ICSC IMAGING Module 3
Section 2_ICSC03
Instructor Dr Chad Warshel
Video Lesson: 1:06:16

This second module is going to continue our discussion of various imaging modalities left off after the first or at the first hour, we are talking about x-rays and radiographic procedures and what their strengths and weaknesses are. It is time to get into some of the other diagnostic imaging procedures that we may or may not need to use. What are their strengths; what are their weaknesses; indications, contraindications, and so forth. Going back to my tool reference, we want to know every tool available to us and when we should be using those tools. As we start getting into these different tools, the next thing we would come to which we are not going to spend a lot of time on, but something that is a very interesting modality is fluoroscopy. This is marketed under several different names. You might see something called a digital motion x-ray. You might see video fluoroscopy, but at the end of the day, it is all fluoroscopy. What fluoroscopy is, is a live time motion picture x-ray. When we start thinking about looking at our regular radiographic procedures, standard x-rays, those are snapshots. It is just like taking a still picture and it is exactly what it is. It is a still picture of that single moment in time. There are times when we want to look and see is their instability.

If we are looking for somebody who had any kind of severe neck injury, we are worried about ligamentous damage. I was just reading an article about skeletons rider the other day, and their face is only inches away from the ice, traveling at 80 miles an hour. Sounds like a potential neck injury there. Look for ligamentous damage. Well, how do we really assess ligamentous injury? We do that by utilizing flexion-extension radiographs. That is the gold standard. It is what we have always used.

The idea with flexion and extension radiographs is, they are fantastic for looking at the end ranges of motion when the person's chin is tucked and they are all the way forward. Then when their chin is jutted and they are all the way back. But what if this person has an instability where vertebrae move too much, we talked about the translational and angular types of instability. What if that instability is somewhere in the middle of the arc of motion? When they are fully flexed, they have got enough muscle spasm and guarding that it is pulled everything back to where it is supposed to be. Same thing in extension, they hit that terminal range of extension, and everything guards, and you know, the muscles can help align the bones. That person might look normal on conventional radiographs. What if somewhere in the middle of that arc, between terminal flexion and terminal extension, right about here, that is where the person had a clunk? That is where fluoroscopy comes into play. Fluoroscopy lets us look at the entire range of motion as the person is doing it, to see if there is any mid-range instability. It'll also show us terminal instability, but it is, what it is really designed for is middle ranges.

Things about fluoroscopy, our big indicator, why do we do it? Looking for instabilities. What are the downsides, why do not we just do fluoroscopy on everybody then? Well, a couple of downsides. One is it is not nearly as readily available. While most imaging centres have C arms that do fluoroscopy and things like that, they do not really do MSK fluoroscopy looking for the instabilities. It is not as widely available. The image quality is quite often very poor. Has it gotten better over the years? Naturally, it has, but when you look at a lot of fluoro images, fluoro images are not necessarily crisp and clean and clear. Because of that, one of the things that you really need is if you are going to have a fluoro study of a patient, you also must have at least a minimal diagnostic series of x-rays. So, I pick on C spine because that is the one that we do most with fluoro. I must have at least my three-view series, AP, AP neutral, lateral, then I do the fluoro. This is something that is above and beyond looking for those motions because it is not great for looking for subtle things, small fractures, things that are difficult to see like that. It is more for growth structures. Because this is something that must be done in addition to a minimal series of x-rays, we are looking at some additional radiation dose. The radiation dose, when we look at a well-done fluoro study for a C spine, is about the same radiation dose as a seven-view cervical

conventional radiographic study. The dose is not super high, but keep in mind that you are also doing the minimal series on top of that. There is a dose consideration that must be used, and it really is, is very operator dependent. You have got to be sure you have somebody who is careful with the fluoro unit and sure they are not overdosing. Other downsides, they are only good for small structures. When we start looking at the fluoro that are in use in most chiropractic style settings, they tend to be small office underpowered units. Because of that, they are great for C spines. I can use them for wrists and ankles, looking for some different kind of instability through there. They are not great for the lumbar spine. There are really a couple of reasons that are not great for the lumbar spine. One, they are underpowered for dealing with larger lumbar, and two, your field of view is that large. It is one thing to keep a C spine inside of a circle that large when you are doing flexion-extension, but if you are trying to keep the lumbar spine inside that little field of view as a person's flexing and extending, a lot of times they are in and out of the field of view. This is where it got its pluses, it got its minuses. The other thing that we run into is one that there is a lot of different laws and rules around fluoro, picking on here in the USA as an example, in California, as a Chiropractor, you can own and operate a fluoro unit. In the state of New York, you cannot own it, you cannot operate it and you cannot even order it. In other countries, there is going to be different laws with fluoro.

Video presentation placement 06:28
Just to show you a fluoro study that is kind of an interesting fluoro study, and before I go further, I am going to apologize right now, even as far as fluoro goes, this one is not great quality. But it does demonstrate a nice example of a concept. You are going to watch the arc of motion through here and what I want you to do is I want you to focus in on the upper cervical spine. So, they just bump the arm up a little bit. Now they have got the person flexing forward and then they have got extending, flexing forward. Hopefully, you notice as this person is flexing and extending there is way too much motion there at C1. So as the person is there in neutral, and as they start to flex, C1 has translated forward, which gives us that dens versus transverse ligament concern. But as this person goes into extension, which you will see here right now, notice that the anterior tubercle landed right on top of the C2 body. Because C1 has translated posterior, that means we know that this is a dens differential, and this is a patient who turns out to have an Osgood-ontodium.

From there, we come into our next imaging modality. As far as things that we as chiropractors look at, we look at a lot of x-rays, the number two thing we look at, MRI. We look at magnetic resonance imaging a lot because this is really the best tool there is for looking at a lot of soft tissue abnormalities. MRI depends on state country requirements, what you are allowed to do and what you are not allowed to do. This is what we order a lot of, or we are going to end up having patients follow up to get the MRI studies. Now, as we start looking at MRI, magnetic resonance imaging, when you look at your pre-chiropractic education, for those of you who may have had organic chemistry, before you ever went to chiropractic school, sorry for a bad O-chem flashback, but for those of you had O-chem, you remember NMR, nuclear magnetic resonance, you would take a chemical, you put it in a small little very thin glass tube that had fins on it. You drop it in the NMR, spins it up, and then you got a peaked graph that showed you the different chemical compositions of the material. Well, Docs, that is an MRI unit. That is all an MRI is. An MRI is the same thing as the nuclear magnetic resonance that you did in O-chem.

So why is it not called NMR? Well, originally it was called NMR, and then, well, the problem was this became commercially available as an imaging tool in the 80s and nuclear was a bad word in the 80s. So as a marketing thing, they changed it from nuclear magnetic resonance to magnetic resonance imaging. By the way, I am full of useless facts when it comes to radiology. Why MRI? Why is this the second most common imaging modality that we as chiropractors utilize? Because it is great for soft tissues. The thing that MRI does is we are able to distinguish all the different soft tissues of the body. Not only are we looking anatomically, but we are also looking physiologically. We can start assessing not only if there is a tendon, is there oedema in that tendon? Is there oedema around the tendon? Is there fatty atrophy of a muscle belly? We can get anatomic and physiologic information all in one fell swoop, which is really,

really nice. We also do not have the restrictions that we have with a conventional x-ray. With an x-ray, we are squeezing a three-dimensional person onto two-dimensional film. Because of that, there are a lot of overlapping structures. One of the terms that you are familiar with from an x-ray standpoint is the mock effect. If you are looking at an AP open mouth radiograph, sometimes you will see the gap between the incisor teeth looks like a vertical fracture of the dens. Well, one of the things with MRI, is we do not have overlapping structures that way because we are taking individual slices of the patient. We get to do these slices and we can image in any plane, we can do axials where we go down and we are just slicing through. We can do coronals, the same way we can do sagittal, we can do any view. If I want to be 22.7 degrees off the axial plane to see something, I can do that. Probably the single biggest benefit of MRI, there is no ionizing radiation. Unlike x-ray, unlike CT, fluoro, and bone scans, there is no ionizing radiation. This is a giant magnetic field. So, because of that, there has never been shown to be any negative consequence to having an MRI, unless there are certain contraindications that we'll talk about it a little.

That being said, MRI centres tend to be a little bit more cautious about imaging pregnant patients because they do not want to take the risks. What if something were to happen, same thing with infants. Not to mention they move around a lot. So, but, they even do fetal MRI. If they are trying to evaluate, if there is something abnormal about fetal development, fetal MRI is a thing. It is a great tool, and it is a very safe tool. Is it always super comfortable? No, because there are the downsides of a tight little tunnel and the bigger the patient, the harder it is to fit them in. Most regular MRI units can fit somebody up to 250 pounds, maybe 300, if you are pushing it. There are now what are called open bore MRIs. It can get patients up to 500 pounds, these are widely available. If you get somebody who is particularly large, we start getting into the powerlifter category where we are dealing with very large individuals, realize that one of the options available for those athletes, where you get somebody who's starting to push over 400 pounds, and the table cannot handle them, there are veterinary MRI units. It is something that I have seen done with a 600-pound patient who needed a lumbar spine MRI. They went to the veterinary hospital, and they used the horse MRI on them. There are some interesting availabilities there. The downside of MRI, it is not super readily available everywhere. Here in the US, MRI centres are widely available but outside the US, it might be much more restrictive. It might be more difficult to get your patients in. We run into problems with metal.

Video Placement 13:07
I am going to show you an interesting MRI of somebody who has a knee replacement here in a little bit. Claustrophobics, this is a very tight little tunnel. If you think back to the original picture on this one, actually, let's just go back to that original picture. That is a small tunnel, and particularly when we are talking about things like brain MRI, on a brain MRI, this is called a head coil. The person's head goes inside that little cage and then their body goes inside the giant magnet. Claustrophobics can have quite a bit of problem with MRI and that is where open bore MRIs come into play, and that is also where open MRIs are an option, though I'll be honest with you docs, I try to avoid open MRIs at all possible costs. Is it there? Yes. Is it functional? Yes. Is it great? No, I would much rather have my patient get a closed MRI. The larger the patient, the harder is to get a scan, again, 250, 300 for closed MRI, 500 for bore MRI and open MRI. We will talk about contrast here momentarily. This is a more expensive study. It does cost quite a bit more and trying to get approvals is not always an easy thing to do.

Now the question who can have an MRI and who cannot have an MRI? Going back to my pre-chiropractic background, I was an automotive machinist slash mechanic, and I still do a lot of work for fun using grinders and there is metal in the air. Before I can ever have an MRI, I have to have an x-ray of my skull. That is a requirement. I must get an x-ray on my skull to make sure there is no metal in my orbit because if I have little flakes of metal that are implanted into my cornea, they can move around in an MRI and lacerate my cornea. That is the low end of things but what about the high end of things. What if there is something that is magnetic, like say an aneurysm clip in the circle of Willis? This is old school. The newer clips are usually MRI-safe, but older MRI clips might move around. Probably a bad

thing if the clip holding your aneurysm closed is starting to wiggle around. Pacemakers, now again, these days, there are MRI safe pacemakers. There are pacemakers that can go into the MRI unit and not have a problem. But if a person has a pacer, that is an issue. So before getting an MRI, you are going to have to find out what kind of pacemaker is it and make sure you get approvals. Another really good resource if you are ever questioning this ask yourself, "Is this something that I can do at MRI?" ***MRIsafety.com*** is an excellent website and has some great information there.

Video Placement: 15:46
Some relative contraindications or some things that make things a little bit more complicated. Metal in the area. The first rule, if there is a joint replacement, you do not do an MRI of that body part. I am going to show you a knee MRI of a knee replacement here shortly. But what about things like inner body spacers when somebody's had a fusion or if I have got somebody who has pedicle screws? We can work around those. There are techniques, that decrease metallic artifacts. We can work around those things to the extent possible. Now, what if I have somebody who has a pacemaker and cannot have an MRI? It is not an MRI-safe pacer or maybe they are not sure, then we go to a CT and we'll work around things that way.

Most imaging centres will have protocols for pregnant patients. I read for an imaging centre that does not image pregnant females, they'll refer him to a different centre in town. They just do not want to deal with any possible complications there. Claustrophobic patients. With claustrophobic patients and obese patients, the same kind of thing, that is where open MRIs can be useful or open bore MRIs. The ones that can accommodate larger patients also have a bigger tunnel, so it is not quite as claustrophobic, still not fantastic, but it is better. There is also the option of having your patients sedated. They can give the patient medications, anxiolytic medications, and things like Ativan that will help them be able to tolerate the MRI. But again, that is a very patient-dependent circumstance.

The other thing that we need to know about MRI is this is not a class on MRI interpretation, but we need to understand the basics much like we need to understand the basics of x-ray. When we talk about MRI, one of the things that gets thrown around a lot when we are talking about what something looks like on an MRI, is what does it look like on T1? What does it look like on T2? How's the grading on echo? MRIs come in these things called waiting's, otherwise known as pulse sequences, and what these are is they are different settings on the MRI that let us highlight different tissues. So, I'll talk about this here momentarily. Big deal though, you do not need to tell the imaging centre what pulse sequence is to do. The imaging centre has predefined pulse sequences. What they do is they base their study on what it is that you are trying to rule out. So, when your patient is getting this appointment, when you are getting the preauthorization, the big question is, okay, you want to MRI the lumbar spine? **Why? What's the purpose**? Because if you say MRI lumbar spine to rule out disc herniation, we are going to look at a disc herniation set of pulse sequences. If I tell the imaging centre that this is an MRI of the lumbar spine to rule out spondylodiscitis, I am going to be looking at different pulse sequences and they are probably going to put contrast on the lumbar.

Video Placement 18:57
So that is where letting the imaging centre know what it is you are looking for is important in this circumstance. What I am going to do on these pulse sequences is I am going to talk you through some of the slides here, but I am also going to do some live demos. You can see some of this MRI from the perspective of the radiologist. Now, main pulse sequences, I could spend hours talking about pulse sequences, A, because I am a nerd, and B, because there are a lot of them, but these are the major pulse sequences that we will see as we look at MRI, T1, T2, proton density, gradient echo, fat suppression, and diffusion. Those are the big sequences and I'll touch on each of these individually. You will see, there is also a lot of brand-specific names. Hitachi might call a gradient echo one thing, Siemens might call a gradient echo another thing, and Toshiba might use a third name. So those are brand specific, but they are still gradient echos. I am approaching these from the terms of the generic names.

Of the two pulse sequences or of all the pulse sequences, the big two are T1 and T2. Everything else is kind of a hybrid of T1 and T2. Now, without getting too much into physics and without reading repetition times and echo times and things like that, the thing about T1 and T2, everything in the human body has two major compounds in it. There is some water and there is some fat. And when I am trying to evaluate different anatomic structures and pathologies, I might want to see something that is more towards a fat side, more than more towards a water side. Well, T1 is fat, T2 is water. The way to remember that, T2 H2O. So T2 H2O. T2 shows me water. T1 shows me fat. Now, why do I want to look at fat? Well, I am not talking about subcutaneous fat here as a generality. I am talking about marrow fat. I am talking about epidural fat. I am talking about fat pads around joints and around muscles.

Using the spine as an example. How do I know it is a T1? Well, you compared neural structure to CSF neural structure. Myelinated axons have a lot of fat, and CSF is pretty much water. When I say that a pulse sequence is good for something, what I mean is that is going to be bright on the MRI. So, T1 is good for fat. Fat's going to be bright. T2 is good for water. Water's going to be bright. As I look at this thing, the myelinated axons are brighter than the CSF because, well, the fat is brighter. As I look over here at the axial, I can see the thecal sac, individual nerve roots in the lateral recesses, surrounded by epidural fat. So, T1 is good for fat. Now, what am I looking for? Epidural fat marrow. T1 is the pulse sequence that we spend the most amount of time looking for marrow pathology. One of our really important things to remember is T1 bright all right. If something is bright on T1, that means it is got a lot of fat and generally, a lot of fat means it is not malignant, particularly when we are looking at the bone marrow.

If something is dark on T1, again, particularly looking at bone marrow, that is a big problem. The other side of the equation is T2. So T1 is good for fat. T2 H2O, T2 is going to show me water bright. I am not looking for pure water. I am looking for CSF. I am looking for joint effusions. I am looking for oedematous changes in soft tissue structures. So, the same patient as before, and now I can see where if I look at the conus medullaris, it is darker than the CSF, or the other way to say it, the CSF is brighter than the conus. It is good for water and what the T2 is really from a spine standpoint, it is designed to look inside the thecal sac so we can see the spinal cord or nerve roots, depending on where we are at. It is good for looking at the hydration of discs, and this is the best sequence to really detect disc herniations because we can see where the disc is displacing the thecal sac. So, good for looking for oedematous changes. Now, something to realize is that T2 pictures are not quite as high-resolution.

In comparison, I am going to do a live demo that'll make a little more sense for this. Other pulse sequences, proton density, PD. Now with proton density, a proton density is a hybrid of T1 and T2. W

hat that means is it is not great for fat and it is not great for fluid. What it is great for, are tendons ligaments, and fiber cartilage, and it is really high resolution. So where I spend the most amount of time looking at proton densities is really when I am looking at knees or I am looking at wrists and I need to evaluate for meniscal injuries. It is also really great for tendons and ligaments. So and we'll see that in a little bit, but just as a quick demo, so notice T2 I can see a meniscus, but the resolution isn't fine. Over on a proton density, now the meniscus is really jumping out at me, but on a proton density, things like an effusion, do not jump out at me because it is not bright. We can see where this patient has a suprapatellar effusion.

What about gradient-echo? Gradient echo, not getting into physics on this, but when we look at gradient echo, what a gradient echo is really strong for is showing a T2 effect with much higher picture quality. So, when I am looking for small structures, I want to look at a gradient echo. So where are gradient echoes really used? Small extremities, and I always want gradient echoes on wrists and ankles and hands and feet. We also see it in the axial cervical spines. So axial C-spines will generally have a gradient echo done because that lets us see those smaller cervical nerve roots.

Another major pulse sequence, fat suppression techniques. There are a couple of different terms that you will hear thrown about when it comes to fat suppression because of one of the problems we run into. So, I am going to back up a few pictures, if we look at this spine. So T1 here, T2 here. We know that T1 is good for looking at fat. T2 is good for looking at water but notice that on both the T1 and the T2, the subcutaneous fat is really bright, again without getting into physics, that is a problem. So sometimes what we want to do is we want to make sure that we kill the signal from fat. And we kill the signal from fat and what that does is it really highlights any kind of oedematous tissue. As we start looking here, we are looking at a T1 and a stir coronal on a knee. This is a patient who has a tibial plateau fracture. Notice we can see the oedema much better here on the coronal stir. Now it is not a high-resolution picture, but I can see it better. Because here's a thing, I can see this on the T1, why are we so worried about this? Because neurology, one of those things that we understand from a neurologic standpoint of the neurology of visual and visual detection, human eyes are naturally drawn to bright, shiny objects. So our eyes see bright things better than they see dark things. Because of that, these stir sequences really help the oedema jump out at us, even though I can see oedematous change as a darker signal on something like a T1. And it also helps us characterize what kind of tissue something's made of. Now, we have already seen this patient. We saw this patient in the first hour, they were complaining about a mass in their lateral thigh. An x-ray was done and on the x-ray, there is air, fat, water, bone, and metal. It is a fatty density superimposed on the area, the vastus lateralis. Well, when we go to MRI, so we are looking at an axial T1, and on the axial T1, there is the mass, it is got a lot of fat to it. Then on a coronal fat suppression sequence, we can see where, fantastic it suppresses, it is got a huge amount of adipose content. It is an important thing for this one because what do we think of when we see a fatty lesion? We think lipoma. Well, except there is also liposarcoma and various other soft tissue fatty tumours. Well, the fact that this has so much pure fat too, really helps confirm that I am dealing with a lipoma and not a liposarcoma.

Video Placement: 27:40

It is now time to look at a live DICOM demonstration to show you some of these things live time. I have pulled up a lumbar spine MRI. Recommending that you have your own DICOM viewer for you to pull these things up, and I am not going to get heavily into how to interpret these, but just as a light version thereof. We can see over on the left side, that as we are looking at the MRI, we have got all the different pulse sequences, and this one's nice enough to label things for us where T2, T1, and so forth. When I start looking at spinal MRI, I only use imaging centres when I am sending patients for spinal MRI. I only send them to centres that will do a stir sequence in the spine because I want to make sure I see that oedematous change. As I am scrolling through, I can see, well, okay, everything's really dark except for the CSF column and some blood vessels. In this particular case, as I am evaluating this patient, looking at this MRI, one of the things that I can see very nicely, and one of the things that these fluid-sensitive sequences are good for, everything lining up the discs looks okay. Suddenly, right through there, there is some disc material. The stir is specifically designed to look for oedematous change. We are not going to see usually oedema around most disc herniations, but I am looking for fractures and things like that.

Kick over to the T2. Now, you can see it is a lot brighter and on the T2, again, this disc herniation is showing up very nicely. Now, something to be aware of in this particular case is that this person does have a lumbosacral transitional segment. You might have heard the terms, lumbarized or sacralized, we try to get away from those terms, to be honest with you, it is better to describe these as transitional segments. But this person has a disc herniations level above the transitional segment. When we look at T1, T1 is really designed to look at that marrow fat. We can see the epidural fat very nicely as well. And then kicking over to the axials, on the axial T1, do not forget we have to look at all the other structures. We can see kidneys, aorta, vena cava, and so forth. But I am usually looking at the epidural fat. I am looking at the muscular integrity of the paraspinal muscles, fatty infiltration of the multifidi being a very common thing to see. If I am looking for disc herniation, I do not spend a lot of time on that T1, just scanning really quickly. I spend more of the time on the T2. Now, some things to be aware of as we are looking at MRI, pulling a three-up window view here, do not forget to zoom in and zoom out. Remember

to move the images around so that they are where you want them to be. Get them into the centre of your window view. Do not forget that you can also window and level these images to make sure that they are not too contrasty, so play with these features. You cannot save changes to the native DICOMs, they are always going to be preserved, but you can save things as layers. So play with the images, and as we are looking at this, we look at the axial of course. The nice thing with digitals is the little line will tell us exactly where we are. It is called a localizer line. We know that we want to spend the most time looking at that L4 L5 disc. So, we get down through here, and we can see there is that protrusion. It is starting to narrow the lateral recess right through here. Fantastic. The other thing that we notice when we are looking at this sagittal, notice that there are some marrow changes as we are looking at the vertebrae, there are some marrow changes.

I'll talk about this when we get into the spine is this person has something called a modic change. By looking at the T1s and the T2s, I know that this is a type two modic change, which has almost no correlation with symptomatology. It is an incidental finding. But those are our different starter pulse sequences, T1, T2, and stir sagittal axial. Some other pulse sequences, one of the places that we'll see another important pulse sequence, I am going to pull up a C-spine MRI. As we look at this C-spine MRI, I am going to pull a two view window just so you can see the sagittal. This person has some pretty interesting, gnarly-looking disc herniations plus some congenital stenosis. As we look at the axial on this one, one of the things to realize about this axial is, that this axial is what's called a gradient echo. Normally we think about T1 and T2, the problem with T2s in the axial plane is they do not give us the resolution we need, but as we look at a gradient echo, and notice it on this gradient echo, I can actually see the dorsal and ventral rootlets that come together to form the cervical nerve root. So, we get a much higher resolution for structures.

We need to see if there is no flow void artifact created. One of the problems with T2s is because CSF moves and T2 is a long pulse exposure. We run into the same problem, we run into with cameras with long shutter speeds is it can blur things out. But in this case, I can see the CSF very effectively. I can see disruptions in the CSF column for this patient and their fairly large disc extrusions. Then again, we can start to see dorsal and ventral rootlets in the lateral recess in the C Spine. So that is gradient echo.

Now, the other major pulse sequence that we are going to talk about is proton density. Now we do not really do proton density in the spine because we do not want that hybridized T1 T2. We are not so worried about the fibre cartilage. We are not so worried about the small ligaments in the spine. We see this more used with the extremities when we are talking about proton density.

As I pull this one over and we look at the knee, I am going to pull up a side-by-side comparison, called a two-up window, T2 is over on the right proton density, fat-suppressed is on the left. So PD, so it is not good for fluid. It is not good for fat. It is great for fiber cartilage and then you fat suppress it and it makes it even better. As we pan through, so we are starting on the lateral side because you can see the fibula and we are scrolling in, and I am looking in the areas of the menisci. I am coming all the way to the medial side, just so we have a normal. When I am looking at this T2, I do not see the menisci really well because the hyaline cartilage and the fiber cartilage have a similar signal. I do see that this person has quite a bit of oedema in their knee, but I can see the menisci over here on the proton density, I can see those menisci very effectively, posterior horn and anterior. Now, as I scroll through, there is the PCL, there is the ACL. As we come out to the lateral side again, I do not see the menisci really well when I am looking at the T2. But as I look at the proton density, I am really not seeing much posterior horn at all. But one thing I do see is I see there is the anterior horn and there is the posterior horn in the anterior compartment of the knee because this patient has something called a flipped bucket handle meniscus.

So those proton densities, we use heavily in the extremities to look at fiber cartilage, tendons, and ligaments, shoulder studies, wrist studies, knees, and ankles. That is where we are going to see a lot of PDs. Generally, we are also going to see quite a few gradient echoes. In this case, there is also a proton

density for the axial. To pull a single up, and what this is also letting us do, is it is letting us evaluate the hyaline cartilage. As we look at that patellofemoral joint. So, I am going to close out these other windows and take us back to the PowerPoint. So, that was our live DICOM demonstration. Other things that we need to be aware of when we started talking about MRI is one of the questions that is often asked if your office is scheduling the MRI or, you know, when you are sending off a referral letter for request, do we want contrast? Gadolinium is the contrast agent that is used for MRI and it is a very safe material. The big times that we are going to be ordering contrast, first, we have to realize there are two kinds of contrast. There is intravenous contrast and there is arthrography contrast. So that is a question. When do we do these? Well, we start talking about doing IV contrast if I have three big things on a differential list, tumors, infections, or if I am dealing with someone who's had back surgery and I am worried about them having a recurrent disc herniation.

Arthrograms are designed to look for cartilage defects, particularly the two big times I ordered an arthrogram shoulder labrum, and the acetabular labrum. Those are my two biggies. We can also do it in the wrist if we are looking for subtle TFC injuries or for some of the small ligaments of the wrist being injured. But the big two are going to be shoulder and hip. I'll usually order those as arthrograms because it increases my sensitivity drastically. Now, silly little pneumonic, because radiology's full of them, contrast goes where blood flows. What do we do a contrast for? We are looking for vascularized tissue from an intravenous standpoint.

This is a patient who has had previous back surgery and the person is getting recurrent back pain and ridiculous symptoms. Then the question was, well, did they herniate another disc, or do they have excess scar tissue formation? Well, so when we are looking at contrast, this is the T1 pre-contrast. This is a T1 post-contrast. Notice how all of this is much brighter when we compare it against the pre-con T1 that is because that is all highly vascularized scar tissue. This is a patient that had the unfortunate consequence of developing epidural fibrosis. They got a lot of epidural scars after they had their back surgery. That is where this really comes into play is being able to look for things like that. On tumors and on infections it helps us with the vascularized tissue as the body's responding to those lesions. Arthrograms, now conventional arthrograms, do not really do conventional arthrograms anymore. Normally, we might still see these pictures because they are using fluoroscopic guidance to make sure they get the contrast into the joint capsule but this is where I am looking at the arthrogram is on the MRI. So, they flooded this person's shoulder joint with gadolinium and it would let us look at things like the labrum more effectively. So, there is the posterior labrum. This person has a defect in the anterior labrum with a thick rope-like middle glenohumeral ligament. As we start looking at this one, this person has a Buford complex.

It lets us see some cartilage defects much more effectively. Things to realize, we put contrast on board. Contrast, gadolinium is generally considered a very safe agent. However, if somebody has decreased renal clearance, you are not going to get gadolinium. Gadolinium is excreted in the urine and if the person has renal insufficiency, they cannot excrete the gadolinium. It can build up in tissues and in a very small percentage of people, 2.4% of patients that have MRI gadolinium, they can develop something called nephrogenic systemic fibrosis which is a reaction in the body that can result in some pretty drastic consequences. Anybody that has renal clearance issues, they are generally not going to get an MRI contrast. How do we figure that? You get labs. You are going to look at glomerular filtration rates. You will look at creatinine and different imaging centres will have different protocols in place, and they'll look at those things. We also try to avoid using this on pregnant patients, because again, we are also being careful about what medications are put into pregnant patients. Now, things to be aware of with MRI, do not do an MRI of a joint replacement, and I'll be honest with you doctor, the number of times I have had one of these things come across my screen where this patient had a total knee replacement and they were having pain afterwards. Then somebody ordered an MRI, and all I can tell is that there is a giant black hole because the titanium doesn't show up on the MRI. It just creates a large signal void. Again, things like pedicle screws, disc replacements, and interspinous spacers, I can work

around all of those. There are pulse sequences. There are artifact-diminishing things that we can do with MRI but we still cannot do an MRI of a replaced joint.

The other thing to be aware of when we are dealing with MRI is, that MRI is very sensitive to motion. The more the person moves, the greater the probability we are going to have a lot of jitteriness in the pictures. So that is something you just got to be aware of and we might have to work around. Now, how about CT? Computed tomography? It used to be called CAT scans. We do not call them CAT scans anymore, mostly because I think the veterinarians got tired of all the CAT scan jokes. So, CT computed tomography, the real reason we do not call it CAT scan is, that the old term was computed axial tomography. While the images can be acquired in the axial plane, they can be reconstructed so it is not just axial anymore. When would we do CT instead of an MRI? Well, why CT versus MRI? One is it is more widely available. MRI centres, and MRI imaging units, are harder to get into., as they are more tightly scheduled, and regulated as far as you know, particularly with their third-party payers. CT is cheaper. It is more readily available. Because of that, it is sometimes easier to get a CT. There are times when a CT and an MRI are pretty much interchangeable, like for a lumbar spine to rule out disc herniation. CT is 95% as good as an MRI.

Video Placement: 42:47
What else? Why else would I get a CT? Beautiful high-resolution for bony structure, particularly difficult to visualize the bony structure, posterior elements of the spine. The pelvis is an amazingly complicated piece of anatomy. It is fantastic for looking at some of those complicated structures. Or if I cannot get an MRI, I got somebody who has a pacemaker. I got somebody who's claustrophobic. We can get a CT. Now the downside of CT, this is a high dose. When we start looking at a CT versus an x-ray, a CT can be anywhere from 10 to 20 times the radiation dose, or even higher than a comparable x-ray can be. So, that is a problem. We try to avoid that dosing as much as possible. And not as much as in a chiropractic setting, but in an emergency room setting. It has been demonstrated to be grossly overutilized because they got emergency room doctors that just automatically CT everybody, everything. So, because of that, there are some protocols that are put in place to try to diminish CT use. We'll talk about that when we are dealing with our head trauma section.

Now, there is radiation involved, and this is a relatively high-dose study. We try to be cautious about who we CT and how often we CT. The nice thing is the tunnels are bigger, claustrophobia is not an issue. Obesity is not as much of an issue because it is a very short tunnel. If we were to go back and look at the original picture, you have got a much more open field of view. You do not nearly have the claustrophobia feelings there. Great bony resolution cannot emphasize that one enough. Anytime I am looking for a posterior element fracture, if I have got somebody who's had an extension injury and they got focal pinpoint tenderness, I know I am going to be getting a CT because the x-ray is great, but it doesn't have the resolution that CT does.

Let us look at some CTs. So, as we start looking at CT scans, so things to be aware of with CTs, much like MRIs, T1 and T2 waiting's. CT is CT is CT, but we can change our windows to see things differently. Like right now, as we look at this midsagittal, we are looking at what is called a bone window, but I could change this over and I am going to use abdomen. Now, this creates more of a soft tissue window, so I can see soft tissues a little more effectively. It is not as good at distinguishing soft tissues as an MRI, but it is still a very functional and effective tool. Taking over the bone window on this one, this is a person who had a motor vehicle collision. With that, they had an extension mechanism. They were having focal pinpoint tenderness. The x-rays were equivocal, did not really see anything on the x-ray, but as we look at the CT, we can see right through here, that there is a fracture in the articular pillar. And you can tell that that fracture is so small and subtle. What is the probability we would see that on an x-ray? This is something called a reconstruction. The images are required generally in the axial plane. The axials are of higher resolution. So, we are going through the skull base. We can see sutural changes there getting into the soft tissues. There are the dens coming down into C2. We can see all this bony detail. Do not forget

to zoom in. Do not forget the window and level. Now, we can see that fracture extending through the lamina, into the pillar, and then even fracturing through the pedicle. So, something that we would very likely not be able to see on x-ray, but with the degree of pinpoint tenderness on physical exam.

The reconstructions can be done in the coronal plane, the sagittal plane, they can even reconstruct them in the three-dimensional plane. As we start looking at these structures, and again, the sagittal in this case, we can really see very nicely that fracture extending through the articular pillar. I am a big one, anytime I look at CTs, I will not look at just axials. I need axials, coronal's, and sagittal to make sure I am evaluating things from different planes. So, they acquire it in the axial and then the computer reconstructs things put everything back together and then slices it the other way. So one thing though with CTs, we know it is great for bony resolution, but notice that even if I were to kick over to a soft tissue window, which is the abdomen, in this case, I cannot see discs very well in the C-spine. And it is because there is not much epidural fat up against the discs when we look at a C-spine. But if we look at an L-spine, that is going to be something else altogether.

As I kick us over to a lumbar spine study. Looking at the bone window, as I am scanning through the bone window, looking for fractures, things like that, I noticed this person does have a defect in the area of the pars interarticularis, it has nicely corticated bone, so this is a longstanding pars defect. But one of the things that we can see when we are looking at a CT, particularly the lumbar spine, a lumbar spine CT is as almost 95% as good as an MRI because there is much more epidural fat, which gives us good contrast between tissues. In this case, as I look at this, now it is subtle, but one of the things that I can see is that this person has a very large disc extrusion there at L4 L5. I cannot tell that in the C spine as well, because again, in the C-spine, there is not enough epidural fat to get good contrast. Now, between tissues, but as I am looking at a lumbar spine, it is a great way to be able to evaluate for disc herniations. I can see that as I am looking at this axial soft tissue window, as I am going down through the spine, I am also seeing kidneys and I get down into L4 L5 and right there, I can see that very large herniation that is impinging on the thecal sac.

The other thing that is well seen when we are starting to look at CT again, going into the bony detail. Scanning through the shoulder of this particular patient as we are coming down, I can see the shoulder. I do not see much into the lungs. I can see the thoracic cage. The shoulder itself is looking pretty good. And then as I start getting a little bit lower, we have got a patient who has a rib fracture. They are complaining about shoulder pain, but it is most likely in this case, it is referred pain from those broken ribs. Now, the really nice thing is we can also change our windowing and levelling, and this is a shoulder study, but suddenly, I can kick over here, and I can see the lung tissue and make sure that there is not actually a lung problem that is referring over to the shoulder as well. That is one of the benefits of CT. Normally, we think about CT as a bony modality, but CT is also the gold standard for evaluating chest and abdomen pathology. You can see the detail that we are able to visualize in the lung field, just by clicking a button. That is CT and MRI. What else does CT is used for? CT is also great for the brain and one of the big questions, so I have seen brain CT and I have seen brain MRI, which one do I want? I am going to talk about that a lot more in our next hour, as we are dealing with imaging of face and head trauma, one of the big concepts, just as a quick preview, less than 48 hours, CT, over 48 hours, MRI. That is kind of our general rule. If I need it fast, if I need it, you know, I am worried somebody's got a bleed, whether they have had head trauma, whether I am worried about a stroke, anything along those lines, we go to CT. It is a faster acquisition. That is great for acute blood products. On MRI because it takes an hour to get a brain MRI. We do not want to spend an hour if somebody's got a stroke. So those good strokes go to CT. Once we start getting into the more subacute and chronic brain, that is where we get into MRI. With CT, we can also put contrast on board, and again, just like we saw with MRI contrast goes where blood flows. It is great for evaluating blood vessels, evaluating the vascularity of a lesion. However, we start running into the same problem of it having to clear through the kidneys. If the kidneys are not working, you cannot put IV contrast on board, unless you have got some way to help flush things through, if that person's on an IV, somebody's going to have dialysis.

Other things to be aware of when we start talking about CT contrast, is somebody who has a history of an iodine allergy or shellfish allergy, generally, we tend to be very cautious about putting CT contrast on board, because it is an iodine-based contrast agent. Now, this brings us to our next imaging modality and adds ultrasound. I am not going to do any live DICOM demonstrations on ultrasound. Now, normally though, when we think about ultrasound, we usually think of a baby's blood vessels. One of the things we are seeing is a huge cutting-edge field in musculoskeletal healthcare is musculoskeletal ultrasonography. We are seeing where ultrasound of the musculoskeletal system is fantastic for superficial structures, evaluating rotator cuffs, and looking for medial collateral ligaments in the knee. It is an amazing tool, and we are seeing a huge amount of work being done these days in musculoskeletal ultrasound. One of the problems is, that it is an incredibly steep learning curve. It is hard to learn musculoskeletal ultrasound and be good at it. While you might be ok, it is hard to be really good at it. Make sure that you have got good quality equipment and not something that you bought for 99 dollars off eBay. But this is one where musculoskeletal ultrasound, does not much application in the spine, it is predominantly in the extremities. And this is where working with a centre that has a musculoskeletal ultrasonographer and a musculoskeletal radiologist will really get you the best possible applications. The other place where we see this done a lot, and it is really not so much of an issue here from a sports imaging perspective, it is also cutting-edge in rheumatology. It is one of the things that rheumatologists will use to evaluate pannus formation and rheumatoid arthritis in response to medications.

Video Placement: 53:30

The next imaging tool is scintigraphy. We are talking about something that makes the patient scintillate. They give off little glow little lights. Well, when we talk about scintigraphy otherwise known as nuclear medicine, what we are usually talking about from a musculoskeletal standpoint is the bone scan. I am not a huge fan. I do not order bone scans very often. It is not a common follow-up for me. I do not read bone scans because I am not specialized in nuclear medicine. It is got applications, for me, what I perceive as limited applications. We are talking about this person is injected with a radio-pharmaceutical, most commonly technetium. Sometimes technetium depends on pronunciation and tech goes to osteoblasts and it is a way of assessing metabolic activity and bone. The really nice thing about a bone scan is it is incredibly sensitive. It only takes three to 5% destruction before something shows up on a bone scan. Because of that, it is much more sensitive than an x-ray for things like metastatic disease and infections. It also allows us to visualize the entire skeleton at one time. It is great for, you know, polyostotic diseases like Paget's disease. If my person has Paget's and I want to see if is it in one bone or is it in all, you know, how many bones are involved? Great tool for that.

There is the three-phase bone scan. All bone scans go through all three phases, but they are only scanned in certain circumstances. The big-time that the three-phase scan is going to be ordered. Not something that we see as commonly from a sports perspective, complex regional pain syndrome. If I am worried about somebody having CRPS, which used to be known as Sudeck's atrophy and used to be known as reflex sympathetic dystrophy syndrome. A three-phase bone scan is the diagnostic tool of choice for that because there is a blood component to those a vascular component. Three-phase scans are used for that. Bone scan, what's our big indicator? High sensitivity, three to 5% bone destruction, whereas it takes 30 to 50% for radiographs. When I am looking for things that can be very subtle, we know that infections have a long radiographic latent period. We know that, is this a tumour? Is this a stress fracture? Those are some of the things that we can be talking about. I mentioned before the person had a knee replacement who had an MRI of the knee replacement. Well, really, you would've been better served to get a bone scan on that one to see if there is loosening in the hardware.

The benefits, are incredibly sensitive. Three to 5% destruction. The downside is having low specificity. It doesn't generally tell you exactly what something is. It tells you there is something going on and it can have some degree of specificity, but there are still a lot of questions. When do I recommend bone scans? The big time is if I am concerned about metastatic disease. If I see something lytic or I see something blastic in an older individual, you know, 45-50 being my thresholds, I'll order a bone scan to

assess metabolic activity and to see disease burden. Well, in this particular patient, the person was missing a pedicle in their T11. They had pretty much their entire torso x-ray and the only thing wrong was the missing T11 pedicle, but a bone scan that was performed the next day shows that this person actually has 13 sites of osseous metastasis because of that difference in sensitivity between x-ray and bone scan. This is an athletic patient who is complaining about foot pain. In most cases, you know, if we are worried about this being a stress fracture, we get negative x-rays on day one, we treat it as a stress fracture and see, you know, maybe then we can do some follow-up x-rays. This was a high-grade athlete where knowing the diagnosis was really important for return to play. The x-rays were negative on an MRI. It shows that there is focal uptake in a metatarsal neck, consistent with a fatigue fracture. To be honest with you, I would rather get an MRI in a case like that, because with an MRI, it'll tell me if it is a bone, you know, is there a fatigue fracture, or is this a soft tissue injury? The bone scan wouldn't give me that information. This is one where this is an application where I would recommend a bone scan. This is an adolescent patient who's athletic, they have got insidious onset leg pain and it wasn't responding to care. They ended up taking some x-rays, the pain had been there for several weeks by this point in time. One of the things we see on this one is there is this focal cortical thickening on the posterior aspect of the tibia.

When we are dealing with an adolescent, fatigue fractures slash stress fractures, are very common in adolescent patients. But one of the other things that particularly likes the lower extremity and can have an insidious onset of pain in an adolescent is an osteoid osteoma. This is an incidence where the bone scan was actually very useful in confirming that this was a stress fracture and not actually an osteoid osteoma and there are some applications. Just not something I would order on a regular basis. One thing that we also see with bone scans is kind of the next gen of a basic bone scan is something called a SPECT, single photon emission computed demography. This is a bone scan combined with CT-style imaging. We are getting sectional imaging, and what it does is a SPECT scan is more sensitive for getting into the vertebral structure. If we really need to, I look at a bone scan, I see a bright spot. Is it in the body? Is it in the pedicle? Is it in the facet? That can be a difficult call by going to SPECT scanning, I can section through. For a while, into the 80s, and early 90s, when we were dealing with the adolescent athlete who had back pain, and we worried that they had a fatigue fracture, or stress fracture in the pars interarticularis, the recommendation was for a SPECT scan because a SPECT is 10 to 20 times more sensitive for a fatigue fracture than a bone scan. We do not really do it anymore. We would rather get the MRI because the MRI shows us the same information without the radiation dose. But just to show you what I am talking about, as far as SPECT scanning, you can see where we are looking at bone scan style imaging, but it does have that ability to section through the patient starting very far back, moving more forward, and we can see where the areas of the pars interarticularis are lighting up. I would have much rather got an MRI. We'll talk about this a bit later, too.

Video Placement: 1:00:30

The last of our imaging modalities that we are going to be covering in this class is the **DEXA scan**, dual-energy x-ray absorptiometry. What a DEXA scan is if you have had your patients coming, "Oh, I had my bones scanned and they told me I had a bone density of a 20-year-old." Well, you did not have a bone scan. You add a DEXA scan. A DEXA is a way to quantify bone density and it is accurate and it is reliable, and it is valid and it is a fantastic tool. It is much more accurate and reliable than x-rays. It is still an x-ray tool, but it is hooked up to a computer and it is kind of fancy. When we are looking at this, DEXA is kind of the gold standard for evaluating bone density, and really it should be in the spine and hip because when we start looking at, okay, what kind of things? Why do we test bone density? We are worried about osteoporosis. What are we worried about? What's the downside of osteoporosis? Spinal fractures, and hip fractures, because they have high morbidity and mortality associated with them. The DEXA scan is what we use to assess bone density. It is a good way of getting fracture risk. There are some other tools, quantitative CT, and quantitative ultrasound, but we do not see those used as widely, DEXA is much more commonly used. It is a very low radiation dose. It is about one-tenth of a chest x-ray, which is really minimal radiation dose.

You may see people who are involved in exercise physiology and that sort of thing, DEXA scans can also assess body mass index. I believe it is more reliable than caliper methods and that sort of. What we are going to get when we order a DEXA is we get some grainy pictures and a graph and more importantly, tables. When we start looking at the tables, the tables give us the numeric values for a person's bone density score. Notice that we are given two scores. There is T-score and a z-score. What are these different things? One of the ways to remember, T-score and z-score, T-score compares your patient against teenagers. An important thing with DEXA scans, these are always going to be gender and race matched. But the T-score compares your patient against teenagers. The Z-score compares your patient against other patients of the same age. Also, gender and race matched.

Generally, most of the time we are talking about post-menopausal or senile patients and that is where we are concerned about post-menopausal or senile osteoporosis. That is where the T-score is really important because it gives us the fracture risk. We do use the Z score in a very small subset of populations. If we are dealing with younger folks, so men under the age of 50, premenopausal females or kids, and again, one of the places where this can be applied is, we are thinking about the hardcore adolescent athlete where we are starting to see this child is not maturing the way they should. We are getting the female triad of amenorrhea involved with exercise and you know, how is their bone density? We would be using the z-score in that population. Generally, however, the T-score is what we are going to talk about, and the number that we are given is a standard deviation from normal. What we are looking at is, plus one to minus, one is normal because that is a standard deviation concept below minus one we start to deal with diminished bone density, minus 1 to minus 2.5, osteopenia, less than minus 2.5, osteoporosis, less than minus 2.5, with a history of fragility fracture is severe osteoporosis.

These are defined for us by the World Health Organization. The T-score gives us that fracture risk, and as the number goes down, we see an exponential increase in fracture. Minus one, there is twice the risk, if minus two there are four times, if minus three there is eight times the risk. With the younger patients, when we are dealing with the z-scores, so males under 50, children, and premenopausal females, that is where minus 2.0 is our threshold between normal and abnormal.A little bit of a difference there.

That finishes off this second hour in talking about imaging modalities. Next lesson up, we will be talking about head trauma.

[END]