[MUSIC PLAYING]

ERIC WANG: So, I think that increasingly we have come to the acceptance that there are really very good natural corridors through this nose and through the paranasal sinuses to reach a variety of different skull-based pathologies. And the classic is this, a pituitary tumor, which is where we use the sphenoid sinus and the nasal cavity to gain access-- direct access to this pituitary tumor without any neural manipulation. And as you can see, it's really just an extension of many of the sinus techniques that we train our residents on every single day.

Here we're performing a wide sphenoidotomy on the left side, expanding it inferiorally and laterally. And already, you can begin to pick up the sella and then some of the key landmarks, which we're going to take a look at here in just a second. And again, this is a simple extension of a traditional surgery we do every single day for endoscopic sinus.

And all we do in this particular case is we try to take advantage of both nasal cavities by expanding and creating a small posterior septectomy. This really doesn't have much consequence for patients. But for the surgeon, it gives us a tremendous amount a working room. So when we deal with intracranial or pituitary tumors, access or exposure is really the name of the game. And you can see here what beautiful access we have to a pituitary tumor.

And this surgery, while it's first was described here at the University of Pittsburgh many years ago now, it's become widely adopted throughout many centers throughout the United States and throughout the world. And you can see what beautiful access you get. And it's actually much better access than even some of the speculum-based techniques we used in the past because now we can even see broader and wider. So the advantage of the endoscope is it really gives us a panoramic view into the depth. And we can use a combination of high-speed drills, and endoscopy, and multi-handed surgery to gain access.

And here we're going to remove something called a medial clinoid. So this is right between the carotid artery and the pituitary gland itself. And you see here we've created osteotomies around it all. And now this kerrison rongeur can be used to carefully fracture away this very large bony spicule, which you're going to see in just a second here.

And once this gets opened up, it's going to provide an even broader corridor. So we're not confined to just the sella itself, but we can work outside of this. And really this increases our visualization of the gland tumor interface, as well as all of the critical landmarks that could be hurt, things like the carotid artery and the optic nerve, and then within the pituitary itself, the pituitary stocks. So here you see this large spicule bone, which can now be removed in its entirety, and again, create wonderful access to the medial clinoid.

The other thing about tumor resection with an endoscope is you can just see a whole lot better. So here, as we open the sellar dura, you're going to [INAUDIBLE] beside the tumor. And then in a second here, we're going to be able to identify the tumor gland interface.

So this is something that was very difficult with a microscope, much less with a blind eye or microvascular loops. But here, you can kind of very clearly see where the tumor is in the center and then where the normal pituitary gland is. And then we can work around this and get wonderful reconstructions after we have complete tumor removal.

And just for the sake of time, I'm going to slide ahead here. And here, we're removing some of the nasal flora mucosa and using this as our reconstructive tool because this is an area that heals beautifully and very well without a whole lot of consequence. And there you can see this nice floor graph covering over the entirety of the pituitary defect.

So pituitary surgery is where we all started. It has lots of advantages over some of the other techniques we use, especially when we need to go out laterally. It really helps us visualize the tumor, so we can preserve the things that we want to maintain while getting a complete tumor resection. And one of its biggest criticisms early on was that of CSF leak. And at least for the pituitary and sella pathology, this is actually a very, very minor concern now.

But the best things that we're able to provide patients is now we can really preserve a lot of pituitary function. So pituitary surgery doesn't necessarily condemn them to lifelong medications. And even things that are transient, like SIADH are minimized.

So where do we go next? And that's kind of what the rest of this talk is about. I think pituitary tumors are really accepted as kind of the gold standard of endonasal surgery.

And I think the next area that most people work towards is the area right above the pituitary. And we're basically talking about two pathologies here, craniopharyngioma and tubercular meningioma. This is where it gets a little bit more controversial, but I think increasingly people are seeing some of the benefits.

So why do we use an endoscopic and nasal approach? Well, actually even though these two tumors seem to occupy very similar anatomical regions, they're actually very different reasons. For suprasellar meningioma what we're really trying to do is maintain the optic apparatus and the microvasculature to it In craniopharyngiomas, because they arise from the pituitary stock and the posterior pituitary gland, what we're trying to do is preserve their hypothalamic access.

And so even though they seem very similar, like you saw in that MRI before, the exposure to them is actually very, very different. So with a craniopharyngioma, exposing all of this planum is not beneficial. Really all we need to do is get this lower portion called the limbus. And I'm going explain that to you in just a second.

And I'm going to-- and while tubercular meningioma, we have to go as anterior on the sphenoid planum as necessary to get out all the tumor. And you can see this interoperative examples. Here we have all the dura exposed for a meningioma. While in craniopharyngioma, we really just have the optic nerves exposed. So what I hope to explain to you is that anterior access is actually not the key for many of these tumors. It's actually lateral axis getting to those optic nerves because that's usually one of our big goals with surgery.

So again, here in real life, you can see that anterior is towards you. And we can see again this pituitary area here, medially immediately underneath the optic nerve above. So this is the pituitary, and here's the pituitary.

And what we're really trying to identify is this fold of dura here called the limbus of your sphenoid. So it's actually a bony landmark when you come from-- so this is a bony specimen from behind. But you can actually see this dural fold every single time. And the reason it's so important is it helps mark for us where that optic apparatus is going to be. So that's a really critical thing if you're going to operate above the pituitary gland is when you have to preserve that visual optic apparatus.

The next thing we need to do is we need to get direct lateral optical carotid and cistern access. So what does all that mean? That's a long and drawn out term. But the long of the short is, although you may see other people talk about this is enough access for a suprasellar approach, we really don't think that's true. It's opening up this lateral cistern here on each side, which is here, again, for landmarks.

Here is the optic nerve. Here is the carotid artery. Here is the lateral optical carotid recess. And you can see what we're trying to do is perform osteotomies over this portion here. Because it's that lateral access we show here, this lateral access, which is critical for us if we really want to be able to work around everything.

The question then becomes, how lateral do you have to go? And to be truthful, in our hands we go essentially all the way to the lateral optical carotid recess on the side of greater tumor involvement, and sometimes bilaterally. So in this example we see here, again, in this anatomic specimen, you again identify where the carotid artery is, and the optic canal, and here is the lateral optical carotid recess.

And you can see in this actual example from the OR, that what we're really trying to do is we're really trying to get all the way out to this lateral OCR. So this is actually a lot of medial optic canal exposure, which we really haven't had any issues with as far as visual loss but it becomes really critical. And so diagrammatically, what we're trying to do is we're trying to get all the way out. And that keeps careful exposure of the carotid.

But what it also provides for us, is it now provides us access to this distal dural ring. So what is this? This is where the diaphragm of the pituitary comes north over the carotid artery. And it's this dural access, it's being able to get out on this side that becomes critical.

And some people may ask, well, why do you need this much exposure? So here is the optic nerves on each side. Here's the optic chiasm. Here is the pituitary stock. It's so you can identify these little blood vessels. These hypophyseal arteries are critical towards preserving vision.

And they preserve the hypothalamic access. Because from this artery that arises off the carotid, you have three branches, one that goes to the nerve, one that goes to the chiasm-- one that goes to the nerve of the chiasm, one that goes to the stock, and then one that goes to the diaphragm. And it's just like every other thing, anatomical preservation of the structures is not enough. You have to get blood supply to it. So that's why this is so critical.

And let me show you an example of this. This is a craniopharyngioma, one of the tumors we just talked about in a 39-year-old who underwent a previous lateral approach and has undergone multiple rounds of stereotactic radiosurgery, and continues to have significant visual loss. And through an endonasal approach, we really provide beautiful access.

So here is actually the pituitary stock blown out against us. And as you cut right behind the stock, you can clearly tell that the tumor arises from the stock itself. And then we get into this typical appearance of a craniopharyngioma with these multiple densities and calcifications within it.

And here you see this hypophyseal artery. And if we did not have this lateral exposure, it's very difficult to work around the periphery of this and preserve all of those key critical neurovascular structures. So here we're dissecting around that. And then as we work more superiorly, you're going to be able to identify-- we're getting up towards the third ventricle itself. So even through an endonasal approach in the appropriately selected patients, you can preserve all of the vasculature, and then dissect superiorly enough to truly enter the third ventricle itself if you follow the tumor corridor.

Now, it's not the perfect solution for every craniopharyngioma, but for many of them, here, as we see the entrance into the floor of the third ventricle where the tumor is entering, all of this can be accomplished through an endonasal approach with wonderful tumor resections that can preserve all the key critical structures. And here you can see irrigating into the third ventricle itself. And then you can see that's the entrance into the sella, and how deep you can go endonasally. And so this is really, I think, where the majority of craniopharyngioma surgery has gone because it does provide this wonderful tumor corridor.

And here is the post-operative imaging. Here's the pre-operative tumor. You can see all the calcifications that are within it. And now you see the endonasal corridor as well as the entrance into the third ventricle. So all of this is accomplishable, but it's understanding the anatomy and providing that breadth and width of exposure.

So here's a little bit of our experience from our UPMC group. It's a little bit older at this point, but it's a total of 64 patients. And you can see that the majority, 72%, had a gross total or near total resection. When we leave a little bit of tumor, it's often against the hypothalamus because of the restrictions there.

And again, as I mentioned earlier, here's the key things. This is the adult group, and here's the children's outcome. But you can see that the majority of patients, 84%, 85% have either resolution or significant improvement in their vision. And that's accomplishable because of the ability to both see the optic apparatus as well as the microvasculature. And in a similar way, although in smaller numbers, you can see that the children really improved the most.

So the other suprasellar pathology is that of meningioma. Now, this one I think is more controversial. As I mentioned, craniopharyngioma has largely gone to an endoscopic approach, but planum meningiomas are more controversial.

So here is one with a lot of vascular encasement. You can see here the artery running through it, the internal carotid artery below. And here we are opening it. Now here again, as I mentioned, this is the lateral access. Opening the lateral-- the optic canal now provides us all of this access to this tumor.

And unlike pituitary tumor, you saw how easy that was to remove, meningiomas are not that easy to remove. They can be very fibrous. They can be very challenging. There is the pituitary stock. And you have to identify all of these key structures within it. And you can see how fibrous this pituitary tumor is.

And here we're working up against the A2s, so that's your anterior commissures. And you have to have some comfort or ability to work around this intracranial vascularization if you want to dissect these tumors. So this is where experience is really the key. You have to have logged plenty of hours. There is the anterior communicating artery and then the A2 segments on each side. And this is where the team is so critical, both being able to maintain visualization in a dynamic fashion, as well as having the experience of working together for these difficult dissections.

So as we work around the periphery of this, here you see the optic apparatus, which has been completely crushed by the meningioma, the primary reason for the majority of these surgical interventions. And here, again, we're working out laterally. And this is where the lateral pair of-- the lateral artery and the carotid arteries are coming off. And this is where a meticulous dissection and understanding of where that anatomy is going to be is vital. So there is the last of the intracranial vasculature.

And then what you end up with after you get all this tumor out-- there you have the final tumor removal. And you can see, it's pedicle off the distal dural ring. And it's that optic nerve opening that really allows us to get a complete tumor resection at that site. So again, width of access is just as important as anterior access. And then here I'll show you the final defect in just a second. Here you see the intracranial vasculature, that's been dissected, the ACOM complex, and then here is the pre- and post-op MRIs.

So one of the biggest criticisms of doing it this way, in addition to dissecting off those delicate arteries through an endonasal approach is putting it back together. And here's what we typically use, which is a nasal septal flap. This is the typical defect. It's about a centimeter by centimeter and a half, which you can see by the ruler motion. Very similar to what you just saw, we use a DuraGen underlay graft, and then a second layer, which is our nasal septal flap. So and we'll talk about this a little bit more at the end, but vascularized reconstruction has really been critical towards the successful implementation of these surgeries.

So here you can see our experience, which is a little bit older now. And well, you can see that almost 80% have a growth total resection. And I think we're actually even better than that now.

But the critical thing is how much visual improvement you get. So as I mentioned, the majority of the time what we're doing this for is visual loss. And you can see that in the vast majority of patients, almost 85%, they have an improvement or resolution of their visual defects.

So the advantages of using endoscopic approach is early devascularization, lower Simpson-grade resections, which basically means removing the bony portion of it as well as the underlying dura, which is inherent to the endonasal approach, and a possible improvement of visual outcomes. And the limitation is the higher rates of CSF leak.

So I'm going to transition from the suprasellar region to the enterior cribriform. And I think this is near and dear to our hearts as otolaryngologists because this is what we use most frequently for sinonasal malignancy. And in the interest of time, I'll quickly skip through these surgical steps.

And we've talked about this in other venues, but it's key to identify your landmarks, orbit, maxillary sinus, sphenoid sinus, because when you have a tumor obscuring your visualization like in this particular situation, and filling up the whole area, it becomes critical to know where your limits are. So opening the sphenoid early on, if you can get past some of the tumor so you can identify this, working on the contralateral side, which may have less tumor involvement, and then performing a septectomy to, again, gain this binaural access, which you see here, really can be all critical steps towards helping you really get a complete tumor removal.

But for most things, it's this Draf III frontal sinusotomy and identifying the crista galli, which really defines our anterior limit. So here we're doing a Draf III with a high-speed drill, finding the periosteum of the lateral nasal wall. And then you can just drill towards the frontal recess. This is called an "outside-in" technique.

There are many different techniques for Draf III frontal sinusotomy, but their common characteristic is you remove the entirety of the frontal sinus floor so you can gain access to both sides of the frontal sinus. And you end up with a final defect that is this horseshoe nature opening here.

And this anterior projection is your crista galli. So this projection, it really defines the anterior limit of your skull-based resection. and that's the-- in addition to giving you adequate space, that's the biggest benefit of the Draf III frontal sinusotomy.

So you end up defining the margins as-- in this atomic specimen here, you find the-- you find the Draf III frontal sinusotomy here, the crista galli, your anterior limit here. Your lateral limits are the orbit, although you can expand beyond that. Your posterior limit is wherever you need to on your sphenoid sinus, and then inferiorally at your septum.

And then you can devascularize a tumor because we have access to the anterior and posterior ethmoid arteries, which are depicted here. And that can help cut down on some of the sniffing and bleeding. And then you can perform your skull-based osteotomies.

So you can see that they're outlined here. But removing this crista galli really defines the anterior aspect as well as this frontal recess, and then you can form your lateral osteotomies, which is depicted, again, here in this cadaveric specimen. And then here is your dural resection. And the dura-- and then you can take margins off the dura circumferentially. And in essence the dura section ends up being an en bloc resection.

So let me give you an example of this here live and in person. So this is a patient with a adenocarcinoma, which involves the skull base. So here we're cutting-- the osteotomy is performed, and the dural cuts are now being made laterally on each side. And then they're pedicle off the olfactory bulbs posteriorly, which are then coagulated and transected. And then you can take margins around the periphery of this, and your final defect looks like this.

So the question then becomes, how much intracranial involvement can you remove? And here is a very nice woman who came in with a biopsy proven esthesioneuroblastoma. And you can see through this series of images what significant intracranial extension it is.

And I think that in different groups hands, they would manage this in a different-- in a variety of different ways. But here in our institution, we tend to still approach this through an endoscopic corridor. So you can see here the osteotomies have been made. We made our dural cuts. And here we're dissecting the plane between the brain and the tumor. You'll see the olfactory bulbs are draped over the tumor itself, which almost provides a fascial plane-- or a fascial-like plane to dissect along.

And you can remove the entirety of this tumor using an endoscopic approach. It's the same thing, it's just more height. And then you can take your margins off the periphery of this. And the defects apparent-- essentially looks the same every single time because our dural resection is maximal in this particular scenario when we do bilateral transcribriform resections.

So the surgical approach is very much team-dependent. And I think it's not wrong to use a combined craniotomy as well as an endonasal resection. But the key, of course, is getting an oncologic resection with negative margins. And this often, of course, takes a multi-disciplinary approach with both the surgical services as well as radiation and medical oncology.

So here is a review that was published in *Head and Neck* last year, which is a meta analysis looking at open versus endoscopic resections. It's 36 studies with 609 patients. And there's really no difference in local/regional control.

But the endoscopic group had a better-- or improved overall survival when you look at all patients, high grade by Kadish stage, which is basically an anatomic description, and high grade by pathology, which is the Hyams grading. And it has increased disease-specific survival across all patients as well as in that Hyams group. So I think our evidence is really growing.

Here's another study that we participated in, a multi-institutional, an international trial. And this is 109 patients from multiple centers. 61% were treated endoscopically, and 65% of them are this higher Kadish C.

And when you match them stage for stage, the endoscopic group had a higher rate of survival. And that's probably directly related to a higher rate of negative margins. So again, it's that key towards broad access and visualization.

So we also do a lot of posterior fossa work. This is, I think, where endoscopic surgery has really found its true niche is in these kinds of things, like these residual chordomas, which we see here. This was approached through a pterional craniotomy and has some residual disease here. And these can be very, very challenging cases, but I think this is where endonasal surgery shines.

And I won't go through the entirety of the video. But this is the same tumor pictures. But I'm going to skip here towards some of the intracranial dissection.

And here you can see what beautiful visualization you can have of the basilar artery. And here we are dissecting all of the brain stem perforators from this scarred in residual tumor and dura from the open pterional approach. And you can see if we didn't have this visualization, how difficult it would be to preserve these very small microvascular vessels. And this is really where endonasal surgery can really shine because it does provide this panoramic viewpoint and this dynamic endoscopy so we can look around and look around corners to allow us to get these complete and-- complete tumor resection.

And these are really critical in chordoma where it is a cancer. And the necessity of getting negative margins, the ability to get gross total resections is absolutely critical. So here you can see the post-operative MRI. Might be a little bit difficult to appreciate, but the residual tumor knuckle is up here, which is now completely resected. And-- oh, excuse me-- and here is the nasal septal flap reconstruction with a gross total resection.

So to quickly look at this data, this is an older study now. But you can see that our gross total recession rates using an endoscopic technique versus the more traditional lateral approaches is very comparable. Although our CSF leak rates are high, they are comparable with the open literature as well. So that's not a huge advantage.

But I think where we really do have a big effect is in cranial neuropathies. So the lateral access really requires dissection around cranial nerves to get there. And the endoscopic route has a risk for cranial nerve VI palsy. But short of that particular cranial nerve, we actually have much lower rates of cranio neuropathy.

So the elephant in the room about this is how we put it all back together. Now, this has always been the primary criticism of endoscopic skull-based surgery because CSF leak rates are still the-- or post-operative CSF leaks are still the greatest challenge of this particular surgical technique. And vascularized reconstruction has improved it significantly, but there's still a lot of controversy in the literature because they group all these things together. And as you can imagine, a small pituitary defect is quite different than an anterior skull-based defect or a defect towards the basilar artery.

So we've looked and we were fortunate to have a large enough case series to look for risk factors for CSF leak. And this was a retrospective review of 615 patients, which was published in a *Journal of Neurologic Surgery,* which really demonstrates that the things that are associated with CSF leaks are all the things that increase pressure.

So in BMI-- in Western Pennsylvania we do have a larger population. Almost 70% of our patients have a BMI over 25. So that's quite a large percentage. But we really did find a significant change in CSF leak rates purely by BMI. But when you break this down by gender, and we know from spontaneous CSF leaks that women who have obesity have much higher pressures, in general, than men, that that difference then plays out. So in patients with leaks who are female, the BMI was very significant.

And when you look at the multi-variate logistical regression of this, you can see that BMI plays out, has an increased odds ratio of 1.75. Surgery before vascular reconstruction also was a problem. But preoperative hydrocephalus, so increased pressure, all of these things work against our reconstructions.

And so women who have a predisposition towards having higher CSF pressures, patients who already have preoperative hydrocephalus, all of these things work against our reconstruction. And that makes sense because we can't suture in the depth. So you have an airspace on one side, and you have pressure working against the other side, if that pressure overcomes the reconstructive material, then you're going to get a CSF leak.

So that brings us to the role of CSF diversion. So where do lumbar drains play a role in this? And the truth is we don't really know.

Lamar drains have some risks. There are things that can be very, very bad from lumbar drainage. And traditionally, people have used this based upon what their institution does. And we don't really know what's the benefit or what patient population benefits the most from this, and so that prompted our team to design a randomized controlled trial, which was completed here.

Looking at perioperative lumbar drainage, here is our inclusion criteria. I'll point out that it was actually a very strict inclusion criteria. These are not pituitary tumors. These are things with large arachnoid dissection, or an entrance into a ventricle like I showed you earlier in this talk, or a dural opening of at least one-by-one centimeter. So these are not small skull-based defects. These are sizable skull-based defects.

And the way the procedure worked was we completed the surgery, and completed the reconstruction, and then the patients were then randomized to either getting three days of lumbar drain at 10 cc's an hour, which is a fairly aggressive rate of lumbar drainage, or no lumbar drains. And then we studied the anatomical subsites.

So here's the data from the paper. There's a 170 patients who are randomized and allocated. Because it's a short-term trial, there are essentially no dropouts.

And our initial power analysis told us we needed 230 patients. So the question always becomes, well, why come we only had 169 or 170 randomized? It's because we actually found a clear and significant difference between the groups in our safety analysis.

So when we had a drain-- when we had to drain, at least in these high-risk patients, the leak rate was only 6%, which is comparable to pituitaries. When we there was no drain, we had a leak rate of 22%. So I think this is pretty compelling. And you can see that the other risk factors we looked at weren't particularly significant, but lumbar drainage was the critical risk factor. The other thing-- and here is that the p-values to support that.

But there's more to the story than just a lumbar drain. We talked about anatomic subsite being so important in understanding that. And we found that to be true in this subgroup too. Although we didn't power the study to look at each individual anatomical subsite, we had enough numbers to start exploring that.

And the truth is that lumbar drains really do eliminate the difference between the subsites. So in this particular patients with drain, you can see that the leak rates were all about the same. And those without drains, it's statistically significant.

So looking at these specific subsites, in these anterior fossa-- in this anterior fossa group here, you can see that with a drain, the leak rate was only 5%, 6%. Without drain, it's very high. But there are no postoperative CSF leaks in esthesioneuroblastoma.

So it suggests that meningiomas, which have this sort of big cavitation into the brain itself and result in something called a pontine cave, or pre-pontine cave, are probably different than these esthesioneuroblastomas. And this is probably something we need to continue to study.

But in posterior fossa, I think you really can't argue. These are all gigantic defects. You can see the average defect size in 7.2 square centimeters.

And here I think a drain is really critical. Lumbar drainage I think is our standard of care now based upon this because it can really reduce the rate of CSF leak to a very, very acceptable level. And when you compare it to the open chordoma literature, it's outstanding.

Now for the suprasellar region, this is a different story. These are the craniopharyngiomas and the meningiomas I was talking to you about. Here are the different sizes. As you can see, it's considerably smaller at 1.4 centimeters, and there's not a real difference in the leak rates.

So I think this is about defect size. That nasal septal flap covers that out in an excellent way. And here is probably a group that we do not need to use lumbar drains in. So unlike the posterior fossa, I think that suprasellar lesions really can be well controlled with just vascularized reconstruction.

And this is the defect side story. Of course, we stopped the trial early, so it's not quite significant. But I think if you were to able-- if you measure the difference in defect size between those with and without leak, that it will end up being a critical issue.

Of course, there were a couple of complications. But we are very worried about things like thromboembolic events because lumbar drains do minimize patient's mobility afterwards. But we did not find a difference in either that or respiratory complications. We did require two blood patches. And there's one retained lumbar catheter.

So I think lumbar drains are critical for posterior fossa and then for certain anterior fossa defects, while they're probably not so beneficial in suprasellar defects. And large dural defects probably are the ones that benefit the most.

So I really thank you for your time and your attention. I think that endoscopic, endonasal intracranial surgery really does have a lot of evidence growing towards both efficacy and safety. And it really does provide a very valuable alternative approach, which avoids some neural and vascular manipulation. And you can start to see some of the significant benefits from utilizing this approach. And while CSF leak remains, the primary complication, a shortcoming of the technique, I think we're beginning through prospective trials to understand when and where we need to use adjuncts to help us minimize this complication. Thank you very much for your attention.