suture area. But I just spray it over the entire area. You want it to be thin. You don't need to get too thick about it. But in the spine, when you're spraying it on a dural closure area there, you really want to be very thin because that's a smaller cavity, and if you put on a lot of DuraSeal, remember, it can swell a little bit over the course of the first few days, it can become -- it can cause mass effect. So what I would say, in the spine you really want to do it thin and right along the suture line; in the cranium, not nearly as important.

Now we all know that sometimes patient's dura differs, you know, not everybody has a nice piece of tissue that you can re-approximate. In the case of dura that's difficult to close, very difficult, can you use DuraSeal without any suturing? That is, can you use just fat packing, and then DuraSeal over that? If you have any experience with that reconstruction technique?

Yes, so, again, the question is do you have to always close the dura watertight with suture? Well you don't have to because you can't. There are many times when you get in a situation where the dura cannot be closed. The dura is just so thin, such poor quality that even with other kinds of artificial materials you can't get it quite re-approximated. What you need to do is do the best you can, get it re-approximated. You can use other materials. You can use fat sometimes. You can use muscle. You can use a lot of other tissues that the human has itself right there in the surgical field. But you want to get as close as you can, then place the dura sealant, so you don't ask too much of the dura sealant.

And if you don't have a really good closure, then you may want to consider CSF drainage. You may want to consider CSF drainage with the lumbar drain, potentially, or even what's called a "ventriculostomy," depending upon what the pathology and what kind of surgery is done. But you got to give the tissue a chance to scar and heal over. And if you have a kind of a hole there, then the CSF is going to want to pop through. So you're going to have to take the pressure off to allow those tissues to come together and stick together and then form a sealant.

If you use post-op CSF diversion, what timeframe are you talking about, 24 hours, 48 hours, five days?

Well, again, nobody has an absolute answer for this. And what I would say is that typically for most of the skull base procedures we do, if we feel like we haven't had the closure that we wanted to, the most optimal closure, and we're worried about development of a CSF leak, that we leave some kind of drain, CSF diversion for at least three days. We've done it for a day. We've done it for five. And, again, I think it depends upon how difficult the closure is and how concerned we are about it leaking. There's some other things you worry about, somebody who's had radiation or somebody who is of, you know, poor health status who doesn't want to heal well, those we might need CSF diversion longer, giving a chance for those tissues to come together and seal.

We have a couple more questions from our audience. This one, "What size needle do you use for closing the dura?"

That's a terrific question. That must be coming right from a physician and a surgeon. And, you know, I like to use -- if I'm really trying to close the dura, I like to use a 5.0 or 6.0 Prolene suture, that's what I'm going to use. Now the problem with the 6.0 Prolene suture is it's a little bit flimsy and sometimes it gets kind of difficult, particularly with the artificial substances, to get the needle through. So if I have any trouble, I'll use a 5.0. I don't ever use anything bigger than a 5.0 if I really want a relatively watertight closure. Now Nurolon tends to be 4.0, so it's a little bit more coarse and has these holes. Again, if I'm not worried about a CSF leak, I'll just use Nurolon, but for those that we're worried about CSF leak dealing with the base of the skull, I like to use Prolene in a 5.0 or a 6.0. Most of the time we're using 5.0.

This is a great question. "Have you ever had any adverse outcomes with the use of DuraSeal? If so, how did you manage them and what did you find was the cause?"

Yes, I have had adverse outcomes. Anything you do in surgery, if you use something enough or you do a surgery enough, you're going to have a complication. And in DuraSeal, the complication I had was actually in spine surgery. It wasn't in cranial surgery. You know, I've had wound infections in cranial surgery, but those are related to bacteria, they're not related to any product we use. But in the spine you need to put it on thin. Again, what happens is this material will collect water over the first day or two and it will increase in thickness, so you really want to do it thin. I've had to go back and remove the DuraSeal in the spine once related to too much application of DuraSeal. That was years ago.

Excellent. Why don't we proceed with our next case. I think we have some slides to introduce this case as well.

We do. The first slide is about the surgical strategies for supratentorial. Now, supratentorial, just for those that are not the surgeons, that are not the physicians that are watching this program, it's really for the problems that deal with the brain above the tentorium, which is really about ear level up. And the supratentorial area has less gravity dependent problems than that of the infratentorial. So if we have an

intradural case where we're opening up the covering of the brain and over the convexity, which is right over the top of the brain, and we don't enter the fluid cavities called the "ventricles," and we don't get involved with the bony sinuses, then it's really not so critical about the dural closure. Things seem to seal no matter what we do. So it's not nearly as critical. Obviously it is critical if it's been radiated, so radiation, not involving the bony sinuses with our bone flap, and not getting the ventricles on the convexity. I just put it on like graft. I don't necessarily use a sealant. You can if you want.

Sometimes when I redo surgery I like to use a sealant. Sometimes when patients want to get out of the hospital very quickly I'll use a sealant, but it's not critical because gravity, now, is pushing the fluid down, not up over the convexity, and those wounds tend to heal on their own. But in some place where we have the sinuses or radiation or we're down more along the base of the skull, a sealant and good apposition of the dura with suture is important. So let's go on to the second case here that we're going to show you today. Dr. Coppa, I think I'll let you introduce that.

This is a 37-year-old woman who presents with new onset focal motor seizure involving her left arm. She has a history of resection of an oligodendroglioma in the right frontal region with craniotomy. That was in 2004. She was allergic to Temodar, which is a chemotherapeutic that's commonly prescribed for patients with brain tumors. This particular patient never received any radiation therapy, and her neurologic exam was normal. MRI scan which we had, and we'll show in a moment, demonstrated recurrence of the mass in the right frontal region. And this particular sequence is not with contrast, but rather, it's a T2 axial sequence of the brain, and I'll ask Dr. Delashaw to comment on it in a little bit more detail.

Yes, so this young lady, what happened was she'd been followed for years, and we had removed the tumor in 2004, and all we saw was a defect where this surgery had been performed. But recently she came to our emergency room with a seizure. And when she had the seizure she had this MRI, and that MRI that we just had up, that MRI -- there it is -- that MRI shows on the right side, in the right frontal region, shows this mass. Now, this mass didn't enhance with contrast, but this mass means that clearly something's happened because the last time I'd seen it it had just been less than a year, she didn't have this mass. So something is going on here, and we think it's a recurrence of her oligodendroglioma.

So we decided to -- we talked to her and we decided we need to resect this again, one, to reduce her possibility of having seizures; and two, is to be confident that the tumor hadn't changed in its growth characteristics, that it hadn't become more malignant. So this is this patient here. And I think we'll move on to the video clip to show you the surgery briefly and then to talk about closure of a recurrent tumor. So here we are here, we've done a right frontal craniotomy. Now I like to use a Stealth technology. There are many other kinds of technology, but basically they're all used to help us use a GPS system. So we used a basically Stealth technology to make the size of our bone flap appropriate for the size of the lesion. Remember, sometimes these lesions don't look like anything but normal brain. Now this one is not the case. It actually looked abnormal.

Here we are, we've opened the covering of the brain. Now we're going back to where we had operated before. And we're finding right here this avascular kind of nugget. And I'm actually going around with a sucker, and I'm going around with a sucker and going around the mass. I'm going to try to remove the mass in one piece, and not all surgeons do that, but this is a recurrence, this is in a non-eloquent part of the brain, and I want to get well around it hopefully that I can prevent another recurrence in the near future and hopefully get a longer tumor-free period for her depending upon what the pathology is. So I've actually used the GPS system, the Stealth system, and gone around it and take it out like one large mass, and that's what we're doing here. We're bipolaring around it. We're using that coagulation instrument. And then I'm going all the way around it and I'm peeling out the mass almost in one piece. You can see it here. It looks very different than brain.

Could you elaborate on the difference between, you know, an acoustic neuroma is a well-circumscribed tumor, whereas this, an oligodendroglioma is completely -- kind of a completely different type of pathology.

It is. If you look here, I'm using the sucker to remove additional brain around what's called the "white matter" because this kind of tumor tentacles, so even though we think we've gone all the way around the tumor, there's still going to be tumor cells. With the first case, this is a well-encapsulated tumor. We get the entire tumor out in its capsule. We've cured the patient. It's not coming back. We know this lady will have recurrence of her tumor, it's a question of time, and we're trying to be as aggressive as possible in removing the tumor. And there you have it, I've taken out the entire lesion in one piece and I'm sending it to pathology. We're now placing the SurgiSeal on here which is a hemostatic agent to prevent bleeding over the white matter area. We're going to place this over the entire field, place some irrigation. And in terms of little brownish, as we saw in the other case, and shows us that the bleeding stopped. Then we're going to close the dura.

Now, remember, this dura has been opened before, so this is a second time. So this time, even though it's supratentorial, because it's been opened before, I'm going to want to use a dural sealant to give every advantage to prevent any kind of CSF leak. Now CSF leak in this location would be a bulging of the forehead. You know, and she's a young lady and she doesn't want to have that, and we want her in the hospital for a short period of time, so for me, I like to have really good apposition of the dura with suture, and then I like to use a dural sealant. So here we are, we're closing the dura. We're using suture. And we're going to come up, we're going to try to get those edges post very close to watertight with suture.

And is there a difference in closure technique, interrupted suture versus running suture? What do you think is more effective, or does it really matter?

You know, I think running suture is always more effective. I think you can get the tissues closer together. Sometimes that's not possible, depending upon where you're operating. But if you can, a running suture is going to work better. But what we do is we typically put a couple stitches in, get the dura kind of close together, and then run at the edges.

Now, here, just like always -- not always, but just very commonly, the dura, once we try to put it back together, it doesn't want to come together. So we've taken a dural substitute here and we're going to re-approximate the dura and get a fairly good apposition of the edges with suture. And after we do that, we're going to first tack it in with suture. After we do that we're going to run it, and we're going to run all the way around it, and then we're going to want to use a dura sealant over that area to try to prevent a leak or development of a pseudomeningocele.

So this video is showing us just running the suture here. This can be a little tedious at times. This is a great reason to have a resident so that the resident can do this and you can kind of -- you've already done the big surgery of removing the tumor. You can have the resident help close. But I can't overemphasize that closure is very important. A lot of surgeons, a lot of complications can occur. The surgeon gets tired and doesn't spend the time to close the dura, and when you don't spend the time to close the dura, it will come back to haunt you. You'll get a spinal fluid leak coming through the scalp, a cerebral spinal fluid leak, and then you'll have to take the patient back to the operating room. And if you'd just spent that extra few minutes, been meticulous in your closure, you could have prevented that and had the patient go home happy, without a second operation or without any other complication.

We just had a question come in asking or seeking clarification between --

Before we go on to the question, I just want to kind of emphasize, here's that dura sealant there we're mixing in the syringe. We're going to pull it up, the blue part, that's the polyethylene glycol. We'll get that all ready. And then we're going to connect it to another area where there will be another tube which is amino acids and proteins. And they'll come together on a sprayer. And then what we'll see here, we've re-approximated, we're going to spray it now. It's nicer to get it farther away. We're really doing this to show you that you can stop and start. But if you get a little bit farther away than where this has been, you don't get such the goopy kind of thing, you get a very thin spray. That is really important in the spine. For here, it's not so important, we can layer it on. And there we have it, we've laid the DuraGen on there and we got a nice seal with the dura re-approximated. And then we'll replace our bone flap. She did extremely well. She left after two to three days in the hospital and has done terrific, has had no more

seizures. And, unfortunately, her pathology is showing that it's more aggressive and she's going to have some chemotherapy and radiation in the future.

So let's talk a little bit about the dura healing. This may be difficult to answer, but how long do you think it takes for the dura to form an adequate watertight scar?

That's a real good question, and I think it's dependent upon a lot of issues. One, it's dependent upon good apposition of the dura. The farther away the gap is, the longer it's going to take to form some kind of sealant. It also depends upon the health of the patient, has the patient had previous surgery, has the patient been radiated, or does the patient have hydrocephalus where there's other kinds of things preventing the dura to come together. But in the healthy patient where there's not hydrocephalus, not radiation, I think the dura can seal fairly quickly. Within a matter of, you know, three to seven days it can get a pretty good seal. It's not going to be completely sealed, but it's going to have good apposition to prevent a spinal fluid aggression across the dura.

And how long -- this goes on to say, how long does the DuraSeal last? How long, if you ever had to go back in for a variety of reasons, when does the DuraSeal reabsorb?

Yes, so the DuraSeal, it's kind of interesting, I've gone back for lots of different reasons. The DuraSeal is a blue sealant, what's interesting is it actually -- the blue portion of the sealant will disappear fairly quickly. It will disappear just after a few days. But I've found sealant, I've gone back for various reasons, and I've found sealant there still at six weeks. So it lasts at least four to six weeks. Now, its properties -- its sealant properties are not quite as strong at that time as it is in the first few days, but it is still present at four to six weeks. I've gone back at three months, it's gone. So it tends to hydrolyze and disappear somewhere between four and six weeks after application.

Can DuraSeal -- here's another question. A lot of times hemostasis, you know, can be an issue in that epidural ooze. Can you use DuraSeal -- apply it over FloSeal?

You can.

For those who don't know, FloSeal is a hemostatic agent. It's kind of a powdery --

Well it's basically chopped up gel foam.

Chopped up gel foam, yeah.

Okay. And you can. But, remember, any time you put a compound over the dura and then you put the sealant over the compound, you're not giving the sealant the advantage. The sealant is really meant to be tight and stuck to the dura and to the space between the two edges. And if you put a bunch of material over the dura and then put the DuraSeal, you're probably not using the sealant in its best way. You certainly can do that, but I think it's going to be less effective in having its sealant qualities. My suggestion is to stop the bleeding, then use the sealant rather than put some material on there and then put the DuraSeal on top of the hemostatic agent.

Here's a question from the audience. "Can you talk about what the post-op films looks like with the application of DuraSeal? Does it look like CSF and can you tell the difference radiographically on the post-op scans?"

You know, it looks more like something like a blood, but it's not nearly as impressive as blood. It's not nearly as bright. And you see that more in spine surgery than you see that in cranial surgery, and the reason why that is is that the cavity in the spine is much smaller, so any kind of material in the spine, you know, you magnify and you can see the edges. In the cranium, you know, typically we've got a bone flap on or we've got the bone paste over it, and the amount of DuraSeal there is very, very thin, and it's really difficult to detect, not unless you're putting huge quantities, which I don't do. I usually put very thin

quantities on. That's all that's necessary. You actually see it more often in spine surgery. And it looks like something like an epidural hematoma, but it's quite thin because you're putting it on thin.

This is a point of clarification. "Both patients were diagnosed using a head MRI and without contrast. Is a head MRI preferred over CT scan for these defects? If so, why??

Okay.

That's just a point of clarification.

First of all, both patients had head MRIs with contrast and without contrast. We just happened to show you pictures that were both T2-weighted images. But they actually did have contrast. The first one was an acoustic neuromas, and it lit up like gangbusters with contrast, which is classic. The second one didn't light up at all, which is typical of a glioma that's not malignant. Now the MRI is far more sensitive in seeing the anatomical structures and seeing tumors than a CAT scan. A CAT scan is not very effective for seeing tumors in what's called the "posterior fossa" or "infratentorial region." We use them for trauma. We use them for looking for blood. We can use them for looking for tumors, but they're not nearly as sensitive and the quality of the image is not nearly as good as an MRI.

For the supratentorial area you can use them for tumors also. But, again, I kind of talk -- when I talk to my patients, it's kind of like looking through a bathroom window that's all foggy. You can kind of see that somebody's across the window, you can kind of see they're there, you can actually see if they're brushing their teeth or if they're taking a shower, whatever, but you can't really see the detail. With an MRI it's like a crystal clear window. You can see so much more detail. So whenever I'm getting ready to do surgery, if the patient can have an MRI, I like to have the MRI because I get so much more information, and I think more information provides me with a better idea of what I'm dealing with, I can make a better plan, and reduce the chances of having any kind of complication and have the best outcome for the patient.

This next question, I think, will bridge us into our last couple of slides. This probably deals with very complicated patients that have had numerous surgeries in the past and your standard techniques of reconstruction don't work. So really, the question is, what do you do with those kinds of patients? What are your bailout strategies, your salvage techniques, and what have you learned over the years?

So the question I'm hearing is, for those complicated patients where you're having a difficult time getting closure, what do you do? Is that the question?

Yeah, if it's a healing problem, a CSF leak problem, the scalp -- there's no scalp tissue to re-approximate, what do you do?

Well, actually, I have a series of slides that we can kind of go through that here in just a minute. Let me kind of move forward to those slides, and then we can come back to finish the presentation. So let's go to this first slide here on talking about other ways to close the skull base. You know, again, we're here to talk about dura sealants, particularly DuraSeal, but sometimes you don't have the adequate tissue right where you're operating on to close the defect. And, again, it's really important to get apposition of tissue to allow the sealant to work. And sometimes when we don't have the right tissue right there, so we have to use other tissue. And the kinds of tissues that we would use are like adipose tissue which is fat. Sometimes we use what's called a "pericranial vascular flap."

The skull itself has some tissue over the skull. It's called "pericranium." It's got a good blood supply, and we actually can peel it off the skull and then we can lay it along the base of the skull and help repair the dura. It's got a blood supply. It tends to be very healthy. We can use other tissues like what we call "free flaps." The one we like to use the most is a radial forearm free flap. I'll show you a picture of that. And sometimes we use the larger free flaps. So let's kind of look at those.

Here's adipose tissue. I showed you some adipose tissue for the acoustic neuromas. It's easy to get. Again, patients usually ask me to take more than I need. We make an incision usually in the abdomen,

take some fat, and it's a great tissue to prevent a CSF leak. It can prevent infections like meningitis, and can prevent scarring, it also is an anti-scar material. The fat, though, remember, has not got a great blood supply, and over time it will shrink down, so that can be an advantage and disadvantage depending upon where you're applying it. If you're applying it in an area where you don't want a big mass, sometimes having fat there is nice because it tends to shrink down with time. If you want something that persists for a while, particularly in somebody that's been radiated, the tissue may kind of shrink down and shrink before we've sealed the dura, and then we get a recurrent leak. So fat is one tissue to use.

Local flaps, the pericranium, here's a cartoon of the skull here, we've done the surgery, and we can take the peri-craniograph right off the skull and lay it down along the base of the skull. It's got a great vascular pedicle, it's alive, and it's a workhorse really for skull base surgery, particularly in the forehead area. Here's an example of this. Here's a patient who's had an incision made in the left frontal temporal region. The little blue things are Raney clips for scalp bleeding. And you can see this flap. We've got these two forceps peeling this flap off the skull. You can take the -- when we take the skull off we can lay it down in the defect and close the dura.

Now we can also use free flaps. A radial forearm free flap is a great piece of tissue. It's got a huge artery and vein connect to it. If we take some tissue right from the wrist here, and we got an artery and vein, and we can connect up the artery and vein up in the neck, and tunnel underneath the face and lay it into the base of the skull. It's got a great blood supply. It's not been radiated, particularly talking about patients that have been radiated. And it will heal. So it's a great, great compound to use -- I mean, great thing to use for CSF leak. And this is just another example, looking at the artery and the fascia here on the left for radial forearm free flap. And we can concurrently harvest it as we close. We can have the plastic surgeon harvest it and then place it in there, and it works real well for those complicated closures.

I think we're getting close to running out of time, so I wanted to go back to some slides that we were going to talk about at the end of the talk. So let me see if I can find them and close with these slides. Can you run up the slide here? So I wanted to tell you my personal clinical considerations. I want to emphasize that a dura sealant does not replace surgical technique. Surgical technique is critical in closure. You want to get good apposition of the dura to the dural edges, if possible, to a collagen compound, if possible, or to one of these other kinds of tissues, fat, radial forearm free flap, pericranial, whatever, but you've got to get it close. And it's really important to get meticulous closure if the bony sinuses are involved and violated with your craniotomy, if the corticotomy goes into the lateral ventricle, if it's a radiated area that you're operating on, or if it's infratentorial or if it's in the posterior fossa.

Applications, you've got to ensure hemostasis. You want to apply a thin coat. The thing to remember is "Thin to win." You want to apply a very thin coat. It's not necessary to apply a thick coat. One to two millimeters is fine. You don't need to apply it on the unintended surfaces, it's not critical, but you just don't need to apply it. Apply it to right where you need it. Don't continue to layer DuraSeal dura sealant is the initial adherence is poor. If it's not sticking, regroup, find out why. It may be because there's some blood underneath it. You can remove the dura sealant with scissors or any kind of mechanical disruption. And cover the tissues that don't need DuraSeal. There's no point in using DuraSeal over the entire wound. Really concentrate on the dural area.

Well I think that probably about does it, and I just wanted to thank you, Dr. Delashaw, for joining us today. I'd also like to thank Oregon Health and Science University for hosting today's program and say thank you to our patients who have allowed us to document their surgeries for learning and educational experiences. We'd also like to thank Covidien BioSurgery for supporting this program. And a reminder to viewers, if they've missed any portion of this program, they can see it on demand at any time, and that would be at ORLIVE.COM. And thanks again, Dr. Delashaw. It was a pleasure.

Thank you, Dr. Coppa.