STEMI/NSTEMI and OMI/NOMI Paradigms

Announcer: Welcome to Mayo Clinic's ECG Segment: Making Waves, continuing medical education podcast. Join us every other week for a lively discussion on the latest and greatest in the field of electrocardiography. We'll discuss some of the exciting and innovative work happening at Mayo Clinic and beyond with the most brilliant minds in the space and provide valuable insights that can be directly applied to your practice.

Dr. Kashou: Welcome to Mayo Clinics, ECG Segment: Making Waves. We're so glad you could join us. Today we have an exciting episode planned for you. As we discussed the STEMI/NSTEMI and the OMI/NOMI paradigms. We will be joined by an expert in the field that will dive into both paradigms and help us better understand how we should be thinking about these, let's get started. The ECG can detect myocardial injury and thus remains the most widely used diagnostic tool in the detection of acute myocardial infarction. Early of acute myocardial infarction can impact immediate patient care and long-term outcomes. For such reasons, ECG criteria have been devised to identify such patients and guide patient care. For instance, early recognition and immediate reperfusion therapy of patients with ST elevation MI are known to have better outcomes. Fortunately, most trained clinicians can detect these common STEMI patterns. However, there remains a large subset of patients that do not present with the typical STEMI patterns yet they have similar underlying pathophysiology that is acute occlusive disease, and they would benefit from immediate reperfusion therapy. In fact, there are known ECG patterns that reflect this. However, these patterns are not widely known or accepted in current guidelines. In other words, we are aware of ECG patterns that can improve patient outcomes, although they are not yet implemented in clinical practice, outside a relatively small group of clinicians with prior knowledge. And that brings up us to our focus today, namely the problem with the current STEMI, non-STEMI dichotomy, we will also look at what occlusion MI and non-occlusion MI the OMI/NOMI paradigm, what that is. How can we make an occlusion MI diagnosis on the ECG outside of the STEMI criteria, and how can even the novice ECG interpreter learn how to recognize these occlusion MI patterns on the EKG. We'll be discussing this all today with one of the leading experts in the field on this topic. And with that said, let me introduce you to today's special guest, Dr. Steven Smith. Dr. Smith has been on the Faculty of Emergency Medicine at Hennepin Healthcare in Minneapolis, Minnesota since 1991. He has published extensively in emergency cardiac care, including on the diagnosis of acute myocardial infarction with troponin, especially by way of the ECG. In fact, he has published a 38 chapter book entitled, "The ECG Diagnosis of Acute MI". He has written several other chapters, textbook sections and dozens of peer reviewed articles on the topic. In 2008, he began writing the now famous, Dr. Smith's ECG blog, a free open access site with over 1300 posts, highlighting complex ECG cases. It has garnered a worldwide following with nearly 20 million page views. His ECG insights are sufficiently insightful and cutting edge, and that he's gained a tremendous social media following with over 35,000 Twitter followers and over 80,000 Facebook followers. Since 2014, he has lectured on what he has coined the false STEMI/non-STEMI dichotomy. Recently, he and his colleagues introduced the occlusion MI paradigm as a replacement for the STEMI/non-STEMI paradigm. In promoting this new paradigm, he gave of the annual Keynote Rijlant Lecture at the annual meeting of the International Society of Electrocardiology, and is expected to give the next keynote address this year to the International

Society for Computerized Electrocardiology. Without further ado, Dr. Smith is with us. It's such an honor to have you here. Thank you for joining us today.

Dr. Smith: Thank you so much for inviting me, Anthony.

Dr. Kashou: Yeah, I've been, like I said, looking forward to this conversation, such an important topic, and I don't wanna waste any more time, so let's just dive right into it. And, you know, I think it's best for our audience because this could be new to them to first define what is that STEMI/non-STEMI dichotomy or the paradigm we call it, and what are the current problems with this existing paradigm?

Dr. Smith: The problem with the STEMI/non-STEMI dichotomy is it relies not on the underlying pathology of occlusion, which leads to irreversible infarction of otherwise viable myocardium, rather than relying on that underlying pathology, it relies on one aspect of the ECG, which is ST elevation. If you look at other aspects of the ECG, which include the entire QRST complex, and that you can make the diagnosis of occlusion with much higher sensitivity than with ST elevation alone. But even that does not define the OMI/NOMI paradigm because that paradigm is not defined by a test, it's defined by the underlying pathology. So in all of our studies of the ECG in occlusion myocardial infarction, we don't use the ST elevation or the QRS or any aspect of the ECG as our outcome variable, we use, did the patient have an occluded coronary artery at the time the ECG was recorded? And how can we correlate that underlying pathology with the ECG findings, which are manifold and not just ST elevation and certainly not ST elevation of any specified millimeter or millivolt cutoff. So what we use is, so one might think, okay, just look at the angiogram, was the artery occluded at the time of the angiogram? And if it was, we say yes, that correlates with the ECG, we're gonna call that an ECG of occlusion. But what if the artery is open? The problem is there can be a culprit with an open artery that is open only at the time of the angiogram, but was closed at the time of the ECG. Now, how do we know this? Well, there are many studies about with STEMI, people who truly meet STEMI criteria and are diagnosed with STEMI. By the time they get to the angiogram, which may be 30, 60, 90, or 120 minutes later, the artery is open one third of the time. Now maybe TIMI one flow, TIMI two flow or TIMI three flow, but 20% of the time it's fully open with TIMI three flow. TIMI three means completely normal flow through the artery. Now, remember that the ECG does not measure stenosis in an artery. It only measures perfusion at the cellular level. So if the artery is completely open, I should say, there can be a very severe stenosis, but have TIMI three flow. So the ECG will not detect that stenosis. It will only detect the absence of flow. Now, let's say you have an ECG at the time of chest pain, and it shows maybe very subtle, hyper acute T-waves. And fortunately, someone recognizes that and they take the patient to the angiogram, and the angiogram shows it's open. Now you've confused. It showed hyper acute T-waves but the angiogram's open. You have to remember that the artery is frequently open even with a full blown STEMI. So how do we determine whether that artery was closed or not at the time of the ECG? And what we've come to is we use a troponin, a peak troponin cutoff, peak troponin is a pretty good measure of infarct size. Now it'd be better if we had other more exact measures like MRI, but we can't do MRI at the time of the ECG. What we can do is find out what that troponin did. So there are multiple cutoffs, we've used, for instance, in the past, using contemporary troponin I, which goes in nanograms per milliliter. We've used 10 nanograms per milliliter of troponin I and we've used one nanogram per milliliter for troponin T because that's a much lower

value. And that turns out to be a, in previous literature on STEMI and non-STEMI, those were pretty good cutoffs differentiating between those two pathologies. So based on that, we've gone with using a troponin cutoff in one study by Dr. Oslanger in Turkey, which I was a co-author on, we used five nanograms per milliliter for troponin I, most of my studies have used 10 nanograms per milliliter as a cutoff. It's interesting that we find that in these studies, the exact same number of people who we say on our ECG have an occlusion, the exact same number have TIMI zero, one, two and three flow as have on STEMI ECGs. So we know that-

Dr. Kashou: Now, Dr. Smith, I don't mean to interrupt you, but there's a lot here that you just said, and it's kinda like mind blowing because in some ways we rely on this STEMI/non-STEMI in our guidelines. You know, even though they mentioned some additional criteria, persisting chest pain, hyper acute T waves, they mentioned some of these other findings, maybe even AVR ST elevation in some things that would maybe suggest more urgent therapy, but it's really, I think, most look for a STEMI/non-STEMI, and then the next step is patient management, and it relies on that initial thing, which you're saying is just an ECG finding. And while we know that the STEMIs, you know, likely have occlusive disease, like you're saying, they could open up, but it seems like that cohort should still go to more urgent reperfusion therapy. What I'm hearing is that there's also a subgroup within that non-STEMI cohort and what I've been reading probably over 25%, that may also benefit from more emergent or urgent reperfusion therapy rather than sitting on them. Is that what I'm hearing?

Dr. Smith: Yeah, right, so Khan in 2017, did a meta-analysis of 40,000 patients with non-STEMI. Found that 10,000 of them, all of them taken for angiogram the next day, because they did not meet STEMI criteria. They did not meet the millimeter criteria. Therefore they did not get emergent reperfusion. They went to cath lab the next day, because they ruled in for myocardial infection by troponin. And of course, patients who have open arteries or closed arteries, all need to go to the angiogram and get a stent because they have a lesion there that could in the next year thrombo. So they all go to angiogram. And it turns out that 25% of those 40,000 patients had an occluded artery at the time of the angiogram the next day, those patients had higher biomarkers, compared to the ones with an open artery, the ones with a non-STEMI with a closed artery had higher biomarkers, worse left ventricular function and higher mortality, but the doubled mortality of the ones with an open artery. So we know that, and this is the next day. Now we know that many patients who have a closed artery at the time they present to the ED, open up sometime between the time they present and their next day angiogram, but not necessarily before they have a lot of myocardial damage. So the number is even higher than 25% who have an occluded artery where you can save some myocardium if you take them to the CATH suite immediately.

Dr. Kashou: Yeah, and I wonder, that's why we've seen in the literature that subgroup of NSTEMI patients do worse, they have worse outcomes, and maybe it's because we're not capturing those that we should be treating more early. What are your thoughts on that?

Dr. Smith: Well, exactly. Like I say, in that study and in many, there are studies that were not included in that metaanalysis and in every one of them, the patients with an open artery have lower mortality than the patients with an open artery, and that's about double for a closed artery.

So say 2.5% one year mortality for those with an open artery, 5% mortality, for those with a closed artery at the time of the angiogram.

Dr. Kashou: And so it seems like we have a management plan for those patients, right? One, we just have to identify those patients that should then go more urgently to therapy.

Dr. Smith: Right, we have to figure out how to identify patients who have an occluded artery when they present to the emergency department. Now, the EKG is extremely good at doing that if you know how to read the EKG.

Dr. Kashou: And so we are some of those findings, I guess, that you look for outside of those standard STEMI things, for someone that's novice, what are you looking for?

Dr. Smith: So for it's things like R-wave amplitude, loss of S-wave, QT interval, T-wave size, let's talk about hyper acute T-waves. They're generally defined by most people as T-wave height, but T-wave height has little to do with hyper acute T-waves. It's got more to do with their bulk, their width, how fat they are, how much area under the curve there is for that T-wave. It's also got everything to do with proportionality, which is completely lost in the STEMI/non-STEMI dichotomy. ST elevation, it's also a subtle ST elevation is extremely important. So all of ST elevation, ST depression or T-wave size should be proportional to the QRS, patients with a very large QRS at baseline may have ST elevations proportional or a large T-wave. It also has to do with the type of QRS we have. For instance, we look at normal variant ST elevation in leads V2, V3 and V4, which is sometimes called early repolarization. Those patients have large T-waves. In fact, I studied 343 acute LAD occlusions, and compared it to 171 patients with so-called early repolarization, who have ST elevation of at least one millimeter V2 to V4, the T-wave size was the same in those with myocardial infarction and those with early recall, what was different was the QRS size. So the ratio of the T-wave to the QRS was much higher in acute LAD occlusion, acute OMI, than it was in early repolarization. In that study, we found four variables. We measured many, many features of all these ECGs and came up with a logistic regression formula that uses total QRS amplitude in lead V2, ST elevation at 60 milliseconds after the J point in lead V3, and why do we do 60 milliseconds of the J point? Because that is an indirect measure of T-wave size, if there's a higher slope of the ST segment at that point, that leads to a higher T-wave, R-wave amplitude in lead V4 and QT interval. And we made a formula from those four variables, which is far more accurate than ST- Elevation at diagnosing LAD occlusion. This was all done in patients with subtle ST elevation, not with diagnostic ST elevation.

Dr. Kashou: Now, I mean, you mentioned a formula that potentially is that available anywhere that clinicians can use?

Dr. Smith: I have an app called Subtle STEMI on iPhone app. It's free, you can get it. There's a Android version called Smith ECG, also free, on MD Calc, if you search for early repolarization, it is on there as well. There are a whole bunch of exclusions, before we studied these patients, we made sure they didn't have obvious STEMI. So for instance, if they had Q-waves in V2, three, V4, they were excluded. If they had five millimeters of ST elevation, they were excluded, if they had just one lead that did not have upward concavity in V2 to V6, they were excluded because early repolarization virtually always has some upward concavity. And there eight different

exclusions that can't be left branch block, for instance, you can't have T-wave inversion, you can't have inferior ST depression. All those things are too specific for LAD occlusion to use the formula. So once you've excluded all those things, now you have a truly subtle EKG. One that could be LAD occlusion, could be normal variant ST elevation. And these four variables will help you make that distinction with about 87% sensitivity and specificity, which ST elevation doesn't even come close to. Now, this study was validated by another group in Turkey. So it's not only derived, we derived and validated a three variable formula with our group. Then we derived the four variable formula with our group and the Turks validated the four variable formula, so it works. In their study, ST elevation was 20% sensitive. The formula was 85% sensitive.

Dr. Kashou: So you have a derived validated, even externally validated algorithm, which is one way, this is kind of at least the OMI, the occlusion MI that's one diagnosis. Are there any other patterns that we should clue in on?

Dr. Smith: Yes, for instance, we published on inferior myocardial infarction, and we found that any amount of ST depression in AVL, in a patient who is at high risk for ACS, is, first of all, it's never pericarditis. So people with ST elevation two, three, and AVF of any amount, doesn't have to be one millimeter and especially if they have ST elevation in the later leads, V4 to V6 are often blown off as pericarditis, but we found that not a single case of pericarditis had any ST depression in AVL. So if there's any ST depression, like even a quarter millimeter of ST depression in AVL, it's extremely specific for inferior MI. We combined with a Spanish cohort and found that 99% of inferior Myocardial infarction, OMI, had some ST depression in AVL. So if there's zero ST depression in AVL, it's very unlikely to be inferior MI, and if there's any ST depression there, it's very likely to be inferior MI. So AVL is a very important lead for that. This year, we published on ST depression in leads V1 to V4. So it's been shown in the past that normal individuals hardly ever have any ST depression in V2 and V3, especially. So on some individuals, unusual may have up to a half a millimeter ST depression in lead V2, but it's very unusual. And so anybody who comes in who's at suspicion for acute coronary syndrome, who has any amount of ST depression and V1 to V4 in our study was 96% specific for occlusion MI, for OMI, affecting the posterior wall.

Dr. Kashou: Are you looking for contiguous leads in that?

Dr. Smith: It only had to be in one lead.

Dr. Kashou: Okay.

Dr. Smith: But not contiguous leads necessarily. All it usually is in V2 and V3, often V4. Now one of the big points of this is if you see it in V5, if it's maximal in V5 and V6, then it's much less likely to be OMI, it can be about 33% of the time patients with ST depression in V5 and V6 were due to OMI, but usually it's due to diffuse subendocardial ischemia, which means that the artery is open, but not with transmural ischemia. So the point of the paper was, if the ST depression of any amount, even 0.5 millimeters in V1 to V4, then it's posterior OMI until proven otherwise.

Dr. Kashou: It's really interesting, and there's a lot I wanna ask you. We could look at even AVR or some of the work in when I teach, I still teach it as the Smith Modified Sgarbossa Criteria. So the left bundle branch and all these are different. What I'm hearing occlusion MI, the definition or people are calling them STEMI equivalents, but maybe we just call them a as they are, right? Occlusion MI is OMI. So, I wonder, are there any maybe benign mimickers that we should look out for? Or any other thoughts?

Dr. Smith: Well, there are a lot of benign mimickers. So for instance, I told you about the ST elevation in inferior leads with a little bit of ST depression and AVL. We excluded patients with LVH left bundle branch block, and WPW because those things can also cause those findings, so those are mimickers. Patients with takotsubo is the most difficult mimicker of all, and it's nearly impossible to tell the difference on the ECG between, especially a wrap around left anterior descending artery occlusion and takotsubo. If it's takotsubo, that's ST elevation, much takotsubo presents only with T-wave inversion, which then it's not such a problem, but very often it presents with diffuse ST elevation that is basically indistinguishable. And why is it indistinguishable? Because the cellular pathophysiology we believe is the same that it's diffuse ischemia of all those cells due to small vessel constriction due to catecholamine outpouring. So it that's why you can't tell the difference. It's the same basic underlying cellular electrophysiology.

Dr. Kashou: So we can go on for forever with this. I guess the, before we close here, what are, if you had to just recap some of the key takeaways in terms of say the novice interpreter, doesn't never heard of this, what is maybe one or two or a few findings they should first look at as they're learning about this whole new potential paradigm.

Dr. Smith: First, I'd say that the paradigm is not based on the ECG, it's based on what is the underlying pathology, and the ECG, if you're the best ECG interpreter in the world, you may get up to 90% sensitivity, whereas ST elevation gets about 40% sensitivity, ST elevation at the cutoffs. So one, don't ignore subtle ST elevation. Subtle ST elevation is very likely to be acute OMI, especially if they're associated findings such as Q-waves, such as large T-waves, I won't say tall T-waves, but large T-waves. Get used to looking at how the size of a T-wave compared to the QRS, cause proportionality is everything. Get used to looking at the size, the amount of ST elevation compared to the QRS. If you have a tiny QRS with half a millimeter of ST elevation, that's a high proportion and is very likely to be due to ischemia. If you have something, we started something called terminal QRS distortion in a lead which should have an S-wave, if the S-wave is not there, that's an indication that it's acute OMI. We have many cases where the artery opens and closes. When the artery closes, the S-wave disappears. When the artery opens the S-wave reappears, when the artery closes the S, it's doesn't have anything to do with ST elevation, it has to do with the QRS. So the entire, don't ignore the rest of the ECG. And then when it comes to mimickers, whenever you see something that worries you in the STT part of the E QRS, look at the QRS. The first thing I do when I see something that I think is ischemia, is I examine the QRS to make sure that those findings are not a result of an abnormal QRS, such as ST depression V1 to V4 is frequently due to right ventricular hypertrophy. ST elevation in V1 to V4 is frequently due to LBH or left bone branch block. So always look at the QRS, examine it closely, and then interpret the ST waves in the context of the QRS. And finally, I would say, the way I've come with these formulas is I've been looking at EKGs for 30 years, I've been fascinated by them, and I'm a little bit strange. I have a little bit of an autistic mind, I can

recognize you better by your EKG than I can by your face, so that's how weird I am. So I've been trying for years, what do I see in an EKG that other people aren't seeing? Why do I see it? And all these formulas I've come up with, have to do with me trying to figure out what it is I see that others don't. But my point in this is it's a visual diagnosis, pattern recognition, and the more you see, the better you'll get at this, and you have to see literally thousands of these to become an expert at it. So don't think you're gonna like read one paper or read a few blog posts and get to know this, or follow a couple rules, it just doesn't work that way. The ultimate goal of this then of course, is neural networks. Because really, I don't think as far as ECG reading, I don't think physicians, a high percentage of physicians are ever gonna get to that point. It's just too much work and they have many different things they need to learn. So we need to train neural networks in this, that's the ultimate goal, but in the meantime, don't forget that you might be missing an OMI when you look at an EKG, that's the bottom line. You might be missing it, and how are you gonna figure out if it's something else? Well, you may have to do an immersion echocardiogram. You may have to, if the first troponin comes back a little bit, even if the first troponin's negative, it still could be an occlusion MI. So you have to keep your index of suspicion high, keep doing serially EKGs, compare it with an old EKG, and you may ultimately even have to do an angiogram that turns out negative, if you're not gonna miss this. If you miss it, the patient loses myocardium, maybe it gets congestive heart failure, certainly has a shorter lifespan, so don't miss this opportunity.

Dr. Kashou: That's it, and I just wanna emphasize that when we're learning ECGs, initially we learn about all these criteria and things, and that's kind of the basics. We need that foundation to then be able to approach this, but it is really the pattern recognition and with AI and deep learning, and now in the form of convolutional neural networks, that is it, it's able to capture subtle cardiac biosignal changes that may be able to adapt and do it so way better than a clinician can. And we're like drinking from the fire hose, with all these new devices, new medical literature that we're trying to keep up with. And so, that doesn't mean it's gonna replace the clinician, but also just serve as an adjunct. And if it could benefit our patients, it's amazing. The one final question I have just for those that are new or learning this process, are there any maybe clinical contexts, whether it's chest pain or presentation, you mentioned troponin, are there any other key factors aside from this patterns, all these that you look for are that are highly specific for an occlusion MI?

Dr. Smith: Well, there are patients who present with the new onset, crushing chest pain they've never had before. That that symptom is fairly specific for occlusion MI, fairly specific, I don't have a good specificity for it, but maybe 50% specific for it. But unfortunately the majority of occlusion MI do not present with classic symptoms and they may just have a shoulder pain or a jaw pain or epigastric pain, and you're gonna miss them if you're depending on a classic presentation of crushing substernal chest pain.

Dr. Kashou: Yeah, and the more with experience, you start to see that occurring more often that it's not the textbook presentation or the textbook ECG as we're seeing today.

Dr. Smith: And I would also add that as with every test you use your pretest probability. So if somebody comes in with syncope only, no chest discomfort at all, no shortness of breath and their ECG has some subtle finding of occlusion, I'm much less likely to diagnose occlusion than

if they came in with shortness of breath, shoulder pain, jaw pain, because syncope without any other symptoms is an unusual symptom of ACS, although it can be, so it may be, but the higher the pretest probability, the less specificity you need on your ECG and other testing, the lower your pretest, probably the higher you need on your testing.

Dr. Kashou: Yeah, and that's a key takeaway, that pretest probability with any diagnostic test.

Dr. Smith: Can I make one more point?

Dr. Kashou: Yes, please.

Dr. Smith: A lot of emergency physicians spend a lot of time studying the ECG and dysrhythmias, and I always say that emergency physicians should spend more time on studying the ECG in occlusion MI, and why is that? That's because when you have a dysrhythmia, you know you have a problem, the rhythm's either fast, slow or irregular, and when the rhythm's fast, slow or irregular, you can get help from a cardiologist. And the cardiologist is happy to help you, 'cause they too understand there is a problem. On the other hand, if you get a patient who has some vague chest discomfort and has an ECG that shows occlusion of MI on it, your cardiologist will be a lot less interested because he's not convinced that there is a problem because the vast majority of people who come in with vague chest discomfort do not have acute coronary syndrome, they have reflux esophagitis or chest wall pain or whatever, and you as an emergency physician will also think, oh, this is nothing. So, you will only know that it's something, if you can recognize those findings of occlusion MI on the ECG.

Dr. Kashou: Yeah, and I think as you've probably seen over the years, the ECG with all we learn in medical training has almost become a lost art, yet, it still remains one of the most important diagnostic tools. And like you said, even on the front lines, our emergency medicine providers already overwhelmed, but this is one thing that we want to not miss. And so I guess focusing on what is the critical thing, occlusion MI, like you said, the rhythms, as long as you can stabilize the unstable and get help when needed, I think you're right, the occlusion MI is something that we need to do better with education to ensure that the next treatment is not missed because we have a treatment for it and such a good point. Now important clinical decisions are made each day by way of the ECG. When interpreted correctly, this simple, not invasive and rapid diagnostic tool cannot only save lives, but also improve patient outcomes. It is now more evident than ever that we need updated ECG diagnostic criteria for acute myocardial infarction based on underlying pathophysiology to guide clinical decision making and deliver the high quality care our patients deserve. Dr. Smith, what an incredible work you have done and continue to contribute to the field of electrocardiology. You are a respected leader, an educator and a pioneer in this space. I'm grateful for this opportunity and I cannot wait to see the patient lives impacted by your work on a global scale. On behalf of our team, thank you for taking the time out of your day to join us. It's been a true pleasure.

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