YOGESH REDDY: Hi. This is Yogesh Reddy, cardiology fellow of Mayo Clinic. During today's recording, we'll be discussing the very common clinical scenario of a left bundle branch block on EKG. I'm joined today by my colleagues, Dr. Siva Mulpuru and Dr. Suraj Kapa, both specialists in this area. Welcome.

SURAJ KAPA: Thank you.

YOGESH REDDY: So first, Dr. Kapa, how does a left bundle branch block affect electrical activation and mechanical contraction?

SURAJ KAPA: Thank you, Yogesh. So a left bundle branch block is basically referring to abnormal conduction where the normal typical approach to how the ventricle activates in response to an impulse beginning in the atria doesn't go down the normal highways of the heart. When we think about that, after the atria beats, an electrical signal is sent to the AV node. From the AV node, if propagates through the Bundle of His, and then goes through two major highways, the left and the right bundles.

When you see in this picture, the left bundle branch actually takes that signal and sends it down three further major highways. And typically, those include the left anterior fascicle, the left posterior fascicle, and in many patients, the left upper septal fascicle. Beyond that, those fascicles further go into multiple purkinje fibers that activate multiple areas of the left ventricle almost nearly simultaneously. The reason for these highways and these areas of rapid activation compared to normal myocardial activation is in order to allow for multiple areas of the heart to activate near simultaneously. In fact, the last area of the heart to activate in the left ventricle is the posterobasal section.

By allowing multiple areas of the heart to activate simultaneously, it results in the potential for greater mechanical force. One way to think of it is if you're playing tug of war. When everybody pulls together, it's much more effective than if individuals are pulling separately. So the effort of those highways in actually activating multiple areas of myocardium near simultaneously permits the opportunity for activation and for optimal mechanical contraction.

When we talk about mechanical dyssynchrony resulting from electrical dyssynchrony, it essentially results from the fact that the left bundle branches out. So now you have to go down the right bundle branch, and then you have to, after activating the right ventricle, walk over to

the left ventricle through slower myocardial activation, and then start activating the left ventricle. So you're actually getting somewhere where the right beats somewhat before the left as opposed to both together. And that in part contributes to the development of mechanical dyssynchrony, and in many cases, lower ejection fraction and thus heart failure.

YOGESH REDDY: So obviously an important implications for the diagnosis. So Dr. Mulpuru, since it's such an important thing to be sure about, how do you recognize a true left bundle branch block on EKG?

SIVA K MULPURU: So EKG is one of the greatest tools that we have today to recognize left bundle branch block. As you can see, you know, the QRS becomes wider when you have electrical dyssynchrony. As the left ventricle is posterior in lead V1, you have a negative QRS complex.

There are certain criteria that are describe to recognize true electrical left bundle branch block. Let's go over them. In general, when you have a true left bundle branch block, now the septum is activated from right to left. Therefore, you won't see any negative tiny Q waves in lead 1 in AVL. And you tend to have a discordant T waves. The wider the QRS, more likely it is a true left bundle branch block.

And you also see some signs of fractionated or signs of delayed activation in the lateral pericardial leads. The first peak is an activation of the right ventricle. And the second peak is the activation of the left ventricle. In summary, a wide QRS, more than 120 milliseconds, which is negative in lead V1, discordant T waves and this fractionation in the lateral pericardial leads help you recognize a true left bundle branch block when you see on an ECG.

YOGESH REDDY: Thank you for that. So obviously we've established that it's a bad thing. So how do you correct it Dr. Kapa?

SURAJ KAPA: Great question. So the effort to correct a left bundle branch block lies in the desire to restore this near-simultaneous activation of left and right ventricle in order to make them beat together as opposed to essentially making them be separate, getting back to that tug-of-war idea. So in order to achieve that, we essentially, in the modern day, primarily use a special type of pacing device or a defibrillator device, where in an extra wire, not just one that goes to the right ventricle, but one that also goes to the left ventricle, is used.

Now in using a wire that goes to the left ventricle, traditionally while even though research is still being done in this regard, we place one via vessel called the coronary sinus. Now, what we

mean by the coronary sinus is when you come into the right atrium, most venous blood return from the heart itself returns into the right atrium via the coronary sinus. That coronary sinus allows access for a wire to be placed that can wrap around the epicardial or outside surface of the heart and extend to the left ventricle.

As you can see in these AP and lateral chest X-rays, the lead placement includes a wire that has two coils, those thicker white areas that are extending to the right ventricle, and a separate wire that is more visible in the lateral view that is extending to the more posterior aspect of the heart where the left ventricle, as Dr. Mulpuru mentioned lies. This allows the device to have the opportunity to deliver pacing stimuli via both the right ventricular pacing wire and the left ventricle pacing wire simultaneously.

The mention about those leads V1, V2, one in AVL, as shown in this fluoroscopy-- or X-ray image, is that because of recruitment based on where the left ventricular lead is, in V1 and V2, you'll typically see a very positive deflection because as you pace the left ventricle, you're going to actually have forces that primarily go out towards V1, V2. And because you're pacing and contributing more from the lateral surface of the heart, similarly you'll see that one in AVL will be negative because it's going to be going away from the lateral portion of the heart.

As we see in these ECGs, we're doing right ventricular pacing because you're pacing more from, oftentimes, the septal portion of the heart, leads 1 and AVL will often be positive with net forces going towards them in away from AVR. And we-- this is V1 and V2 will also often be more negative because you're looking from the heart from a more anterior view. Whereas during left ventricular pacing one in AVL will often be negative because you have forces primarily going away from the lateral surface of the heart. As you see here AVR becomes more positive because the forces are flowing towards AVR. And V1 V2 are more positive because you have these forces coming from the more posteriorly-located left ventricle extending out towards the more anteriorly-oriented V1 and V2 leads.

The net forces we're looking for an appropriately biventricularly-paced ECG include being negative in one in AVL and positive in V1 and V2. We're looking for a situation where the net vector is allowing for more left ventricular contribution. You want the primary contribution as you initiate conduction to be left ventricular in order to allow for optimal resynchronization.

Now, there are many studies that have been done in order to look at whether or not there are specific leads that are optimal or better for resynchronization, such as mulitpolar leads. There

are also studies looking at where in the coronary sinus is a lead should be optimally placed. We won't go into those in detail. But suffice it to say, these resynchronization efforts have allowed physicians to permit better activation and more physiologic activation of the heart. While it isn't truly physiologic activation as you would normally see from an intact, His-purkinje system, it does allow, in many cases, for improvement in the myopathy that results from admirable conduction.

YOGESH REDDY: So along those lines, so where do both of you feel the field is progressing now? What is the future of resynchronization therapy?

SIVA K MULPURU: That is a great question. Several advances have been made in the last few years. As Suraj explained, the CRT does not really correct the conduction system abnormality. And we are basically working at the myocardial level.

Some of the investigators thought, what if we paste the conduction system and restore the normal activation of the heart. Will that correct the electrical abnormality? And I think that's a very important advance in our thinking and our understanding of resynchronization in the last few years. Here in this cartoon, you can see the AV node which then continues as the bundle of His, traversing through the membranous septum, which then continues as a right bundle on the right side, on the left bundle on the other side.

So some of the investigators looked into pacing the bundle of His, the conduction system itself, to overcome the left bundle branch block. Now how does that work? Now, in the-- just like how we do our EP studies, we have specially designed mapping catheters. We can map for areas of His bundle-like signals, purkinje-like signals. In this cartoon, you can see a high frequency signal before the complex that lines up with the QRS.

When you screw in the pacing lead in this area, you can essentially result in a QRS that resembles a normal conducted beat. In this tracing, you can see when we are pacing high output on the left hand of the tracing, the QRS is narrow. And as the output is decreased, the QRS widened, showing that we lose capture of the conduction system at low output.

Now, chest X-ray can be a little bit confusing when you see these patients with His bundle pacing. It almost looks like two atria leads in a two big Js. But not to be confused, this second lead is actually placed in the region of the His bundle and actually causing a connected beat that results in a QRS resembling a sinus beat.

Now in this tracing, I want to show you on the first two beats, the QRS is very wide. And it is a true left bundle branch block. And this particular patient we place a lead in the region under His bundle.

So you can see the QRS has completely normalized. We have narrowed down the QRS to 93 milliseconds. So this is a new advance and potentially avoiding that lead placement in the coronary sinus.

However, it is not without downsides. You can potentially injure the conduction system. In this particular patient, you see a development of complete hard block once you screw in this pacing lead. And we see that in about 10% to 20% of the patients.

SURAJ KAPA: In addition to His bundle pacing, there are other studies that are being done both clinically and in animal models in order to understand, can we achieve synchronization through other means? People are looking at placing pacing wires actually on the endocardial surface of the left ventricle. One of the fears about this is the potential for forming clot or thrombus on these leads that can, if it came off, cause a stroke. However, there's some people who believe that it might actually be safe in the modern era, and thus there are clinical research studies being done in this regard.

In addition to this, there are initial clinical feasibility studies of using an uniques form of leadless pacing that essentially involves sending pellets into the left ventricle that can be activated via ultrasounds, and thus result in activation of the left ventricle somewhat through an minimally invasive mechanism without the traditional wires that traverse the entire intravascular system. Another area that people are looking at is use of epicardinal wires that can be delivered percutaneously either through a direct epicardial or outside-the-heart approach through a subxiphoid puncture or other mechanisms.

And then if you talk about the next 10 to 20 years, or even longer, people are looking at biologic pacemakers where we can actually transfect viral vectors and actually recreate an AV node. And people have shown that in animal models they are able to do that. Or other forms of changing the very nature of cells so they respond to light stimuli, a term we call optogenetic stimulation, they might allow for different methods of causing resynchronization without the use of any hardware.

YOGESH REDDY: Fascinating. So thanks again Dr. Mulpuru and Dr. Kapa for these very important insights. And thank you for joining us on the Heart.org on Medscape Cardiology.