ICSC IMAGING Module 3
Section 4_ICSC03
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Video Lesson: 1:08:01

Welcome back. We are going to spend the next two hours talking about imaging spinal injuries. It is broken down into two one-hour sections. As we start dealing with spinal trauma, one of the things that are the major core concepts are the major tenants. When we are dealing with spine trauma, you need to understand two different things. **Number one, mechanism of injury**. How does this particular fracture, dislocation, injury happen? That way, if we know what kind of sport the person was playing, how did they injure themselves during that particular sport, those are the things that we can use to try to figure out, "What am I looking for?" If we see somebody who is playing basketball, they go up for a shot, somebody takes their legs out from under, may land on their neck and shoulders and hyperflexion and rotation. Well, I am going to be thinking about one particular type of injury. If I see somebody who they have a hyperextension, pick on bobsledding, the sled happens to roll and the head goes into hyperextension when the helmet catches the ice, "I am going to be looking for a different set of injuries." We look for that mechanism that really helps inform what might be going on with the patient, and of course, sometimes it happens really fast we might not know exactly what is going on.

The second thing that we need to be aware of with all these different injuries is the concept of instability. Is an injury stable or unstable? Now, again, not a big slide reader but definitions, you have to read those. For instability, the injury creates a potential for additional biomechanical or neurologic damage, in particular, we are dealing with spine. What we are concerned about is their cord involved or is their cauda equina involved nerve root and that sort of thing. Knowing which injuries are stable and which injuries are unstable, is a very important concept to make sure that the person is getting managed appropriately because typically, when we are dealing with somebody who has a potentially unstable spinal injury, those are the patients that are going to be back boarded, collared, and transported to the nearest emergency department? Somebody who has a stable injury, maybe that might be a more casual or urgent at least, referral to a hospital, orthopedic, and so forth. Being aware that the unstable patient is one that does generally need to be transported is a core concept, and when we look at some of these different injuries, some injuries are just by the definition of this person has this injury, picking on burst fractures, chance fractures, things like that, those are by definition unstable so we treat them that way.

The other thing that we have to take into account is, when we look at those are more bony injuries, the fractures, there is the potential for ligamentous injuries. With the ligamentous injuries that we see where there is no associated fracture, particularly things like cervical spine, facet Joint capsule injuries, they tend to let the spine move too much. Not so much in the acute phase where the person is going to damage their cord right then. But more in the okay, as they are healing and there is too much motion, we are going to see accelerated degenerative changes. That is going to create its own problems. There is potential for damaging neurologic structures, again, not so much maybe in the acute phase more in the chronic phase. This is where being able to recognize, are there any findings of ligamentous injury is a very important thing for us because when we are trying to identify that ligamentous injury, what do we look for? C-spine is where we are really talking here. Thoracic spine, ligamentous instability is uncommon, lumbar spine, ligamentous instability is uncommon. It is more of a C-spine finding than anything else. That is where we are looking at neutral radiographs, if you see angular kyphotic deformities, it is always a concern that has this person damage some of that posterior ligamentous complex. Then we will do stress radiographs. Stress radiographs are kind of the core for looking for ligamentous instabilities and that is where we are going to be evaluating for translational or angular motion. This is like I talked about in the first hour of the trauma classes. We will look to see is there a 3.5 mm of translation C-spine, 4.5 mm of translation in the lumbar spine, and then angular motions.

When dealing with spinal injuries, one of the predominant theories that is used currently to assess is an injury stable or is an injury unstable because it answers most of the questions to the best of their ability, is the three-column theory of Dens. With the three-column theory of Dens, it was written for the thoracal lumbar spine but it is since been extrapolated into the lower cervical spine. Of course, it does not work for the C1, C2 complex. Of course, we are dealing with more complicated areas there, but anywhere C3 down essentially is where this is being applied. We break the spine into three columns. There is the anterior column, which is the anterior two-thirds of the vertebral body. The middle column, which is the posterior one-third of the vertebral body, and then the posterior elements, which of course, is pedicles backwards. The way that this theory works is when we look at these columns. If somebody has a one-column injury, it is generally a stable injury. If it is two or three columns, it is unstable, and really there are going to be some exceptions to these rules because there are also some things that involve soft tissues that we do not see, we cannot see the soft tissues, but we know the soft tissues are injured. We will talk about those a little bit. One column that is a stable injury, two columns, unstable injury or more, if it is two or three.

Asterisk. One of the first asterisks is that you cannot injure just the middle column. From a physics standpoint in order to enter the middle column, you typically have to break the back or the front as well. If you see what appears to be an isolated middle column injury, it is probably not. There are of course, some more exceptions. One of the big exceptions for that middle column is the traumatic posterior limbus bone that is considered a stable injury, and then if we see anterior column disrupted particularly, when we start looking things like compression fractures, if there is more than 50% loss of anterior body height, that is an indicator that it is probably unstable.

There are things that we need to be aware of when we are interpreting the imaging on these that create some of those subtle nuances. Just like it is possible to have a one-column injury that is unstable, if you look in- and this is where we are getting into the C-spine. When we look at the cervical, a teardrop fracture. Teardrop fracture typically only involves the anterior column. However, because there is so much ligamentous disruption around the other columns, it does create instability. So, let us start working our way from the top down, cervical spine, and we will go on from there. If we are going to start in the cervical spine, the best place to start is C1. When we look at C1, there are two major fractures in C1. There is the Jefferson fracture and there is the posterior arch fracture.

With the Jefferson fracture this is where mechanism is really an important thing to figure out what is going on with your patient with the Jefferson fracture. The Jefferson fracture is an axial load force, something came down straight through the top of the cranium and it pushed the head down because as that force comes in through the top of the head, what we are going to see, so force is coming down this way. As the force comes down because we are seeing that lateral angulation of the lateral masses, well, as the force comes down and then goes through the occipital condyles, it is going to put a natural force pushing those lateral masses sideways. They don't go sideways. They are held together by the anterior arch and the posterior arch. What we will see in this case though is the anterior and posterior arch fracture and that allows the lateral masses of C1 to spread out. This is a C1 burst fracture. It is blowing outwards. Now, the problem with most Jefferson fractures is we do not actually see the fracture lines, the anterior and posterior arch fractures can be very difficult to discern radiographically. The most important feature when we are looking at this Jefferson fracture, is if you look at the alignment between the lateral masses of C1 and the lateral edge of C2 is that there's overhang, and anything more than two millimeters of overhang is an indicator of potential problems, and if whether it is on one side or both sides, because it is possible to have a unilateral Jefferson versus a bilateral Jefferson. If I see that overhang, that is going to be something that I am going to consider is an instability until proven otherwise. This is a great case where we are going to want to follow up with a CT scan. CT giving us that bony resolution in the axial plane really lets us evaluate the bony C1 ring, and if we are careful about the communicating with RCT technologists, we can also make sure that they angle the Gantry in the CT

machine, to make sure that they are in the same plane as C1. There is one of the problems you know, you get someone who is laying on a CT scan. The C1 might be angled like this and because of that, when they're slicing in a regular axial pattern, we might not be able to see the entire C1 ring at one time. But by angling the Gantry for some specific slices through there, we can really confirm the presence of a Jefferson fracture.

We look for that overhang of the lateral masses, and we can look at the paraodontoid spaces. Now, it is a thing to be aware of. **Paraodontoid spaces are highly variable**, there's a symmetry that is a normal development thing, so those are considerations. The thing is, you tend to think that, okay, well, why would I ever see one of these? It is unless I am on the site of the event. What is the probability that I am actually going to see this fracture? Well, one of the interesting things is, this is a classic mechanism that has a classic presentation and that is the positive Rust sign, where the person is holding onto their own head. They are actually creating their own stabilizing collar because well, I hold on to this and it feels better. Anytime we get to any post-trauma come in positive Rust sign, this is on our list of differentials, and I want to find out what was your mechanism of injury.

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The other important distinction on this is we talked about the other major fracture of C1 is the **posterior arch fracture. That one is a hyperextension mechanism**, and with that hyperextension, the posterior arch gets trapped between the occiput and C2 spinous and fractures at off. The nice thing is a posterior arch fracture C1 is considered a stable injury and six to eight weeks of fracture healing time. So big difference, in management when we are looking at somebody with a Jefferson fracture, this person is generally going to be put into a halo and they are going to be in that halo to try to see if this thing heals on its own short of doing a complete C0, C1, C2 fusion.

What else can be damaged when we are looking at the upper cervical spine? There is Jefferson fracture, posterior arch fracture, and now there is the possibility of the transverse ligament rupture. Typically, we tend to see the Dens break more often than the transverse ligament rupture, but transverse ligament rupturing is absolutely a possibility. What are we going to see, remember you can't see ligament on x-ray, so what is my clue? My big clue is, if the person has anterior translation of C1 with an increase in the atlantodental interval. If I start seeing those things, that is what is going to make me concerned that this person has a transverse ligament rupture. We do know that when we look at an interval, just I am looking at a neutral lateral radiograph and this person has an increased atlantodental interval. There are more than 26 differential possibilities here, could this be rupture, laxity, agenesis, down syndrome, Marfans, Ehlers-Danlos, radical reactive, scleroderma lupus spine angular, rheumatoid arthritis. There are all kinds of possibilities for creating upper cervical instability, but if I have a patient who has a immediately antecedent history of trauma, I have got to consider that this is going to be a transverse ligament rupture until proven otherwise.

There is a little bit of a saving grace on this one. This is an unstable injury because this person is rupture the transverse ligament, the concern is that as C1 translates forward, the posterior arch of C1. So, there's the spine angular junction. The posterior arch of C1 can trap the cord up against the dens creating something called the guillotine effect. How is it that somebody can have this injury and not have immediate cord injury because of something called Steel's rule of thirds. If we were to look drawn on the screen, we are looking at the inside diameter of C1, lateral mass, lateral mass. Here's the dens, and then back here is the spinal cord and I will give it that little **”H”.**

When we look at Steel's rule of thirds, the inside diameter, the ID of C1, 1/3 of that is taken up with dens. One third of that is taken up with cord. One third is taken up with CSF and loose tissue. As a ballpark average, the average dens are about 8mm **A to P**. The spinal cord at C1 is about 8 mm. That means realistically this person has about eight millimetres of anterior translation that can occur before

they generally start to impact the cord, and that is why we can see patients that have this unstable upper cervical complex actually go through and yeah, they have got neck pain and if you look on flexion, they are coming 7 mm forward but they still have not quite hit the cord yet. Steel's rule of thirds is one of those beneficial things and why folks that have these injuries are able to survive.

Now, looking at this from a radiographically view, here we see a patient. This is a neutral lateral and as I look at this neutral lateral, I look at this person's atlantodental interval, and we know the rule for the atlantodental interval 3 mm or less on adults 5 mm or less on children. 16 is the age cut-off between child and adult. We look at this one that ADI is definitely increased. One of the things to consider, if you have your own imaging apparatus, you can do the x-rays in your office. I never do flexion extension until I look at the minimal series because I don't want to do flexion extension if I already know the person is unstable, I am not going to push them into flexion extension if I don't have to.

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Another one, another injury that happens at C1, C2, and this one is very uncommon. This is rare as far as cervical spine injuries go. Atlantoaxial rotary fixation. You'll also see this going by a couple of different names. One of the less commonly used is Atlantoaxial rotary subluxation. Usually, fixation is the term that if you search the literature and find more of those. What we are seeing here is not surprisingly a traumatic injury, and this one has a rotational component to it. This person was injured when in rotation, and this is a partial dislocation. An orthopaedic subluxation where C1 is fixated and rotational in C2. Most of these are post-traumatic. In little children, when we are dealing with children, there is the potential for this to be post-infectious. You get a child who has an upper respiratory tract infection, and the organisms can see it into the adjacent tissues and the child can present with that same kind of appearance. This does have a very classic clinical appearance called the Cock Robin Appearance and what we are seeing is torticollis. This person is rotated laterally flexed and it is really painful. It is because if it is traumatic, there is this partial dislocation. If it is post-infectious, there is also a partial dislocation quite a bit of spasm involved in both of these cases, this is considered an unstable condition.

What am I going to see when I look at this radiographically? An important thing on this one that helps us distinguish the Atlantoaxial rotary fixation versus the Jefferson fracture. Notice that C1, C2 lineup laterally very nicely but a big deal on this person is look at the asymmetry of the paraodontoid spaces. So, marked asymmetry those paraodontoid spaces, that is one of our indicators particularly with the associated history, and this is when you have got to be cautious, because one of the things to remember is there are a lot of asymmetry in the paraodontoid spaces as a normal developmental phenomena. One of the things I look forward to figuring out is this actual rotation between C1, C2 or is this somebody who has got some just developmentally symmetry is to ensure you look at the size of the paraodontoid notches. In this person, the paraodontoid notches are pretty symmetric, and they have about the same side to side, but the paraodontoid notches or a paraodontoid spaces are not, so, we see that asymmetry that says, this is actually a true rotation. As we are looking at this one, just to show you what this looks like and then to show how much rotation there is, we are looking at a CT of the same patient. As we look at the CT notice, the person's head is fairly straightforward to backward, but we can see that C1 has pointed in that direction, so there is a substantial degree of rotation in this patient.

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The next injury is the Hangman's fracture. As we look at the Hangman's fracture, of course, somebody being hung is kind of the classic mechanism for this but that is not really what we are going to see in the modern world. The idea here is to for some of that useless historical information, the radiologists are fairly notorious for, when somebody gets hung, okay? One of the things that happen is there is a shear force that goes between the angle of the mandible and the occiput and that fractures through the pedicles of C2. When that happens, of course, then the weight of the body pulls down and it distracts

the cord and it ends up transecting the cord. There is an extension component when you hit the bottom of the rope, and because we don't see that many people with this occurring anymore, we see this more of the hyperextension. The person is extending, and now we are not going to get the distraction that we saw previously, so when we get to hyperextension, it fractures through the pedicles of C2.

That fracture through the pedicles of C2, creates an unstable cervical spine because there is complete dissociation between the body and the posterior elements and it typically lacerates the C2, C3 intervertebral disc. Because they lack the distraction component, these patients can be neurologically intact at the presentation again, this is going to be another patient for a positive Rust sign or somebody's holding onto their own end. The other thing is, that it takes a lot of extensions to fracture those pedicles, so it is very common to see other hyperextension injuries things as posterior arch fractures, which by itself would be a stable injury. We can also see things like extension teardrops.

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This is a nice example of the Hangman's fracture, this is an elderly patient. This particular individual was walking through her bathroom, and she tripped on a rug and she fell on her chin, caught the edge of the sink, hyperextended her neck, and she landed on the floor. She was still alive. She had problems getting up and moving around. She was found by some relatives, a couple of hours later, and the patient, not surprisingly wound up with a fusion. The idea in a case like this because of the instability, they will try to reduce the C2 body, will try to reduce the C2 body, and then drive pedicle screws through the posterior elements and hold everything into the vertebral body. That is a nice little segue into our next injury called a teardrop fracture. Teardrop fractures come in two flavors, there are flexion teardrops and there are extension teardrops. They are both unstable. That being said, realize there are even degrees of instability. The extension teardrop is unstable. The flexion teardrop is really, really, really, really unstable. The problem is, when we look at teardrop fractures, they really don't look like much because a teardrop fracture is a fracture of the anterior inferior body margin, and it is called a teardrop fracture because it looks like a little teardrop fragment.

We see this little teardrop fragment we can see that there's a small little fragment coming off the corner of the vertebral body. The extension teardrops are usually upper cervical C2, C3, flexion teardrops are usually lower cervical. But the idea being, with the hyperextension in the upper cervical spine, the A.L.L. “Anterior Longitudinal Ligament” transects and ALL also the body corner. Most commonly happens at C2 can happen to C3. You just lost you are A.L.L. That is a major stabilizing structure in the spine. Not surprising that this is unstable. When we see somebody that has a flexion teardrop which is the lower cervical spine in order to get the flexion teardrop, they tore the nuchal ligament, the supraspinous ligament, the inner spinous ligament, the ligamentum flavum, the joint capsule and the P.L.L. typically also last reading the disc and then taking off the corner. Not surprisingly the flexion teardrop is more unstable because there are more ligamentous injuries, and those patients typically also have concomitant cord injuries where you start seeing anterior cord syndrome.

Video Placement: 23:47

Things that are on your differential for teardrop fractures are limbus bones. Limbus bone is a developmental variant where we see the ring apophysis, never really united in. It’s got smooth all around a corticated margin as opposed to the fracture which is going to be sharp and jagged. The other thing that is on our differential list is an intercalary bone, where we see a small little calcification / ossification of the anterior annular fibers, but it is the annulus, it is outside the normal confines of the vertebral body, it is usually not too difficult to figure. As we work our way down the spine, of course, one of the very unique structures in the spine, is the dens, the structure that allows for so much rotation in our c-spines. Well, it is possible to break the dens and there are three types of odontoid fractures. The type one is an avulsion injury, usually, something is distracting the skull and the alar ligament avulses

the tip of the dens. The Type 2 Dens fracture is one that goes through the base of the dens. Usually, this is a flexion extension style injury and this is seen in a very high incidence in older populations because osteoporosis can contribute to this fracturing, and then type 3 is a fracture that extends down into the C2 vertebral body. Typically also starting to get into the facet. The problem with the literature on these is that they are stable or unstable. I want to know the mechanism; I want to know stability. Well, the problem with stability is its variable and depends on the degree. Type 1 might be stable, might be unstable, and type 3 might be stable might be unstable. Type 2 is always unstable. Well, what is the variable, the force of the trauma? There are a lot of other components to it and that is why when we are dealing with any of these, my safe bet is all of these are going to be treated as unstable injuries and I will let the neurosurgeon make those decisions.

When we start looking at these, type 1 is rare, type 3 is uncommon, and the most common type of odontoid fracture is type 2. What we are going to see in these cases, is it fractures right through the base of the dens or looking on the AP or open mouth radiograph to see it. On the lateral view, the biggest tell is if there's the displacement of C1 because we know C1 can go forward or backward when we are dealing with somebody who has a dens injury. Those are the big clue. The problem is this is a subtle injury. That is something that is easily overlooked on radiographs like in this particular case, this patient had a seven-view c-spine and the seven-view c-spine is really normal. We couldn't see any fractures looking at that. But the patient was in really severe pain as was an elderly patient in her 80s, she had fallen down, and she smacked her face on the floor when she fell.

Started off with a seven-view C-spine, and this patient was transported the emergency room. They did a seven-view C-spine, the clinician was really unhappy with how much pain there was, and the negative studies of the patient were sent for a CT. On CT, there is a subtle fracture right through the base of the dens. Interesting on this particular case is they forgot to take the patient's earrings off for both the X-ray and the CT and one of the problems were the earrings and the earlobes are right at the base of the dens, so they actually obscured things quite a bit and even created some beam hardening artifacts on the CT. It was questioned on the original CT and the patient had to have a second CT to confirm the presence of the dens fracture. The concern with these being they have a very high frequency of non-union. So, because of that, and that creates a relatively permanent instability or possibly permanent instability, these patients will quite often be fused but it depends on the patient and the outcome expected from surgery. In this particular patient's case, surgery is actually more dangerous than fusing your dens.

Video Placement: 28:03

The type 3 fractures one that extends into the body a little bit more. We can see here there is a Lucent line that is getting further down than just the base of the dens and don't forget the Mock effect creating problems when we are looking at the base of the dens, sometimes stable, sometimes unstable best to treat all of them is unstable. What else can we see fracture? Let us get into the lower cervical spine and this is where we are going to get into compression fractures. Compression fractures, when we start dealing with spinal fractures, these are incredibly common as far as spinal fractures go. How does it happen, flexion, and or axial load, and it loads the anterior body. In this particular case, this is a motor vehicle accident, so something considers from a maybe a racecar style racing sports standpoint.

This was a regular run-of-the-mill motor vehicle accident. What was interesting in this case is this patient was sent into my office for an outpatient x-ray and had ordered a three-view C-spine, two-view T-spine, two-view L-spine and a three-view fifth finger. The patient was complaining, "I don't know why I need all these x-rays. The only thing that hurts is my pinkie finger." So well, the doctor ordered all these. We are either doing all of them or doing none of them. I can't pick and choose. I have got the entire series on the patient L-spine was fine, and T-spine was fine. When we look at the C-spine, it actually

fractured his C5 vertebral body and notice that there is anterior wedging. Loss of anterior vertebral body height compared to posterior vertebral body height. The reason that he wasn't even really paying attention or wasn't aware of the fact that he had the cervical spine compression fracture was he'd also fractured the ungual tuft of his fifth finger, and that was incredibly painful. This is something called the confounding injury principle when you have somebody who has multiple injuries, which is one of the paying most attention to. The best explanation I have for this one is the homunculus.

If you remember that from a neurology standpoint, when you look at the sensory cortex and you look at the size distribution of parts compared to what they should be, fingers of course have really heavy innervation, we don't see as much in the cervical vertebral body. He was paying much more attention to his little finger than he was to the C-spine. The nice thing is this is a stable fracture, with 6-8 weeks of fracture healing time. Generally, patients might be collared for a few weeks to for pain control but you're usually not worried about neurologic compromise in these patients. Where we are worried about neurologic compromise can be the same mechanism, flexion, and/or axial load, okay, and this is one where we are seeing the cervical spine burst fracture.

Burst fractures. The thing that defines a burst fracture is it involves at least two columns, quite often it involves three columns. This would be easy to write off as just, maybe a compression fracture, where there's loss of anterior body height or maybe even a traumatic end plate fracture like a schmorl's node, but one of the single most important things on this particular radiograph, when we look at the posterior cortex in the vertebral bodies, they should be relatively straight or maybe even a little concave. When we look at our patient here and we look at that posterior body, that posterior body has gone convex. That is where when I was talking before about the three column theory of Dens if you see a middle column fracture, it is not, because when we see that middle column fracture one thing that might happen is this retropulsion of fragments and with the retropulsion of fragments, that is the middle column. If all I see is that convex posterior body margin, yeah, it is a middle column fracture, but there's got to be at least one other column involved in these patients. Not surprisingly, these are unstable fractures with a high degree of neurologic compromise. Will also see a burst fracture with the rack of the lumbar spine, where the degree of neurologic compromise is lower because we are going to the cauda equina region. As you look at the CT on this patient, you can see they actually vertically split the vertebral body and there's that convex posterior body margin as they have retropulsion of fragments that are thrown backwards. We worry about that posterior body height with that retropulsion and make sure we are looking at the posterior elements because there can be some associated injuries.

We've seen vertebral body fractures. What about the posterior elements? It is absolutely possible to fracture the posterior elements when we are looking at the c-spine. Typically, these posterior element fractures are going to involve hyperextension where the individual is loading the posterior elements. Not surprisingly, if you throw in a little lateral flexion with extension, it loads one side more than the other. Extension and or lateral flexion, we are going to see loading in the posterior elements and typically it will fracture the articular pillar but it can fracture the pedicle, it can fracture the lamina. One of my biggest clues that makes me think this is when I am doing my physical exam on the patient and they have got focal pinpoint tenderness because I am palpating the articular pillars now, putting my pressure in through the pillars. I get one pillar that just makes the patient jump up off the table. That is a posterior element fracture until proven otherwise. Because we know that we are dealing with a lot of extension mechanism injuries, there might be diffused neck pain, and really uncomfortable all the way through, but it is that difference of that focal pinpoint you just drove a needle right into the back of my neck.

What are we going to look for? We can see some asymmetry radiographically. We can even see this fracture extending into the lamina. You notice how there's rotation between those articular pillars. We are looking at a posterior element fracture here, big deal on these, this is where we really want to start

looking at a CT. The problem with posterior element fractures is they're notoriously difficult to see radiographically. Could we do special views like pillars and things like that? Absolutely. I am not a big one for wasting a lot of time if I am really concerned about posterior element fracture. I am going to get my patient's CT-ed. As we look at some of these posterior element fractures, we can see a fracture here in the pedicle. Here, there's a fracture through the articular pillar. The nice thing is these posterior element fractures are considered stable. It is one column, it is just a posterior column. Again, this person is generally going to be collared for a little while for some pain control. However, they should heal without any neurologic sequelae and too many ligamentous injuries.

Now, our next injury is the Clay-shoveler's fracture. Well, it depends on where you live and how much clay you have in your soil. This is one, I am in upstate New York in the United States, and one of the things that we have in upstate New York is we get a lot of snow in the winter and when you watch the snow falling, one of the big questions is always is the light fluffy snow and that is going to be easy to get off the driveway, or is this the heavy wet snow? That is going to be miserable to shovel. Well, one of the things that happen with that, wet heavy snow is very similar to what we see with clays is it is a very heavy material. As you dig and you go to throw the shovel full, well that creates an asymmetric pull on the spinous processes in the cervical thoracic junction. What we are going to see here is with that kind of asymmetric pool, you can fracture off a spinous process in the cervical thoracic junction.

Last time I checked shovelling snow is not an Olympic event so if you live in upstate New York, you kind of think it should be. So how else do we see this? Well, we can see it with any kind of asymmetric throwing event. We can also see this with direct impact. This is one word, let us put a 500-pound barbell across my spinous processes and if athletes aren't careful, that is potential there. The problem is, that this can be a very subtle injury. When we look at the clay-shoveler's fracture, this one is pretty blatantly obvious. I can see that fracture through the spinous process. Now, problem is, realize that when so many fractures off a spine are in the CT junction they're going to tend to spasm. Their traps are going to tend to tighten up. Their levator is going to tighten up and it brings those shoulders up higher when you're trying to take a lateral cervical spine radiographs.

Video Placement: 36:48

This is one where again if there's focal pinpoint tenderness right in the midline. Then, I am going to go ahead and make sure I am doing a swim review, my facility is doing the swim view, and I will consider doing obliques. The other thing is to look at the AP view, there's a subtle finding on the AP view called the double spine sign. As we look at this patient, so, here C6, and there's the C6 spinous, here C7, there's the C7s spinous, well, there's spinous 6.5. That is because that is the tip of the C6 spinous the fractured displaced downward. The spinous is will almost always displace inferiorly when we are looking at them. Because of that, they do have a very high frequency of healing non-union, and one of the things that we always have to distinguish is, is this a new clay-shoveler's or is this an old clay-shoveler's fracture? We can see in this case where there is a nicely corticated margin in the intervening space telling me that that is an old clay-shoveler's fracture.

The other thing that is on your differential diagnosis list for a clay-shoveler's fracture is a nuchal bone and that is where we see some ossification of the ligament of nuchal and it is a very common degenerative finding to see some little ossifications on the nuchal ligament. There won't be a matching defect of the spinous process. The nuchal bones tend to run very vertically as opposed to the clay-shoveler's fracture which matches up with the spinous process.

Video Placement: 38:20

That is taken care of a lot of our fractures in the c-spine, now what about dislocations? The dislocations

in the c-spine typically are going to involve the facet joints and they're both going to involve flexion. The difference is, so there's a unilateral facet dislocation and a bilateral facet dislocation. The unilateral facet dislocation is flexion or flexion with rotation. The bilateral facet dislocation is just flexion. In either case, we are going to have somebody that has that posterior component pain with a flexion mechanism, which definitely warrants taking some radiographs in a case like this. What is interesting when we look at these, are unstable injuries, there's a lot of ligamentous damage that occurs with facet dislocations. What is interesting is when they're particularly the unilateral facet dislocation, while it is dislocated, it actually acts stable because everything is locked. One of the other terms for this is a unilateral facet lock and so it holds everything in place. Once it is reduced because there are so many ligamentous injuries, this person is going to wind up getting a fusion.

One of our big clues that we are starting to look for is the unilateral facet dislocation. There's the classic, which is described in the Radiology literature, and then there's the let us be practical and talk about what we actually see. The important thing is, that unilateral facet dislocations will always, 99.9% of the time have an anterolisthesis because it is almost impossible to dislocate a facet without flexion rotation and not have some anterior translation of the vertebral body. That translation is typically less than 50%. I am going to look for that anterolisthesis. The other thing is, as soon as I see any spondylolisthesis, I always look at the posterior elements to see if there is a cause because most spondylus are driven by the posterior elements. I look at those posterior elements and what things were going to look for is something called the Bowtie sign.

It is worthy, two articular pillars are set off from each other and that is why I've got a lovely picture of a nicely actually tied bowtie here. What we are this bowtie sign where it comes from. This segment is neutral, we can see that the articular pillars are superimposed on each other. With a unilateral facet dislocation, it creates an offset of the articular pillars and that offset of the articular pillars creates something that kind of sort of a little bit maybe looks like a bowtie. So that bowtie sign is one of our clues for the unilateral facet dislocation. We can see in this patient as we run George's line, posterior corner here to posterior corner here, this person is a small anterolisthesis and as I am looking at the posterior elements, I can see and there is some rotations lower segment, which makes this a little confounding, but there's an articular pillar there. There's an articular pillar there, draw these in, here's a pillar, and then here's a pillar. This pillar is still articulating here. This pillar is no longer articulating, so that is a unilateral facet dislocation.

Our other big clue is steep rotation on the AP view. Notice that the C7 spinous is roughly in midline, and the C6 spinous is deviated way over to the side. That is because to get that unilateral facet dislocation, there will have to be some degree of vertebral rotation. These patients were of course emergency and transported to attempt to reduce the dislocation. The couple that I've gotten to see one of them was athletic. One of them was not. The first one was a gymnast, she was doing the Vault and when she did the Vault, she hit the Vault really well but she missed her landing and occasionally landed on her neck and her shoulder in flexion and rotation. The other one was a gentleman who was just jumping into a swimming pool while inebriated and didn't see a step. His shoulder caught the step of the pool and rammed his head into the side of the pool. But in both cases, they were flexion-rotation mechanisms. The bigger the injuries are the bilateral facet dislocation. This one is a pure flexion mechanism. This is where somebody has thrown forward, and as their head is thrown forward, they tear all the posterior ligaments to structures, not just the facet capsule but also the nuchal ligament and all of those. This person again, our big clinical clue, even if we miss the dislocation component. This person's going to have at least a 50% anterolisthesis of the involved segment because to get both facets to jump that way requires a large translation, so not surprisingly this tends to lacerate the discs as well as a lot of the other ligamentous structures in the area.

Big anterolisthesis gapping in the inner spinous space which is also our indicators of ligamentous injury and not surprisingly a very high incidence of neurologic deficit because the spinous process will start to approximate the posterior corner of the vertebral body. That is going to transition us from the cervical spine into the thoracic lumbar spine. One of the things that I would be remiss is if we did not cover disc pathology when we are talking about the thoracal lumbar injuries. Disc injuries also happened in the c-spine, but the single best article and kind of the gold standard for reporting imaging these days is a journal article called Lumbar Disc Nomenclature Version 2.0. This is actually a free article if you just Google Lumbar Disc Nomenclature Version 2.0, this was published in the spine and it was released as a free article because it is basically foundational.

When we start looking at the original article lumbar disc nomenclature, the original was written in 2001. Version 2.0 is the revised version from 2014. This is one were understanding how to classify disc lesions is incredibly important and this is the standardized language that all radiologists should be using. Unfortunately, we see some that are still behind the times on that, but this is the gold standard. When we start looking at disc herniation, and disc lesions, of course, we usually think of those as that generative phenomenon, but they can also be post-traumatic. It really applies when we are dealing with traumatic incidents. I am going to talk about three things relative to disc herniations, well disc pathology. Annular fissures, disc herniation, and modic changes. When we start looking at disc as it either breaks down or there's the possibility of traumatic, there's a phenomenon called annular fissuring that can occur. Now, if you're familiar with the original article, it is written back in 2001, these annular fissures were actually originally called annular tears. The problem with tears is tear implies a traumatic etiology. Because of that, the term was changed away from tear into fissure because yes, these can be traumatic, but more often than not, they're actually a degenerative breakdown of the annulus. We have got rid of tears and we now call these fissures. When we look in the finding section of a radiology report versus the impressions, one of the things you'll also see is something called an HIZ or HIZ, the high-intensity zone, that is because it is a bright spot in the annulus on T2.

They do typically happen in the posterior disc that can happen anywhere. Just to posterior disc is the more load-bearing component and there are three types, transverse, concentric, and radial. The radial's is the ones that we worry the most about. For the transverse tears, I've given you a schematic here, so we are looking at a sagittal view of the vertebral body and disc and vertebral body and then an axial view of the disc with the annulus on the outside, the nucleus on the inside. The transverse annular fissure, is right at the edge of the end plate where the annular fibers are inserting via Sharpey's fibers. We can see there's this nice bright spot here, so that is very much hugging the end plate, so that is a transverse annular fissure. Typically these don't allow for much nuclear migration, sometimes we can see similar things on radiographic appearance with a small vacuum cleft which can indicate in a trauma case that this person does have some avulsion of angular fibers. Generally not considered super significant.

The concentric fissure, which is actually the most common of the three types of fissure, is a delamination effect, we are actually seeing. We think about the concentric layering of the annulus much like the steel bands in a radial tire. So we see those alternating bands of ligamentous tissue and sometimes you can get a separation between some of those annular layers and that is a concentric annular fissure. It is going to be vertically oriented on the sagittal and it is going to be not surprisingly, concentric when we look at the axial. We can see that there's this bright spot in the posterior annulus. It is vertical and then there's this bright spot that is running around the outside of the circumference. The radial annular fissure is the more significant of the three because this is the one that allows for nuclear migration to occur. Where we are seeing this fissure cutting across annular layers and not surprisingly the nuclear material can push into that radial region and allow for a disc herniation and this is where we start seeing extrusions in particular and sequestrations. These radial fissures, we don't really see very well in the axial usually, the bigger tell is on the sagittal. We can see where it is cutting across multiple

layers. Well, these are problematic one because they can allow for nuclear migration, but two, they also allow the radial fissure can hit those outer annular layers, where we see the innervation and that can create some pain.

Then we get into herniations. I realize I am talking to my chiropractic audience, and we are the owners and specialists in spine pathology. I am going to go through this quickly, but just to make sure that we are all using the same language when we are talking about disc herniations. For those of you who have been around a little bit longer like myself, a long white beard help's to know I have been here for a while. You remember back when MR was really a new thing and when we started, we could send patients off for MRIs. If I sent the same MRI to three or four different radiologists, the reports would look completely different. Somebody might talk about a bulge, another way to say it is prolapse on the else might say are herniation and that complete disarray in the language is what prompted the American Society of Neuroradiology to create this standardized nomenclature.

This is what everybody should be using and most radiologists really are on board, particularly neuro rads and MSK rads. One of the things to consider is if you are getting your reports from your Imaging center and maybe the body imager was the one that was on duty that day, you might get a non-standard report because the body imagers are more interested in the chest and abdomen. They might not be as conversant with some of the spine terminology which is why I am a stickler for imaging should be read by spine rads or MSK rads. Those are my big preferences there.

When we start looking at the different kinds of discs, what is interesting is if you read the article in 2001 and then you read it in 2014 there not surprisingly, are some changes. One of the big things is in 2001, there were four kinds of disc herniation: bulge, protrusion, extraversion, and sequestration. Well in 2014, Pluto, was not a planet anymore and the bulge is no longer a herniation. Bulges are considered asymptomatic incidental degenerative phenomena of really minimal clinical significance. They are not even qualified as herniations anymore. Protrusions, extrusions, and sequestrations are. Notice that you have got some little brackets here. In protrusions, the annular material is contained or the nuclear materials are contained by the annulus, in the extrusion and the sequestration or sequestered fragment, the nuclear material is not contained by the annulus.

An important thing when we are looking at discs is you have to make sure that you evaluate both the axial and the sagittal when you're classifying disc pathology. If you look at just one or the other, you might miss some of these findings. Another thing to consider is to remember that you are looking at MRI, different centers will have different protocols, some use thicker slices, some have bigger gaps between slices, and sometimes disc material can hide. That is why we want to make sure we look at both the sagittal in the axial to correlate what it is that we are seeing. Where do I send my patients for imaging if I am sending my patients to a center that does high-quality patient-centered imaging or am I sending my patients to a center that is kind of notorious for, well, we move the meat, okay, one of the colloquial phrases for we get as many patients through per unit of time as possible to maximize profits? Profit is important, but so is good patient care.

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The disc bulge, again, is not even herniation anymore but when we look at a bulge for seeing the disc material going beyond the vertebral margins, now it has to go more than two millimeters. If we were to draw a line from corner to corner in the vertebral body, the disc material has to go more than two millimeters past that line. When I go corner to corner here, I can see, okay, that disc material is definitely two millimeters beyond. Anything less is just considered normal physiologic bulging has to go more than two millimeters and a disc bulge by definition has to involve greater than 25% of the disc circumference. I will be honest, most disc bulges involve 100%. Because one of the things we see here is

the disc desiccates, N plate, N plate with nuclear material in between as that disk desiccates in the end plates approximate, the annulus just starts to bulge all the way around. It is kind of like that middle-aged bulge that happens. When we look at this thing on imaging, we are looking at the T2 Disc material which is going back. There's some disk off, see if I complex up front, but an important thing is we look at this on the axials. That is axial through the end plate, we are looking at a bone slice in this particular case. Then this is a disc slice and these two images have the same size. When we compare these two images, an important consideration, notice how the circumference of the disc is bigger all the way around than the bone is. Well, that is because that is that annular bulging that is occurring as the N plates approximate, the annulus is starting to bulge out. It is evolving 100% of the circumference. Fantastic.

One of the analogies that I like to use for disc bulges. Not surprisingly, radiologists like food, so, I like to use a food analogy here. If you've ever made smores, I don't know how American of a thing smores are versus an international thing, but if you take two graham crackers and you put a marshmallow in between that you heat it up on the campfire and then you squeeze the graham crackers together, the marshmallow loses all the way around. Well, that is essentially very much like a disc bulge. Now, bulges can be symmetric all the way around and very circumferential and if you have somebody with scoliosis or some side bending, that can create symmetry to the disc bulge. But again, it is more than 25% of the circumference, it is a bulge. What the literature tends to tell us is that bulges are generally asymptomatic incidental findings where lots of people have these and never have pain. Getting into true herniation is the disc protrusion. Protrusion and extrusion have very similar definitions. They're similar but actually opposite. When we try to figure out is something a protrusion or is something an extrusion, we look at a couple of things. We look at the depth of the disc material and we look at the width of the disc material. A protrusion should be wider than it is deep. Wider than it is deep, that is what makes a protrusion. Because the protrusion is contained, this is a disc herniation that is contained. If we think about the annular fibers that plug-in corner to corner if the disc material cannot go above or below the level of the end plate. If it goes above or below the level of the end plate, that has to be an uncontained disc.

When you look at this particular case looking at sagittal and axials, so we can see that disc material is coming back here. It is staying between the end plates. Then on the axial, the disc material outlines it here, right there. The disc material is going from here to there, that is the width. It is going from here to there, that is the depth. This disc is wider than it is deep, so we are looking at a protrusion. Now notice, I am really only focusing on the T2s. We don't really use the T1s to look at this material. I have just included them for completeness' sake. When we start getting into the literature, one of the things we saw in the '80s and '90s when MRI first started being widely available is that there was a massive increase in spinal surgeries in the '80s and '90s and it is because of the structural pathology phenomenon. There is a structural problem with the disc. Surgeons were cutting on a lot of discs. Lots of patients with back pain. They did an MRI, they found disc lesion like a protrusion. The person had to diskectomy and then in the late '90s and early 2000s, all the literature started saying, well there's a huge amount of failed back surgery, because are these really structurally that important, are they likely to be pain generators?

The epidemiology studies really came out that showed when we look at asymptomatic people, people have never had back pain in life and we look at an MRI their lumbar spine, there's a huge incidence of disc protrusions. Because of that protrusions are one that could it be an asymptomatic issue? Yes. Is it dislikely? Not so much. That is as diametrically opposed to the extrusion. Extrusions are usually symptomatic because we are dealing with uncontained nuclear material and it creates a host versus foreign reaction. There's an immune reaction to this. We are looking at extrusions again, we are going to compare the depth of the disc to the width of the disc. We look at how wide it is versus how deep it is. An extrusion is going to be deeper than it is wide because this material's now, the toothpaste consistency nuclear material has now extruded beyond the margins of the annulus.

This is where we also have to make sure we look at the sagittal and the axials. As we look at both the axial and the sagittal here, this looks like an extrusion on both. It is on the axial, it is wider or steeper than it is wide. On the sagittal, it is dropping down below the end-plate level. But what about something like this? Where okay, the disc material staying between the end plates but on the axial, it looks like an extrusion, well, it is always whichever one you're considering whichever one's worse, that is the one it is. So it looks like a protrusion on one and extrusion on another. It is an extrusion. Same thing here, we can see broad-based extrusions. But as soon as it is dropping down below or going up above that end plate, that is extruded material. We start looking at the imaging on these and here this to me looks like a uvula. Looks like there's a large uvula of tissue hanging down. It is still connected to the parent disc, which is what makes it an extrusion. If I look at it on the axial, if I were to outline the structure, there's the disc material there and it is definitely deeper than it is wide. We are looking at an extrusion in this case, and of course, as chiropractors, we know that extrusions tend to do pretty well with conservative care. That is one of my favorite quotes from the literature, I love throwing this one up. 90% of extrusions with radicular symptoms, manage non-operatively with aggressive conservative management have been shown to do well. I always loved the "to do well" part without throwing on some actual qualifiers for that one, but we know that these patients generally do well with conservative care and as we start looking at them, one of the considerations is a lot of times, the pain that we are seeing associated with these is because of an immune system reaction because we are seeing an inflammatory response and that can create its own localized pain.

We can look at some of the axials and if you get poor quality sagittal, or patient the moves. Here, we are looking at a disc slice and I am seeing disc material still a disc slice and disc material. I am getting into the inferior end plate and they're still disc material. Now I am into the mid-portion of the next body and I am still seeing disc material, so I can tell that that is an extrusion. Bulges, protrusions, extrusions, I see all the time. Sequestered fragments, I don't see that often as somebody who reads film every day of his life. I only usually see 3-5 sequestration is a year and that is an outside number. Usually, extrusions are much more common than sequester fragments. The idea here is that it is uncontained. The nucleus is broken free of the angles, but an important part is a sequestered fragment, the sequestration doesn't have a connection to the parent disk anymore.

I use a baby analogy for these. Sequestration is a fetus. It is still got an umbilical connection to the parent. When we look at sequestration, this is a baby's umbilical cord being cut. It is free and by itself. We are looking at the little baby there that is the sequestered fragment. The same thing that we see with patients that have extrusions, these are going to be generally painful, there's going to be an immune reaction to this uncontained disc material. Subtle, we don't see them that often, but as I look at this patient, I can see there's disc pathology here on the sagittal, but the annulus itself looks intact. When I look at the axial slice the annulus has a normal contour, but then, when I am up here in the mid portion of the vertebral body, there is disc material. So, looking at sequestration. What is interesting. We do not usually do contrast when we are looking at sequestered discs, but we've seen some and it is because we might be looking at a differential of, is this an epidural hematoma is a possibility? Could this be some kind of tumor or lesion because maybe these are fairly large? As we look at this case, we can see that there is this large bolus of material behind the L4 vertebral body. This is a case where the initial read by the radiologist was, is this an epidural hematoma or is this a mass? So they put contrast on board on this one. Now, before I show you the contrast, one thing I will tell you is that this is a very fresh sequestered fragment, because one of the things I notice about this material is, that it is incredibly well hydrated. This is where we really get into that traumatic disc etiology. If I can see, I know that the trauma was within the last two to three weeks and I see how incredibly hydrated that extruded disc material is sequestered disc material, I know that this is tied into that acute trauma. Because one of the first things that happen with these uncontained discs is the hydration is removed from the nuclear material.

We do not typically put contrast on board because there were differentials of epidural hematoma versus tumor mass like a meningioma or neurofibroma. This one had contrast put on board, and it really illustrates an amazing concept. As far as that immune reaction, we know that one of our terms is contrast goes where blood flows. Well, when we look at this thing post-contrast, so we are looking at T1 fats at post cons, here's the disc material and notice that there's a ram of bright white around that disc. We see the same thing over here on the T1 fat set, post-con. Well, contrast goes for blood flows. What we are seeing is we are seeing the immune reaction where there's increased blood flow in the immune cells is being attracted to that foreign invader material of the nucleus. It really illustrates the concept of chemically mediated pain. Why disc material in an uncontained disc material will resolve itself given time because there's an immune reaction where the macrophages are actually phagocytizing that nuclear material. One of the other things that we need to consider with these discs lesions is where are the disc lesions, and we talk about them in a couple of different locations, central, subarticular foraminal, extraforaminal, realizing that most herniations are in the central and subarticular range. Realize that there used to be a different term for subarticular. We also used to use the term paracentral, and I'll be honest with you, the lumbar discs nomenclatures designed for lumbars and it is been extrapolated in the c-spine. If I am in the lumbar spine, I use the term subarticular because that is consistent with the article. When I am in the c-spine, I will still use the term paracentral because of course the set orientation is different. You will still see some of those terms used, but so central and subarticular most herniations are, it is a very small portion being foraminal or extraforaminal.

The last topic for this first hour is Modic Changes. This is something that if you have been keeping up with MSK literature, modic changes have seen a lot of press over the course of the last 15 to 20 years. Now, modic changes are in a small percentage of the population that we have no idea who gets them, but in some people, they get a marrow response to disc degeneration. As we look at this marrow response, there are three types: modic 1, 2, and 3, and they happen in order. First, there's one, there's two, then there's three, and they never go backwards. You'll never see a two turn into a one or a three turn into a two. If you do that, actually means you are looking probably the spinal infection. But when we look at these modic changes, the first thing that happens, first, there's almost an inflammatory reaction. There's a fiber vascular infiltration of the marrow. Then there is a fatty replacement, and then there's bony sclerosis. And the bony sclerosis is rare. Most people stop the modic two.

The modi type 1, we look at the T1s and the T2s. The modic type 1 because this think about this is an inflammatory process. We are seeing edema on the T2. So bright on T2, dark on T1 and one of the things and if you follow the literature, you know that literature can be all over the place on these motor changes. The predominance of the literature I have seen says the type one modic changes are going to be associated with discogenic pain. So if I see a type one motor change, I can reasonably believe that I am dealing with somebody who has got pain coming from that area.

Now, as that a diva eventually burns itself out, it is going to be replaced with fatty tissue. And when I look at this, what I am really going to see the important part is it is bright on T1, because of fatty materials, bright on T1. On T2, sometimes it is a little bright, sometimes it is a little dark, and sometimes it is the same as the adjacent marrow. The important thing is it is bright on T1. Now, this fatty replacement, this one is not associated with back pain. This is the inflammatory phase is and then as it trickles out, eventually that stops being associated with pain when we see the fatty replacement.

Type 3 modic change is bony sclerosis. This is going to be dark on T1 and dark on T2, and again, it also poorly correlates with symptomatology. That is going to take care of this first hour of spinal trauma, I will see you back for hour two.

[END]