Good afternoon, everyone. My name is Amr Abdelgawad from the orthopedic department in Texas Tech El Paso. I work at UMC’s Children Hospital. I’d like to thank the committee for inviting me to come today to Carlsbad Medical Center.

We’re going to speak today about pediatric femur fractures. And the objectives of our talk today... the first thing will be that we're going to speak about the epidemiology and anatomy and pathology of the femur fractures in children. The second thing we’re going to discuss is the general management of a child who comes with a broken bone. And then we'd like to identify or know the red flags that can help us identify fractures that are associated with non-accidental (NAT) trauma as heard in the previous lecture. And at the end, we're going to outline the treatment options for the various types of femur fracture.

I’m going to try as much as possible to stay away from the surgical details and be concentrating more on the general management of a child who's coming with a pediatric femur fracture. This is actually one of the topics that are very close to my heart. I did a lot of research about pediatric femur fractures and have already published three papers on pediatric femur fractures; and next Saturday we're going to present the symposium on surgical treatment options for femur fractures for the orthopedic surgeons in Phoenix.

So, what is the epidemiology? Femur fractures are relatively common fractures. About 2% of the pediatric fractures are femur fractures so that translates to roughly 30 fractures per 100,000 per year. It depends on the size of the city that you're working or that area that's going to send patients to you. So, for every 100,000 you will get 30 of them a year which is a relatively big number. And most of these are males -- so 3:1 male/female ratio
And most of the pediatric femur fractures will be in kids between six to 12 and between 13 to 18. We’re going to discuss the mechanism later on but you still have a considerable number that can come who are less than two years. And these are the ones that you have to suspect that this may be due to non-accidental trauma.

And as we’re going to discuss in the second half of this presentation, 70% are diaphyseal. So, the femur is a big bone and we classify the fractures... there is a proximal femur, diaphyseal femur, or the distal femur.

Seventy percent of the fractures are diaphyseal femur so we’re going to discuss more of diaphyseal fractures than proximal and distal. And as you see here this x-ray shows you two types in the same patient. Here's a fractured neck which is proximal and here's diaphyseal fracture. So, it’s very important when you get the x-ray as we're going to discuss later, you have to see the hip and you have to see the knee. If you can't get them in the same x-rays, get the separate x-ray of the hip and separate x-ray of the knee.

Now, let’s discuss the mechanism of injury. Remember, the femur is the biggest bone in the child or even in the adult -- the biggest and the strongest bone we have is the femur. You need to have a really considerable amount of energy to break your femur. So, you have to make sure that you examine the child as a whole and not be concentrating on his femur fracture. And again, if you get a child less than one year old, you have to make sure that this is not due to a non-accidental trauma.

We’re going speak in detail about non-accidental trauma and its relation to the femur fractures. In adolescents, most of these happen due to recreation and sport activities. We're seeing more and more kids playing soccer or football and then they are tackled and then you do a twisting injury. Our bones are weakest in twisting injury and they can get femur fractures. And, of course, motor vehicles crashes (MVCs) are a common cause in all ages.

If you get a child that the mechanism of injury is struck by a car, remember that can lead to triad. It's a head injury, abdominal injury, and femur fracture or extremity injury. And remember, the definition of a pediatric femur, it means that the growth plate is still active. The difference between the pediatric femur and our femur is we don't grow anymore. So, we don't have a growth plate. But kids have a growth plate and we’re going to see that and how that can affect them later on. If they get an injury to the growth plate, the growth plate is the area which we grow from; so that can affect their growth later on. It can cause them to completely stop the growth, or it can be delayed growth, or it can grow in a crooked way -- inward or outward.

And head injury is very important. If the child has a femur fracture and head injury, this is very important to consider that in your treatment options. And we're going to discuss one case that the child had a head injury and how that affected our treatment. And very important... if he also has an abdominal injury, you have to make sure that if you're going to treat them in a cast, that you give a chance for the surgeon so that they can have an access to the abdomen or can have access to examine the abdomen.
This is the mechanism of injury in cases of being struck by a car. And if you see here, this is why we see it as maybe a triad of injury. He may have a head trauma, abdominal injury, and extremity injury. Whenever you get a child hit by a car or the person is a pedestrian and he has a femur fracture, always consider that he may have a head injury and abdominal injury.

So, physical exam: As we said, the lecture before me was an excellent presentation about the general examination of injury to the child. So, you have to do a full exam for the child -- head, chest, abdomen, and other skeletal injuries. And then from the point of view of the extremity, most important is you have to see distal to the fracture the neurovascular exam. So, you have to make sure that this child has good pulses distal to the femur fracture in the extremity that he has the distal femur. And you also have to palpate all bones because remember, the femur is the biggest bone so it causes the most pain. He may have another fracture but he's not complaining as much because the femur fracture is distracting him. So, you have to palpate all other bones and make sure that there are no other injuries to the child.

First aid is a splint or traction. So, if you have a femur fracture, the first thing that you'd like to do for him for the extremity is a splint or traction. And you can choose any of them. Or sometimes if the child is small, you can put in a knee immobilizer and that should control some of the pain.

The next step after you do the examination is the radiological examination and you have to make sure that you get an AP of the pelvis; and then you have to see, as we said, the hip and the knee joints because there is 5% chance that he has a fracture proximal or distal with the fractured shaft femur that he has. And again, the shaft femur is the biggest bone. You see it very easily, but if you don't look for the distal or the proximal injuries, you may miss them. So you have to get AP and lateral of the femur. If that x-ray is not going to show you the hip and the knee clearly, get a separate hip and knee x-ray and then a pelvis x-ray. Are there any questions up to that? Again, we publish articles about the orthopedic management of children with fully trauma. It's very, very important that you're not distracted with the femur fracture. So, remember A, B, C, D as we heard in the previous lecture the general assessment and evaluation of the child and then look to the extremity.

For the extremity, align and splint, neurovascular examination, and if there is a wound still, cover it, or a sterile dressing. So, again, the general management has to come before the extremity. Even if the child is screaming from the pain of the femur because it's very painful, don't be distracted. Go for the A, B, C and then for the extremity. Three things - align the extremity with traction or a splint and then neurovascular exam, and then if there's a wound, apply a sterile dressing. I would consider that this is the most important slide here in the presentation.

Let's speak now more about the femur fracture itself. It's either open or closed. Open fractures mean that there is a wound connected to the hematoma. And this can be type 1, 2 or 3, depending on the size of the wound. Open fractures are fractures that have a hematoma that's connected to the external compartment. Even if it's a small wound, you'll find that it is continuous oozing of the blood because that wound is connected to the hematoma.
Location of the fracture: We're going to discuss that in detail later -- if it's proximal, diaphyseal or distal. And as I said, diaphyseal is 70% of the fracture. So, this is the most common one of them. Distal about 25% and less than 5% are proximal fractures. And then it depends on the fracture pattern -- sometimes it is transverse, spiral, oblique, comminuted. But these are the classifications of the femur fracture.

So, now we're going to speak about non-accidental trauma in relation to the femur fracture. It's very hard from an x-ray to know if this is an accidental trauma or non-accidental trauma. Actually, it's impossible because we get that question a lot from the child protective service or law enforcement asking us from the x-ray, "Is this an accidental or non-accidental trauma?" The x-rays... the fracture will be the same if it's accidental or non-accidental. It's all the things around the fracture that can tell us. So, it's very hard from an x-ray to know if this is a fracture that is accidental or non-accidental. What we classically say is that the non-accidental traumas are usually spiral fractures; but still spiral fractures are very common in accidental trauma. So, accidental and non-accidental both have spiral fractures of the shaft of the femur. And, as we heard in the previous lecture, it's very common. It's about 1 to 1.5% of the children are abused annually. So, it's a big percentage. And if you'd like to transfer that to a number, it's 70,000 to 2,000,000 children a year are subjected to abuse.

This is an x-ray from one of our patients. He came in with a nonaccidental trauma. Spiral fractures of the shaft. But again, spiral fractures can happen with accidental trauma. So, it's a little bit more common with nonaccidental, but it's still common with accidental trauma.

Nonaccidental trauma is the new expression for child abuse. What are the risk factors? Any child can have a nonaccidental trauma. It's not associated with a certain socioeconomic or a certain background; it's every child for all ages can be exposed to that. And it's very important if you are dealing with one to keep that in mind because more than half of the children with nonaccidental trauma will come with extremity injury. So, despite the fact that they can come with head injury, torso injury, but if you're dealing with bones and extremities, more than half of the children with child abuse will come in your specialty and about 65% have isolated long bone fractures.

Risk factors to keep in mind: First-born children, premature infant, disabled children. It's very common in children with CP or mental retardation. You'll find that they are subjected to abuse more. And at the same time, they also can be exposed to fractured femurs because they have brittle bones. So, it's not every child with the CP (cerebral palsy) that has a broken bone is non-accidental trauma. He has very brittle bones and they can be in the therapy and they can break his femur. So, keep that in mind. Disabled children have more incidents of child abuse; single-parent homes, drug abusing parents, families with low income, and children of parents who were abused as a youngster. Why is this important? Twenty-five percent of these that are missed can have another non-accidental trauma and up to 5% can end in death, so it's very important to get that child in a safe environment. Child abuse is the second leading cause of mortality in infants and children (this is the first one in children less than one year; and in infants and children together, it is the second leading cause).
So, we said that from the x-ray itself, you won't be able to know if that femur fracture happened from accidental or non-accidental trauma. So, how do you know? It's mainly history. This is very important... if the history does not match the injury, that's most probably child abuse. History and injury has to match together. And if you’re listening to different histories... the mother will tell you the history and the boyfriend of the mother will tell you another thing, that's inconsistent history. That also goes with child abuse. If there is a delay in presentation... it's very strange if you have a child with a fractured femur that comes after two or three days. So, why was he left all this time? And the parents can be either hostile or indifferent. So this is one of the things that can lead you. If you look here, the four things that are presented have nothing to do with the fracture itself -- how the fracture looks -- because the fracture itself can be the same in accidental and non-accidental trauma.

Evaluation needs to be a team approach: So, get child protective service and get the pediatrician involved and also get the law enforcement people with you. And again, orthopedic surgeons, as we said 65% of the patients present with bone injuries from child abuse. And it's very important to know that healthcare providers are waived from liability if they report the child abuse in good faith. So, if you report it, it might be a child abuse for the child protective service and it turns out it's not child abuse, you're waived from any liability, so long as it's in good faith.

This is one of the patients that we treated. He had a clavicle fracture and a femur fracture -- so, he presented with both. And again, it's a spiral fracture, so it's a little bit more common with non-accidental trauma. So we put a cast on him.

The thing that they won’t to tell you... the relationship if you want to know one thing about femur fracture and non-accidental trauma, any child less than one year old with a shaft femur fracture is a red flag. So, a femur fracture in a child less than one year old -- which is the usually the age at which the child start walking -- if you have a fractured femur in a child less than one year old, that's a red flag. And that makes sense because it's very hard to break your femur if you’re not walking. You may be walking, you trip, you fall down, and you break your femur; but if you're not walking and you get the shaft femur that's a little bit strange. One thing if you want to know from that from non-accidental trauma here is that a femur fracture in a child less than one year old, which is the walking age, is a red flag for non-accidental trauma. The other thing is also multiple fractures or fractures at a different age, so if you see a fracture of the clavicle and it has a callus, it means it happened two or three weeks ago and then you have a new fracture here of the femur, that's also a red flag that maybe it's a non-accidental trauma. One thing to remember is that a femur fracture in a child less than one year old is associated more with non-accidental trauma.

Now, let's go to the femur. We're going to speak now about the method of treatments. Again, the femur is the strongest bone; biggest bone in your body. We classify as proximal femur, shaft femur, and distal femur. Shaft femur is 70% of the fractures; so most of the fractures will happen here. You will have a few here and a little bit more here. So that's the classification that we are going to continue for the rest of the presentation.
Diaphyseal fractures can be managed either surgically or non-surgically. Non-surgically, we have two types of nonsurgical treatment which is a Pavlik harness. This is the same brace that we use to treat the kids with DDH with the hip dysplasia; or hip spica. And the surgical treatments: There are four types of surgical treatments: Either plate and screws, rigid nail, flexible nails, and external fixator. We're going to speak about these in a little bit more detail.

The Pavlik harness is the method that we use to treat kids with DDH who present with hip dysplasia when they are born. It has like a harness here that goes around the nipple and then there are two parts that go to each extremity and then you have two straps: One here to control flexion/extension; and one behind to control of abduction and adduction. It's enough for kids who are very small, like if you have a child that is less than four or five months old with a fracture, the harness can control that fracture okay. So, we use it only for very small kids --kids who break their femur at less than six months. This, as we said, most probably going to be the result of child abuse or it can happen sometimes at birth because sometimes when they're pulling on the child, they can break the femur. A Pavlik harness should be fine in this case. And you apply it for not more than two or three weeks. And then the child has healed by that time.

The spica cast is one of the common methods that we use to treat femur fractures. Indications for treatment of femur fractures in spica cast are most probably used to treat a small kid. We put here less than five years but this number is going down and down. It's very rare that for a kid that older than for four years, we would put him in a spica cast now. The spica cast is very bothersome for the families. You can't deal with a child in a spica cast very well, especially if you have a working mother. Actually, now we're having more and more people asking us to do surgeries for the kids because they don't want to deal with the spica cast. So, spica casts are usually for young kids… I would say, less than four years old and the fracture itself has to be amenable for a spica cast. What does that mean? It means that the fracture has to be stable. You can't treat a fracture which is highly comminuted or has a severe shortening with a spica cast. And we will see two examples of how this can turn out. So, the spica cast is mainly for young children. I would say four years and less and for stable fractures. And it is better that they don't have abdominal injuries because once they put the spica cast; the surgeon will not be able to reach the abdomen. And also if they have massive swelling of the thigh that may be also a contraindication for the spica cast.

So, what are the problems of the spica cast? With a spica cast, you don't control the fractures very good with a spica cast because it's an external immobilization; it's not internal in the body. So the fracture can move and it can get shortened. Also, the spica cast... especially in the summertime, it causes a lot of hygienic problems for the kids. And we can see... this is one of our patients if you see. He has lots of macerations of the skin. So, of course El Paso is very hot and in the summertime, it gets very hot and they can get macerations of the skin. Especially if the family does not take good control of the spica cast and then it gets wet. And there have been some reports of compartment syndrome with the spica cast. With the spica cast now, we do them more and more extension. We used to do them in 90° flexion of the hip, 90° flexion of the knee. We stopped that. Now, it's like 45° extension of the hip and the knee.
So, this is a girl, three-year-old, that presented with a spiral fracture. We did a closed reduction and put her in a spica cast. If you apply it, okay. Usually they are happy. Usually you apply them for about four or five weeks and then you take it off. And we tried to make like a bar here that the family can hold them from. And if you select the patient well, usually it's a very good treatment for femur fractures. For kids who are less than four years old with a stable fracture and a family who can take care of the spica cast, it's a very good method of treatment.

Still application of the spica cast is not easy. There are some places that can do them in the ER with conscious sedation but I wasn't able to do that. I think it needs at least two or three people helping me. So, we have the spica table so the anesthesiologist has to be holding the head completely; there are two or three people. I usually sit on the table holding the two legs. And then two people are putting the spica cast. I think it's very hard to do to them in the ER. I think it's much easier to take the child to the OR and have better monitoring for him especially because after we apply the spica cast, we start turning him to the right and the left to do the molding of the cast.

This is the child that was presented here. It was after six months. You may say, “Oh, it's turned.” Yes, but she's still growing and with remodeling, she will continue to be straight; but there's no shortening as you see here. There is no shortening of the femur. So, you have to pick your patients. They have to be young and the fracture has to be stable.

Again, the spica cast is not for every... I think this patient is a little bit older. The fracture is highly comminuted. A spica cast was applied and that's how he ended... he ended up with shortening. If you see here, this is his medial mall on the affected side is much shorter than this side. And at his four-month follow up, you can see the difference here. It may get a little bit better by the time he has finished growth, but definitely it will not be the same. So, the spica cast has to be a stable fracture. You can't apply a spica cast for an unstable fracture.

All right... Now, let's pick up. So, we spoke about nonsurgical treatment; we spoke about the Pavlik harness in very young kids; and we spoke about the spica. Let's speak now about the four options for treatment of surgical treatment of femur fractures.

First is the external fixator. At one time, this was a very popular form of treatment for pediatric femur fractures. The advantage is minimal blood loss. You put them on with no opening. There's no incision. You apply two pins above, two pins below. You reduce the fracture and connect them from the outside. That's why we call it the external fixator. And it's a relatively quick procedure. It gives an advantage in cases where there is an open fracture because there is no metal inside the patient. The pins are coming out. And there's no internal fixation. So, it's a good indication for open fractures or provisional fixation. However, there are a lot of disadvantages for external fixators: Pin tract infection (I would say 100% of the patients will get that -- if you leave them long enough, they'll get pin tract infection). And sometimes that can go up to toxic shock syndrome. And patients don't like external fixators, in general. They get caught in the linen. They can't put their clothes on. So, it's not patient-friendly. And the most important reason why most of the people stayed away from external fixator is there is a high incidence of refracture -- up to 22%. So, when you put internal fixation you're not in a
hurry of taking this thing out. But if you put an external fixator, the patient is not happy and the family is not happy, and they want you to take this thing out. So, you take it and then that may end up in refracture in 22%. It can happen at the site of the old fracture, or it can happen at the site of the pins because these are relatively large pins and they are (unintelligible at 25:01)for the bone. Of course, we can also associate it with deformed malalignment or malrotation or limb length discrepancy.

So, external fixators... if you see the American Academy guidelines now they are less desirable than more rigid fixations or submuscular plating and their complications are high so most people are staying away now from external fixators. Unless there is an open fracture or the patient is extremely unstable, we don't do external fixator for our patients now.

This is a girl that presented to our clinic. She had an external fixator. The fracture started to heal in varus. It means that the distal part is pointing medially. We took the fixator off. We put her in a cast for extra protection. And that's how she ended up. She ended up with about 25° of varus deformity and shortening. So, again, external fixator has limited indication -- open fractures or in the case of an unstable patient where you would like to do something quickly. Again this is another child that ended with a pin tract infection on this pin. If you see here that's an osteomyelitis and this kept draining for about 1½ years.

Let's go to the one of the common methods that we use: Elastic nailing. Elastic nails... it's an intramedullary fixation but as its name says, it is a flexible nail... elastic. Most of these are made of titanium. The diameter goes from 2.5 to 4 mm and it depends on the child's height.

What are the indications for using flexible nails? We use flexible nails in stable fractures. In stable, diaphyseal, midshaft fractures. So, it's midshaft transverse fractures because you can't use them in a spiral fracture. When use them in a spiral fracture, the fracture will start to move and the pin will stay inside. So, it's very good for patients who are less than 100 pounds with a midshaft transverse fracture. This is a perfect example. A child here presented to our ER; midshaft transverse fracture was reduced; we put in these flexible nails. It's very quick. The procedure takes like less than one hour. And the only problem is it caused some knee irritations -- these pins here... when the child flexed and extended, so we removed them after about four months. But it's relatively quick and it gives good results. The alignment is usually very good with the flexible nail. So, flexible nail -- midshaft fractures, transverse in a child less than 100 pounds. If it's a heavy child, these two pins which are 3 mm cannot hold his weight.

So, the advantage: It is a very small procedure; it takes less than one hour; two small incisions over the knee. But they are not very stable. Again, these are flexible. You can hold the pins and you can move them in your hands. And they cannot be used proximal or distal. So, if the fracture is up here or low here, you can't use a flexible nail in them.

This is a child that presented; he was in this car, and that's how he presented: A six-year-old boy in a motor vehicle crash with head trauma and right femur fracture. And actually I'm the one who did it. I did the flexible nail for him. But, unfortunately, I didn't notice that he had head trauma and he started to get convulsions after that -- because again, these are very flexible. They're weak fixations. So, now he
started to get convulsions and he started to get contractions of first quads, so he started to collapse and pins started to come out here. And we had to revise that. So, we took him and we put in a plate.

We spoke about the external fixator indications of open fractures or an unstable patient. We spoke about elastic nailing. Elastic nailing is mainly for stable fractures for children less than 100 pounds with a midshaft transverse fracture.

Now, rigid nailing: Rigid nailing is becoming now more popular in kids. Rigid nails, it means you can’t bend the nail in your hand. It’s not as the previous ones. It's not flexible. And then you lock it, this knee. You lock it proximally and distantly. So, you're not worried about shortening. It will not shorten because it's fixed here and fixed here. So, this distance can't get shorter.

This is one of our patients with a midshaft fracture who is a little bit older so we applied the rigid nailing. And this is the fourth month. Usually, they heal very well because you don’t open the fracture, so the fracture heals faster. So, the advantage of the rigid nailing is it is a very rigid fixation and you're not worried about shortening because there is locking of the proximal and the distal parts of the knee. But the disadvantage... why was this not common previously because we're going to show now that the blood supply of the femoral head is very close to the area that you put your knee. And previously, with the old nail design there have been lots of reports about AVN or avascular necrosis of the femoral head because of that nail insertion.

So, this is the proximal femur. This is how it looks if you're looking from above. And previously, the old nail used to go from here. Here is where the blood vessels are and here are all the blood vessels coming to supply your femoral head. So, if you go here which the old designs were, you may injure your blood supply to the head. Again, this is the blood supply. This is your medial femoral circumflex artery which supplies the head. And we all know that the blood supply to the head is very close to the area that you put your knee. And previously, with the old nail design there have been lots of reports about AVN or avascular necrosis of the femoral head because of that nail insertion.

So, in the previous design, we used to go from here. It's called piriformis entry. And this had at least a 5% chance of AVN which is a very catastrophic complication if it happens to a young child. So, later in the 80s we started something called trochanteric entry. And here it is still very close to the blood supply. So, the instance is less but still there have been reports with trochanteric entry. Now, the new design starts here. It's called an adolescent nail. This is the old -- very old; here is the trochanteric here which is what we use for adults (we are still using this entry for adults); but this is the adolescent. It's more towards lateral side. So, we enter here which is far away. It's not far away but it's far from the blood supply and we have to be very cautious not to injure the blood supply; so we go from here and we try to get a little bit anterior because the blood supply is coming posteriorly. These are the rigid nails. So, if you see the entry here is not from here and not from here -- it's further lateral. These are the new design. That's why they have more bend here. They're called the lateral entry nails.

This is a 15-year-old. We use them usually for adults. For kids who are older than 12 years old because their neck is bigger now and the blood supply to the neck is further away if you use the trochanteric nail. So, here's a 15-year-old child coming with a femur fracture and he's a perfect
candidate for the lateral entry nail. We go from here; we lock it proximally and distally; and he can weight bear the next day.

We spoke about external fixators. We spoke about flexible nail, rigid nail. Let’s speak about plates and screws. So, plates and screws... this is the very traditional way of fixing the bone. We used to strip everything and then put a plate and screws and then people started to get better. They strip only what they want to see -- the area they’re going to put the plate -- and then submuscular... this is the technique that started in the late 90s. You open very proximally and open very distally and then you slide the plate. That's the idea of what submuscular plating means. It means that you open only proximal and distal and then you slide your plate. This is the classic plating. This is this one or this one. This is the classic plating. You do the incision; you reduce the fracture; and you put your plate. And it works. It has a little high incidence of infection or nonunion but it works in 95% of the cases. So, it is an acceptable method of treating.

But this is the submuscular bridge plating and this is, I think, one of the three centers in El Paso that published in the submuscular plating for bridge for pediatric femur fracture. So, we open proximally; we open distally; and then we slide the plate; fix it proximally and distally; and leave the area of the fracture. So, first we get the entry point; we put the child traction; putting him on the triangle so we can get the reduction; and then we measure the plate. We do a proximal incision; a distal incision; pass the plate under C-arm so every step is under the C-arm. And then we fix that plate. We bend the plate to take the shape of the femur. And then we apply the screws. First preliminary fixation with K-wires and then we put screws there. So, that's how it ends here -- two incisions -- the plate is on the bone and then you fix the plate proximally and distally. That's how the end product works. So, fixation proximally, fixation distally, and then you leave the area of the fracture.

We depend on indirect reductions. There's an instrument like... we use this instrument. We call it the "F-Tool" because it looks like the letter “F.” And then we use the C-arm, triangles, traction. This is the bone hook. We use different tools to try to get the indirect reduction. And then we fix the proximal, fix distal, expand the whole plate. And this is their follow-up. Here is another example of proximal fractures: We pass the plate; fix it proximally; fix it distally (small incisions); and then usually it heals very quickly because we didn’t open over the fracture.

On this five-year-old child, we tried a cast. It didn’t work; so the same thing -- proximal fixation; distal fixation; and then you leave the fracture and it will heal faster. Another example here: There is a small incision over here; small incisions there; put the plate; and this is the end product. Another 13-year-old with osteogenesis imperfecta... Again, two small incisions; we pass the plate; fix it proximally; and fix it distally. And usually they have very quick recovery.

And we just published this article in May in the “Clinical Orthopedic and Related Research.” We use it for unstable injuries. We use it usually in the kids below 12 years old because after 12, it's better to put rigid nailing. It's faster and a little bit technically easier. And we use it for metaphyseal fractures because the nails are not as rigid in the proximal and distal part.
Principles of Treatment of Shaft Fractures: We discussed some of the surgical treatment so we spoke about the external fixation; we spoke about the flexible nail, rigid nail and the plates. So, if it's a stable fracture in a young kid, we can apply the spica. If it's very young, you can apply the Pavlik harness; elastic nails for kids which are less than 100 pounds with stable midshaft fractures. And then for unstable fractures, if they're less than 12, you use the submuscular plating; if they're older than 12 that means that the diameter of the canal is bigger and the physis are further away from the trochanter, we use the trochanteric lateral edge nail. And of course, if there's polytrauma and the child is not stable, you can apply Ex Fix (external fixation). If you don't have a C-arm, you can do the conventional plating as we said.

Are there any questions about diaphyseal fractures and methods of treatment?

Now, we’ll discuss the proximal femur fractures. The proximal fractures are all this area of concern -- the proximal femur fracture this is the growth plate that, as we discussed before, is the area in which the child grows. If it happens here, it's called type I; if it happens in the neck here, it's called type II; type III is at the base of the neck; and IV is intertrochanteric. Why do we discuss proximal femur fractures separately? Because again, we discussed the blood supply to the femur -- there is the blood, the medial femoral circumflex artery comes from here and gives the blood supply. So, if you have a fracture here in the neck, you will affect the blood going to the head of the femur and that can result in affecting the blood supply to the head.

This is a child here who had a fracture of the proximal neck here in this area. So, we tried to get the reduction without opening if we can. We put him on a fracture table; get the reduction; get the C-arm pictures; and if the fracture is reduced -- if you see here, it's reduced. It's reduced here. We also try to aspirate the blood because this is one of the theories. Why? Because if you have a fracture, you will have blood in the capsule and that can compress on the blood supply going to the head. So, we try to decompress the blood and then we fix them with the screws or a plate.

This is another example. This is a ten-year-old, fractures. This could not be reduced closed, so we had to open and put a plate for them.

So, proximal fractures are considered an emergency because you don't want them to have an effect on the blood supply. So, as quickly as possible you'd like to reduce the reduction, aspirate the hematoma, or do an open reduction. If you do an open reduction, of course, that will aspirate the hematoma itself. And then you apply fixation. So, for a proximal femur fracture, try to treat them as quickly as possible to save the blood supply going to the head.

We spoke about the shaft; the diaphysis; we spoke about the proximal and now we'll discuss the distal type. Distal fracture: There are three main types of distal fracture. It's either a buckle fracture; or minimally-displaced fracture; it can be physeal injury; or it can be a metaphyseal injury as we see here.

This is the distal femoral physis. So, this is the proximal femoral physis and this is the distal femoral physis. The distal femoral physis is the most active physis in our body. Children grow 1 cm a year from the distal femur. That's why most of the tumors -- most of the disease -- happens in the distal
femur because this is the most active growth plate in our body. And it's very non-forgiving. So, if you have an injury to the growth plate of the distal radius (which is very common), 95% of them will not have an affection of growth; but with the distal femur, 50% of the children with injury to their growth plate will have an affection of their growth.

So, the growth plate of the distal femur is very non-forgiving because of the shape of that growth plate. It fuses around the age of 14 years old in girls and 15 years old in boys. About 1 cm a year we grow from here. It is about 6 mm. This is the second fastest one. But this is the most active growth plate in our body.

The first type is the minimally-displaced supracondylar fracture. And this can also be associated with child abuse. The treatment is very simple -- either the spica cast or high above knee cast. This is patient here who presented with a femur fracture, minimally displaced. You can apply a spica cast or just a long above knee cast.

Physeal injury: The physis type I injury in which you have a separation of the physis along the entire length of the physis. If you have a piece of the metaphysis, it is type II; if it's a piece of the epiphysis, type III; type IV, piece of the epiphysis and piece of the metaphysis; and type V is a compression injury.

Type II is the most common type. A physeal injury of the distal femur is very important because in this area, the popliteal artery is very close to the bone. And it is this area in which the popliteal artery goes through the adductor magnus and it cannot move too much. So, when you have a distal femur fracture that has been pushed, it can affect your blood supply.

The growth disturbance: Let's speak about growth disturbance. Around 50% of the kids who have a distal femur fracture can have a growth disturbance. This is a kid that had an injury to her distal femur when she was five years old. She presented when she was 11. And this growth plate is much slower than this. She has a 5 cm difference. So, we applied an external fixator rail; we broke the bone; and then she kept lengthening herself 1 mm a day till she was nearly equal. So, this is the shape of the external fixator. And this is not an external fixator for trauma. This is external fixator for lengthening.

Management: Examination of the neurovascular bundle is very important. This is the one that you read if you have a proximal tibia or distal femur growth plate disturbance, you have to examine the neurovascular bundle because the physis are very close. Urgent closed reduction versus open reduction because you don't want to have a compression over your vessels for a long time and the fixation is either by K-wires or screw fixation. So, we will see some examples of that. But most importantly -- if you have a distal femur fracture, you have to get a very good assessment of the neurovascular bundle and you have to try to get your reduction as soon as possible.

So, here is a patient who presented with an open distal femur fracture. You can see the bone here. Here's the growth plate. So, this part has to be here. This is the AP; this is the lateral view; and this is the clinical picture. We assessed him with an angiogram and if you can see, the blood vessels are still continuous here; and here are the blood vessels there -- very close to the injury. So, we reduced them
and we put smooth K-wires. We'd like to put the smooth K-wire across the physis so you don't add an injury to the growth by adding a threaded wire. And this is after five months.

This is another injury here. We reduced it and we put screws around it, but you can't cross the growth plate with the screws because they can affect the growth. So, if you put the screw, it has to be parallel. This is type II because it has a metaphysis here.

Metaphyseal fractures: These are the ones that happen a little. So, here's the growth plate. If the injury happens here, it's a physeal injury; if it happens above, it's a metaphyseal. This is more common in adolescent and in high injury.

And this is another patient with a fracture here. We reduced the fracture; put a plate and screws; and here is his function after, I think, eight weeks. We published that also: Distal Femur Fracture Fixation.

This is the last case example we're going to present. This is a child with a dirt bike injury. He had a shaft fracture but also at the same time, he had a distal femur fracture and patella fracture. And this is his CT. You see the patella is broken and the distal femur is completely comminuted. We put in a submuscular plate. We opened here. We opened here. Slide the plate and we did an open reduction of this part. It was in a CPM machine. And that's how he ended. At the final follow-up, he had a 5 cm shortening because that growth plate was completely destroyed. But he had reasonable function and I offered him the same lengthening as the other girl, but he didn't want that. That is his function. And that's his final x-rays one year later. So we see the difference -- but he healed here and he healed here.

So, the take-home message from the lectures is the femur is a very strong bone, so if you broke your femur, that's a high-energy injury. You have to really examine the child. The previous lecture was a very good orientation for us about how to examine and evaluate a child with an injury. And then femur fracture in a child less than one year old, or in other words a nonambulatory child, is a red flag. It can be due to nonaccidental trauma.

And for the shaft femur, there're multiple treatment options that you can use. It depends on the child's age or on the fracture pattern.

A proximal femur fracture is an emergency. You'd like to reduce them as soon as possible to avoid AVN of the femoral head. And the distal femur fractures can be associated with neurovascular injury and can lead to eventual growth disturbance later on.

Thank you very much.

Presenter: Amr Atef Abdelgawad, MD

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