DR. MEGHA PRASAD: Hello, everyone. I'm Dr. Megha Prasad, the cardiovascular fellow at Mayo Clinic. During today's roundtable review, we'll be discussing five keys of ICD tracings. I'm joined by my colleagues Dr. Paul Friedman, who's the vice chair of Cardiovascular Diseases, as well as Dr. Siva Mulpuru, who's also an assistant professor in the divisior of cardiovascular diseases. They're both specialized in electrophysiology. Thank you so much for joining us today.

DR. PAUL FRIEDMAN: Thank you, Megha.

DR. MEGHA PRASAD: To start off with, could you talk to us a little bit about what are some important things to consider in the history, physical, and chest dexterity when evaluating a patient who's having trouble with their device?

DR. SIVA MULPURU: I think history provides important clues to the reason why patients receive shocks. If patients have a passing out spell, or if they at least experienced palpitations, it's more likely that patients were experiencing arrhythmias before shock delivery. If the patient is completely asymptomatic, and all of a sudden, they start receiving shocks, you think about device malfunction. If they are in an unusual situation, in situations where you can experience electromagnetic interference, they won't be symptomatic, but there is a possibility of receiving ICD shocks.

DR. PAUL FRIEDMAN: It's good to ask the patient what they were doing at the time of the shock. So for example, if they say they were throwing a football, or doing something with their left arm, and the device is on the left, you think about the lead moving. And if there's a break in the cable, the filers, the small elements, rub together and make electrical noise, the device thinks it's been ventricular fibrillation, gives an unneeded shock. Or if they were using power tools in a wet basement, I've actually heard that one, you think, well, there's a high likelihood of electromagnetic interference.

The chest x-ray can also give some additional clues, and if we look at this one, for example, here you see a patient with a pacemaker. And you'll notice that the lead is all twisted and coiled up here. And if you follow down there, even some coils down inside of the body. This patient had Twiddler's Syndrome, that is, the person inadvertently or subconsciously, rather, would sit and twist the device in the pocket. You see it more commonly in people who are overweight, women more commonly than men. And often you'll ask them, and they're not aware of it, but you see this turning and twisting, which tends to twist and twist the leads, putting tension on them, and ultimately, leading to their breakage. And if you look at the next slide, you can see, side by side, the more typical, so-called normal one, where the leads tend to be more straight, versus this very twisted and coiled appearance.

Another important area to look at, is the region just under the clavicle. Part of this depends on what implant technique was used. And if the lead is placed using an anatomical subclavian approach, So the implanter puts his or her hands to feel the anatomy, and then comes in at a very horizontal angle, often the lead may pass just under the clavicle, between that and the first rib. They can actually go through the subclavius muscle, that's just under the clavicle, or its tendons, and that muscle, or its tendons, can exert mechanical force on a lead, right where we see this arrow on the x-ray. And that can cause, as you can see here now, a lead that was removed. Here we see the actual outer insulation is disrupted, and the filers, that is the individual coils within the lead, were also mechanically disrupted. So those kinds of clues on an x-ray may give us some hint, in terms of what led the device to malfunction.

DR. MEGHA PRASAD: Those are some really interesting chest x-rays, thank you for sharing those. What about a normal electrograms? How do you go about interpreting those?

DR. SIVA MULPURU: So with a commonly defibrillator system, in this example, we have a single chamber ICD, which has a generator in the pre-pectoral region, which is commonly connected using either a single coil or a dual coil to the right ventricular myocardium. So we have various sets of signals that are recorded on the device. We'll go over the first one, which is a near-field, where the device is recording between the tip on the ring, that denotes local myocardial de-polarization. The device decides whether it is normal rhythm, or abnormal rhythm, like ventricular fibrillation, by analyzing this near-field signal.

The device can also record from the tip to a coil, a bigger antenna. recall it as a far-field signal, and it is useful for discrimination of rhythms, whether it is an SVT versus VT. You can also see a marker channel below. The device look for these signals, and annotates them, whether it is an atrial event, or a ventricular event. Lastly, the device can also record a signal from the can, to the SVC coil, typically it is annotated as leadless ECG. So the ICDs have a property of looking at dynamic signals. They can look at a regular myocardial de-polarization during normal rhythm, but at the same time, change their sensing to be able to see changing morphologies of signals during ventricular fibrillation.

DR. MEGHA PRASAD: Could you talk just a little bit about how to interpret the abnormal electrogram?

DR. PAUL FRIEDMAN: Sure. So if you're seeing a patient who received a shock, or there's some question as to whether the device is working properly, the first question is, well, how are you going to get the electrograms out to look at them? And there are two common ways to do it. One is with a programmer. So, a programmer's a device like a small computer. The newer ones are based on a tablet. You hold a wand over the patient, and push an interrogate button, and it'll give you a printout, and we'll go over some of those strips.

But the other thing to remember is that a lot of patients now have remote monitoring. They're getting their signal interrogated at home. So when they go home with a defibrillator, they'll get a small box, they'll put it on their nightstand to plug it in, and every night it will wirelessly communicate with the implant, then send that information over to a secure network to a server, and that information is available. So often, we may have information readily available to us, just by contacting the manufacturer, or the physician's specialist who put in the device, if we need access to those.

If we then want to look at tracings, there are certain characteristic findings. And the first one that we'll look at is from a patient, a 60-year-old man who was working overhead all day, and then he received a shock. And so, on the top, we see the atrial channel. So this is recorded from an atrial lead, and it tells us that the atrium, we can look down here, where it says 8 paces being paced. And what you notice is on the bottom now, there are two V paces, and then there's all of this high frequency signal that looks abnormal. This high frequency fluctuating in a time saturated signals are characteristic for a lead fracture. And you may say, well, why does a broken lead cause this? Well, the leads are made up of multiple small conductors. And those small conductors are intertwined to form a cable. And if a cable is broken, it's usually not a complete break, it's a partial break. And as those little metal elements rub together, they create these high frequency signals, and you can see what happens.

We see noise, we say, this does not look like a normal heart signal. But the defibrillator's saying boy, this is rapid, it has very short intervals, it could be ventricular fibrillation. You get enough of these together, and the device will say ventricular fibrillation has been reached, and give a shock. Now if you have the person in clinic, and you turn the device off or put a magnet on it to deactivate it, then you have them do maneuvers. Take your hands and push them together, pull them apart in front of your chest. You can reproduce these.

If someone is being paced by the defibrillator, you may also get a pause, because the defibrillator's seeing all these extra beats and saying, oh, I don't need to pace. Or there may be a ventricular arrhythmia going on, so it stops pacing and starts detecting arrhythmia. So that's one characteristic, very high frequency. And in this slide, it's really classic. Unrelated to the heart rhythm, it's usually intermittent, you don't see it for the whole time. Sometimes motion of an arm or parts of the cardiac cycle will put the lead in a position to cause that kind of noise.

On the other hand, if we look at this next slide a compendium of potential kinds of malfunctions. So we saw on the left a conductor fracture. That this is the first image on the left, kind of shows that. In the middle is electromagnetic interference. And I just want to highlight, Siva pointed out that we have far field and near field signals. A far field signal, as he pointed out, was large conductors, an RV coil to a can, separated by a great distance. And when you have that, the physics of it gives you a big antenna. So it's very sensitive for picking up signals from far away. The near field, tip to ring, closely spaced, small electrodes, just senses a tiny bit of muscle.

If you have something coming from outside of the heart, you'll likely see it in both, as you can in this middle panel labeled EMI. It has nothing to do with the heartbeat, the frequency is much higher than the heart rate, but notice it's bigger on the far field than the near field. The big antenna's more sensitive to it generally. Myopotentials would be like the diaphragm. You get high frequency muscle, and if we had a longer segment, you may see this come and go at a respiration cycle length. So it'll get big when you breathe in, and then get small, or something like that.

And lastly, this is what VF looks like. There are actually intervals between it when you look at a defibrillator and the cycle length, the time interval between these may be 250, 260 milliseconds. And the last electrogram that is interesting to note, is this one. So here we have atrial signals. Here we have ventricular signals, and sometimes, you can see we get double counting. And here what's happening is the T-wave is so big that the ventricular lead sees it and the QRS, we get T-wave over-sensing, and since the first step for deciding if arrhythmia is present or not is the time interval between events, it's going to count this inappropriately as a VF event, and it can add up to give a shock.

DR. MEGHA PRASAD: Could you tell us a little bit about interpreting impedance and threshold numbers?

DR. SIVA MULPURU: So the device frequently monitors how much resistance is there between the can and the lead tip. So it keeps track of the values over time. And when it exceeds above a particular value, or below that particular value, it can send an alert in the remote monitoring. And the patient may notice audible alerts from his device. So in this picture, you can see a pre-pectoral device that is connected to the heart muscle using a lead. And if you imagine if you have a break in the conductor that carries current to the tip, you can have a very high resistance. So lead fracture typically is associated with non-physiological signals, like the noise that Paul has described, associated with a very high impedance. And the reason for that is the rubbing together of these filer elements, sometimes that don't make any contact at all, like as shown in this picture. The impedance is going to be sky high, and you won't be seeing any signals.

On the other hand, if you have a break in insulation over time, the current now can easily travel to the tip through the blood stream. So the impedance values can be lower than programmed values, and patients can experience an alert. So it's important to note that the absolute numbers are not important, but it's the trends with time. If you have an abrupt increase, or an abrupt decrease, it may suggest you have a lead malfunction.

DR. PAUL FRIEDMAN: Are there any numbers or ranges that you keep in your head? For a pacing lead, what's kind of a normal range for a defibrillator lead, and if it's more than this number, I worry, if it's less than this number, I worry? Just kind of a reference that's useful for us to think about.

DR. SIVA MULPURU: So in general, for a pacing lead, if the number is less than 200, I worry about insulation break. And if it is more than 1,000, I would worry about conductor problems. For a defibrillator lead, when we look at coils, because of a larger surface area, the impedance is typically lower. And if you have a coil fracture, the impedance is more than 100 ohms, in general.

DR. MEGHA PRASAD: Lastly, could we discuss how you would approach a patient in an emergency situation, who's being shocked, who we know has the device?

DR. PAUL FRIEDMAN: Sure. I think the first thing to do is stay calm. Remember, you have control of the situation, and there is an absolute algorithm, and I'll put up a slide and just walk through it. If a patient is in front of you, the very first thing you want to do is determine whether there is an ongoing arrhythmia, or low blood pressure, as we normally would with any cardiovascular patient, and if so monitor, and begin ACLS. If the patient is conscious, and they've had frequent shocks, or they're getting shocks, step number one is apply a magnet. Applying a magnet to a defibrillator will disable shocks. It does not affect pacing, but it will disable shocks. So that's a key thing to remember. If you're in an emergency, if you apply a magnet, you now have a patient without a defibrillator. It's a standard cardiovascular patient, that you would apply advanced and basic life support, the way you would any other patient. Always good to have an external defibrillator and put it in place, call the ACLS team, the code team, if you don't already have those resources with you.

Then, if that person has no ongoing arrhythmia, and you put them on the monitor, and you see shocks without any arrhythmia, then clearly, the device isn't working properly. So apply the magnet so they don't get any more shocks. Keep them on the monitor in case any arrhythmia does develop. They need to be admitted for a consult. That system has to be repaired, and you want to prevent inappropriate shocks. So again, you see a shock during normal rhythm, magnet turns the device off, call the consult.

On the other hand, suppose you monitor them in the emergency room, and you don't see any arrhythmia, and you don't see any therapy. Then you talk to the patient, and get a little more history. If there was just one shock, if the patient. otherwise feels quite well, if they've not had a number of similar events recently, so you say, well, maybe the last one was two years ago, five years ago or never. And they feel well, then you can say, well visit your heart rhythm specialist tomorrow, or in two days, I wouldn't wait too long. But it can be done non-urgently. It's just the device probably did what it should do. And remember that many people have remote monitoring equipment, so they could send a strip right away, and if there were a problem, you could find out right away.

Otherwise, if there's a change in status, if they say, well, I got two, three, four shocks, or if they have shortness of breath, or chest pain, or other symptoms that are concerning. If they fainted, well then you're going to want to admit that patient to further work up what's going on, and what triggered the device to become active.

DR. SIVA MULPURU: And the shocks are very painful, so if the patient is experiencing multiple shocks, sedation, if it is you do in an arrhythmia, is also a reasonable option.

DR. PAUL FRIEDMAN: Yeah, absolutely. In fact, in some cases, if you have VT storm, general anesthesia not only alleviates pain, but will lower autonomic tone, and is one of the treatments for the arrhythmias.

DR. MEGHA PRASAD: Thank you so much, Dr. Friedman and Dr. Mulpuru. Those were some very educational points you made. Thank you for joining us on theheart.org on Medscape.