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CSF

Chiari & Syringomyelia Foundation

Built On Leadership, Vision,

And Commitment To Find A Cure

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Thank you very much for being here and for giving me the opportunity to talk as well.

Fraser gave me this topic about different fusion techniques, so I'm going to go historically through them. The pioneers are Dr. Pilcher and Dr. Foerster. Dr. Foerster is mentioned in most of the literature as the first one; but I was actually able to dig up an earlier case by Dr. Pilcher in 1910. Both of them did just occipital fixation with bone only.

There are some common ingredients in craniocervical fusion techniques. There are different modalities about how we instrument the occiput, different modalities in which we instrument the spine, the bone matrix

we lay on top. The principle for fusion is the same of armored cement. If

you build a pillar only with cement, it's going to crumble. If it's made only of metal, it's going to bend.

The sum of the two is better than the sum of their individual strengths.

So you want hardware to be reinforced by bone which initially comes from the

matrix, which is a sort of grapevine onto which the bone of the patient grows.

Immobilization is also important for a good final result, and the

convalescence is an important key as well for a good outcome.

The late complications have actually been the driving force for

evolution in this field. One is these complications is the so called metal fatigue.

After a while, if the bar is not reinforced by an adequate amount of bone, the bar is going to bend; and the initial advantage of the distraction gets lost over time. Ultimately, with a paper clip effect, it can result in a breakdown of the bar, which can be serious if it's bilateral.

A pullout can occur in certain syndromes, especially the syndromes in which the bone is very soft, mostly for older people . . . et cetera.

The painful profile is the unsung -- not hero, but the unsung villain of craniocervical fusion. It is considered so common that it practically becomes background noise in the mind of neurosurgeons. So I say, All right, you had atlantoaxial instability, you had major fracture, you had craniocervical instability, you had retroflexed odontoid -- I fixed all that for you. So don't complain about the hardware. This is what most neurosurgeons would say.

The point of soreness for the patient is neuralgia in the field of the C2-3 nerve roots and in the great occipitalis nerve. That's always the beginning of the chain every time you put a lot of foreign bodies in the area.

The evolution of craniocervical fusion has evolved during the years from about a hundred years ago and has evolved in how each one of those elements I described before -- the occipital anchoring, the spine anchoring, et cetera -- evolved. And also the materials have changed from the stainless steels of the beginning to the modern alloys with different mixes in the titanium.

Hardware design has evolved in order to make it surgeon-friendly and, to a point, patient-friendly as well; but surgeon-friendly has been the driving force between the two, the bigger driving force.

These are the first four techniques historically. In the beginning people were just slapping bone in the area after decorticating the regional anatomy, generally harvesting the bone from ribs or hips; and then they were putting the patient in a halo jacket or some kind of similar contraption. And then when wires made of stainless steel became available, these two things were reinforced and a solid bone graft was put in the area. Then rod and wire. And rod and hooks. This is the part A of the evolution, and I'm going to go through some examples.

So this is a postoperative anatomy after a Chiari I decompression with C1 laminectomy. And this is the posterior anatomy, the craniocervical junction, which is the place where craniocervical fusions take place. So imagine to go over there with a drill to roughen up all these areas, which you can go up or down -- in the beginning they were going all the way down here --

and then you put cadaver bone or some solid grafts, and then you put the patient in a solid fixation like the halo jacket. This, over time, is going to take, especially in children, they're very easy fusers; and this is going to lead to the first form of craniocervical fusion. Sometimes you cannot put anything else.

The halo jacket – (this is an example taken from the Internet, it's not a patient of mine; so he gave clearance for this picture to be posted and viewed) -- is a very barbaric medieval contraption. We have this halo, which is a ring, which is fixated to the skull by a bunch of screws, and stays there for a period of between three and five months. Obviously, it's not very comfortable, and after a while you smell because you cannot take a shower.

The second evolution of this was this one: you roughen up the area and you put two struts. And the struts generally can come from ribs or a piece of iliac crest or from autologous, which is from the patient's own body, or from cadavers. Autologous is better. And then you fix it to the area, instead of just let it floating around, with cables, made of stainless steel in the past, and now with titanium. And then you kind of tighten them together.

Obviously, this is an improvement from the first technique; but like any knot that you guys do in your shoes, after a while, especially with the mechanical stresses of this area, many of these wires have a tendency to fail.

Therefore, we went to the next evolution. And the evolution was the introduction of the Steinmann pin.

The Steinmann pin was able to get part of the stress that before was taken by all these cable wires and the graft, and is redistributing in these little segments, and you're breaking down the action. And then on top of this you put either your strut or crushed cancellous bone -- whatever you want to put on top. So you want to reinforce it. In this case, this is a creative fashion with this plug over here made of iliac crest.

The bars, the Steinmann pins, they tend to be difficult to contour it to the site of the patient. So often you see here, you have something poking out through the skin and is not very comfortable. The issue is that if you use a modified Steinmann pin, which is very thin, you can contour it to the skull; but it's not going to be as strong as a Steinmann pin, which is going to be thicker.

So one way or another, you have pros and cons.

And as you see here, you are wiring everything to the skull and to the posterior part of the cervical spine.

The next level was to introduce hooks. Hooks were more stable, they were just capturing one side of the spine. They were going from above, from below, you are having creative geometrical distributions; and you are incorporating in the Steinmann pin and eventually later on to different kinds of bar plates, and you were kind of passing them through. This was a more advanced technique than using the cable wires. But after a while, since the hooks were not solidly attached to the bone but just juxtaposed, they were having failures of its own before the design was pushed to the second phase.

The second phase of these four techniques: Plate with screw fixation techniques. Combined rod-plate fixation. Independent occipital fixation. And the condylar screws.

So that was part one, and this was the second. The second advance was you have screws that you put in the skull and in the spine. Biomechanical studies have led us to believe that the use of screws was superior than the use of hooks and cable wires, very easy to understand, especially if you hang something on the wall. And then how do you fix them all together, how do you

prevent all these things from moving in relation to each other. So in the beginning they designed these plates which had holes in fixed places.

Now, like one suit, one size fits all, this was ideal for this drawing and for some patients; but not for some other patients.

So they started creating multiple holes.

The multiple holes were making the bar plate more weak, and sometimes you were not really exactly feeling, you were trying to fit a square peg in a round hole; therefore, this lasted for a little while. They went to design a bar plate.

The bar plate has one part with holes, which then is continually connected to a part which is the bar. So you have a bar and a plate, and this is one solid piece. And it comes out of the packages something straight or something slightly bent; and then the trick is that you have to use your hands and some tools to contour it to the profile of the anatomy that you're dealing with, because you want the hardware to be flush against the bone in order to decrease the discomfort of the patient but mostly to prevent pullout and biomechanical problems such as the torque effect, et cetera.

I don't know who designed these sets, but most of the benders that were used to contour the bar plates were pretty awkward, and they were awkward to be used, awkward to be handled. So most of the people who were doing a lot of this, they were using their own instruments, their own pliers in order to create the best created contours.

So you now have a bar plate, which is secured to screws which are inside the spine and inside the skull.

This is a lateral view in an X-ray so you see how long it is. In the beginning people were going down to C4 because you thought, okay, if you have a high building, you need a big foundation. Then people started -- like the skirts during the late '60s, they started getting shorter and shorter. So we ask ourselves how high we have to go in order for it still to be anchored, and the tipping point was considered to be C2.

I'm going to spare you a lot of other discussions about the stress in C4-5, it's not the topic of this. But people started doing occipitocervical fusion limited to C2 and 1. In this case there is a pedicle screw at 2 and a lateral mass at 1. And in this case there is a transarticular screw between C1 and 2. And you see here the screws in the back of the skull.

This is just a little drawing showing how the screw can bridge from between 2 and 1. These are individual choices driven by anatomy, comfort of the surgeon, et cetera.

This is how a bar plate supplemented by bone ideally shows over time. So you see bars that now are covered by all this bone in the patient. In the case of a craniectomy, the bar is not very big. You are respecting the decompression you had done before.

The problem is that many people with connective tissue disorders, since they have defective collagen, et cetera, you need collagen to create good bone. You throw a lot of things inside which is everything plus the kitchen sink; and then you go afterwards later and you find something disappointing like this, you say, Where did the beef go? Where did the bone go? And you see a very extensive reabsorption.

And even if you put sizeable chunks of ribs or pieces of iliac crest, the fusion between the block and the bone is less than you would expect from other classes of patients who are not EDS. So people with EDS, the bottom line, they're more exposed to metal fatigue in the craniocervical junction because of the suboptimal way of incorporating the bone fusion matrix.

Some people started getting tired about having calluses on their hands to contour these bar plates to the skull; therefore, they started working on a different concept together with engineers, which is to get them separating the two things. So you have one bar for the spine, and one part that you attach to the skull with different shapes. And you connect the bar to the spine, and then you connect, like an Erector set, to the piece that you put in the skull.

So just for an example. So you don't have a bar plate anymore but one bar that you articulate with the two pieces.

Different kinds of designs, same principle.

This gets away with all the bending and contouring but makes it for a more bulky -- you know, you can imagine these two things, they cannot be very comfortable. So it makes for a more bulky profile.

Whenever craniocervical fusion is combined with Chiari patients and

Chiari surgeries at the same time or staged, there exists particular subsets of problems. The first one, like this morning Doug Brockmeyer was discussing, you have a complex Chiari, and the patient needs a Chiari decompression and a craniocervical fusion, in either a staged or a combined fashion. With Dr. Milhorat, for ten years, we did it staged. With Dr. Rekate, we did it combined. Problems come from both.

My personal favorite is to do it combined.

The other problem is that posterior fossa decompression and craniocervical fusion compete for the same piece of the real estate.

Everybody likes to put the screws where the posterior parts of the occiput is the thickest, which is the supraocciput or over the midline. But that has to go with the posterior fossa decompression. So the Chiari surgery removes bone. The craniocervical fusion creates bone for the area.

The other thing is craniocervical fusion needs wide access to the occiput in order to succeed. In simple words, we need a sizeable area to fit my bars and my screws.

But I also have to have enough space left to have my bone fusion to take; otherwise, the hardware is going to fail. The other thing is that you cannot shortchange one at the expense of the other.

So back in 2009 a guy called Uribe came out with a salvage procedure that you do when you do not have any more viable bone in the posterior part of the occiput to do a craniocervical fusion. So he focused on the condyles. So for the people who are not neurosurgeons in the room, the condyles are these things here in white.

They are pretty sturdy pieces of bone.

They're oriented in kind of a V-shape orientation. And here, you see

they're painted in pink. And this is the posterior part of the skull called the occiput,

is rotating around so you have an idea where the condyle is, which is the very

base of the skull. They're articulating with the first vertebra.

This is the lateral mass of the first vertebra, from here to here, and is

attached to this. And this big rock over here is the condyle, which happens to

be a big thick area of the skull. The condyles are two cm long and 1 cm thick, so when you insert two big screws in them you have a much better configuration

than not putting multiple short and small screws in the back of the skull that very often, in a patient with

Chiari, is thinned by the underlying pressure.

Obviously, this is a busy anatomy. You have the vertebral artery passing by, you have the internal jugular artery over here, the hypoglossal -- so it's pretty busy. But once you're done with the dissection, it's a very easy insertion. It's the equivalent of putting the screws in an anterior cervical diskectomy and fusion.

Another important part is this hole over here through which there is a vein called the emissary vein, which goes from the skull to the internal jugular. And it's important to dissect this because without that dissection you cannot come here where you put the screw.

It's also a very busy area for venous anatomy, as everybody knows.

But you can put two long screws over there. And the advantage is that you're not shortchanging your decompression, which is up here. You have

a C1 vertebra here. There's a C2 with a retraction band. These are the two screws in the condyles. These are two screws in C1, two screws in C2, lateral mass, and pedicle. Then you put the bars, and you're done. So instead of having a hardware which is 15 centimeters long, you have something which is three and a half centimeters long and you're putting all these pieces together.

This is the way it looks from the side.

So finally, after a number of years after I was waiting to play with this technique, I had a patient that had enough bone removed in the past and this was the only salvage fusion technique I could do. I do it, and to my surprise, the patient wakes up and doesn't complain about the profile of the hardware.

And I say, All right, let's do an X-ray. And I see that this sticks much less than I was anticipating. Then I realized afterwards, to make long story short, the patients were complaining for this part of the hardware most of the time; but they were not complaining for the cervical part of the hardware.

So the condylar screws, in terms of positioning, is kind of like a glorified spine screw. It is not really a posterior occipital screw: it is not in the back of the skull, but under the skull.

So sure enough, after a while I started just phasing out my craniocervical fusion from the standard technique to this new technique; and now, two and a half years later, I've done 102 of them, and -- I did a retrospective analysis of all my outcomes, and there was just one complication coming from these screws, again 204 total (righ and left). One of the screws compressed

the hypoglossal. The patient had a deficit that was reversed by unscrewing the screw

during a surgical revision; and the patient did a total

recovery 12 months later. I never had problems with the vertebral arteries, I never had

problems with venous drainage, I never had problems with anything else.

And the surprise of my analyses afterwards was that 52 percent of the patients that had this surgery, at the six-month check, they did not have any complaint about the hardware profile, while the vast majority of the other patients who had the standard craniocervical fusion were having major complaints with the hardware profile, so much that we're kind of dealing with it as a given.

This morning Dr. Brockmeyer was presenting a similar picture of this area, and this brings me to another couple of things.

We're talking about the capsular failure on this area. And what we have found intraoperatively is that the ligaments over here in people with EDS are compromised. And if we do manipulations during the surgery, you see that there is a very dramatic posterior gliding translation of the condyle in relation to the lateral mass of 1. So the entire piece slides like this, in and out; and that translates in an elevating pathologic version of the BAI, which is half of the Harris measurement that Fraser was describing this morning.

On the other hand, in other patients there was what we would call traditionally a cranial settling. And the cranial settling was when the vertical component of the joint was compromised, thus resulting in an abnormal change in the BDI, the basion-dens interval, which is the other half of the Harris.

So part of the consensus last year, we said CXA is important, Grabb is important, and we put Harris as a third. And Fraser this morning was saying, you know, I like the Harris very much. I like it too, on the grounds of this thing.

The other thing is this morning Heiss was saying, Okay, I don't see a lot of flexion-extension going on here, I see more between 1 and 2. You can see the relative shape of the joint between the . . . [22:30] lateral mass of 1 and how much is rocking of the superior articular surface of 2. You understand that most of the action is here, while the shape of the C-01 joint is aiming for a different kind of movement.

One thing that I started doing was, I was there, I was having all my joints involved, exposed, and I say, I'm sticking a drill into it. The concept of the fusion is that, craniocervical fusion, all these years we shot for what is called onlay grafting. So you put the bars over here. And then you have a piece of bone reinforcing the bar, which is far away from the joints. Now when you go for an anterior cervical diskectomy and fusion, what you're doing, you violate the joint, you put your appliance here and you put the bars and the screws. And everybody knows that the ACDF is one of the most biomechanically friendly fusions you can get.

So I was there, I was from behind; so I started sticking a drill over here, between condyle and C1, and between C1 and C2 .

And sure enough, I started seeing more and more some increased fusion here and in closer proximity of my onlay grafting that before was over here.

So I do not have any biomechanical testing; I did not decapitate any of my patients to bring into the lab to do biomechanical testing. But I listened to the patients. And some of these patients that were failures of the former classical fusions, they came to me and said, “My head feels much sturdier now than after the failed fusion, even before it failed, even when he was relatively well." So I do not have the specifics of the biomechanics; but I can tell you that patients who have compared the old, and the new version of their own body, they have told me it feels more sturdy.

And if you look at it, it makes more sense. An onlay graft over here on top of a fusion looks different from something with an onlay graft closer to the joint . . . [25:00]

So I do not have a lot of hardcore messages to give out to this experience other than the following:

Number one, condylar screw fixation is not as difficult as anticipated by the pioneers of the literature.

So far, I did 102. The complication rate is much less than anticipated in the literature.

Number three, the hardware profile and the tolerance by the patient is much higher from in accord that I found so far in what has been my historical experience with all these patients otherwise.

And so what do I say? Do I say everybody should use this? Hell, no, I'm not saying that. I'm saying, craniocervical fusion has evolved over the years and we have sure made big progress from just throwing a bunch of bone on the corticated areas and putting on a halo jacket.

With all these screw-and-bar constructs, you do not need a halo jacket anymore. You put them in a collar for a few weeks, sometimes up to three months, and you're okay, and you have good results.

But the take-home message is we've made a lot of progress with the screw fixations. There are different designs which can apply from one patient to the other. Chiari patients can restrict the choice of our application because of the presence of the large decompression in many, many cases. And condylar screw is not just a rescue technique but should be kept as an alternative because it's not as difficult or dangerous as formerly anticipated.

Thank you very much.

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Q. I think one of my biggest concerns, Dr. Bolognese, is bone space left in the muscle insertion when we do these suboccipital decompressions. Decompressions often takes away a lot of the bone surface for muscle attachment. Those muscles are very sensitive and very much tied into the vestibular nucleus of the brainstem. And I think we do a lot of harm when we remove that space, to the muscle attachment.

One of the things I really like about your condylar screw fixation is that it maximizes the space of muscle attachment.

My big concern, of course, is the potential for injury to the hypoglossal nerve.

A. The first thing is this incision to insert the hardware is so much shorter. The incision is very, very short; so there is less disruption of the soft tissue and is more comfortable for the patients.

The second thing is that concern about hypoglossal, it's a legitimate concern. But out of the 102 that I did, it only happened once and it only happened that day because the neuro monitoring of the tongue on that side was not picking that side; but I had two electrodes, one on the right, and the left was not recording.

After that, I started screw stimulation. And I have thresholds for normality. So now I have a double standard:

One is the EMG coming from the tongue, the other is the screw stimulation; since then I've had zero bad.

And it's not difficult at all to put the screw there. The only thing is that you don't want to stay high; otherwise, you are going to go towards the hypoglossal canal.

But there was some literature, some concerns about hypoplastic condyles, they were saying that that's a no-no for screw insertion.

Twenty percent of my patients have hypoplastic condyles; I got no problems. So it's a learning curve.

But again, as I said before, the risk of hypoglossal injury is not zero; but it's an easier screw and safer screw than initially perceived.

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