Jeffrey Klein, MD  Welcome to our RadioGraphics podcast. I’m Jeff Klein the editor of RadioGraphics. I am pleased to have with us today the authors of the paper entitled “Frostbite: Spectrum of Imaging Findings and Guidelines for Management” which appears in the current November 2016 issue of the journal. I’m pleased to welcome today our two main authors of this paper, Dr John Millet of the Department of Radiology at the University of Michigan Health System; and Dr Benjamin Levi of the Division of Plastic Surgery in the Department of Surgery also at the University of Michigan Health System. Let me begin if I may with John. John, let me begin by asking you how your group came up with the idea of developing a paper for RadioGraphics on the imaging evaluation and management of frostbite? After all this isn’t really a topic that we’ve seen much about at least in the radiology literature.

John D. Millet, MD, MHS  Right well first of all thanks so much for having us. It’s a real treat to be here with you. The idea for this paper really came out of a particularly cold winter that we had here in Michigan a couple of years ago in which we were seeing a lot of frostbite patients. As we were reviewing the multiphase bone scans for several of these patients, the initial patients, and consulting with Dr. Levi and some of our surgical colleagues, we realized that we would get much more useful and more detailed information that’s more useful for our surgical planning, if we added SPECT/CT to these multiphase bone scans. To our surprise when we actually took a look at the literature, we realized that nobody at that point in time had actually described using SPECT/CT for frostbite patients. Furthermore, actually no one had even really done a thorough up-to-date review of frostbite imaging. And so really the goal of this paper was to put together a comprehensive, high yield, reference for radiologists and referring clinicians about frostbite imaging. That answered a lot of the questions that we had as we were initially seeing these patients and drawing on from the wealth of experience that we had here at the University of Michigan treating frostbite.

J.K.  Well that’s great. Your group really has done a terrific job of putting together a lot of information that again I think is really has not to this point been available in the literature. Let me move on to ask a question to Dr. Levi. Ben, in your role as a surgeon dealing with these patients I think you’d agree that there’s a role for catheter directed thrombolysis in the reestablishing of distal perfusion in the patients with frostbite who present in the first 24 hours. Your paper includes an algorithm which details the role of these techniques in dealing with affected patients. Can you summarize for the audience which patients with frostbite at your institution go directly to angiography upon presentation?

Benjamin Levi, MD  Yeah thank you and thank you again for allowing me to be part of this even as a surgeon and not radiologist. It actually, when I think back to my training like earlier when I started probably you know over ten years ago, we didn’t actually have this ability to take patients for a direct catheter thrombolysis and so when I started out my training there was this saying “frostbite in December, amputate in June” and that was kind of it. We didn’t have anything to do for them. We’d maybe give them some NSAIDs and so since you know in the middle of my training when we started to do a lot more of this and do you know work with the radiologists and you know bringing them in to do the thrombolysis, it really has made a huge impact on our patient population. In those patients who come in in the first 24 hours basically you know the algorithm that we use here is you know we looked – we first obviously rewarm the patients and then we look at the capillary refill as well as Doppler pulses of the digits after rewarming. In those patients where there isn’t any improvement, we then look for any concurrent trauma or any contraindications that the patient may have the thrombolysis, you know sever hypertension, recent hemorrhage, or other contraindications to any other type of thrombolysis. And then we work with the radiologists to look at an actual diagnostic angiography and if there are in fact perfusion defects then they will go ahead and do the thrombolysis. So basically any patient that I see that comes in the first 24 hours the first thing I’m thinking is getting these patients to the cath room because it really makes a difference in how much of their limbs they’re going to be able to save. In here we’ve been very good at getting the patients directly you know from the ER you know to the cath lab. There are some other papers out there from surgeon where they talk about urban frost bite and where they get patients that may have been on the street for a long time and they don’t come in until too late, and so someone who has been on the street for about 48 hours, at that point those patients are no longer really eligible. But for the patients that come in early with frostbite it really has made a huge difference in our management and in our outcomes for our patients.

J.K.  Great. It sounds like timing is obviously really crucial in trying to minimize the damage of these particular patients. John let me go to you and ask can you for the au-
About the surgical management of these patients. So clearly there's any tissue that needs further addressing with surgical management after these patients are treated.

J.D.M. Sure, sure so multiphase bone scintigraphy or it's easier to say multiphase bone scans are primarily used to evaluate the depth of tissue injury. These scans are typically done after two days to four days after the original injury or after they've been treated with intraarterial thrombolysis. Really any patient with second, third, or fourth degree frostbite should be getting a bone scan. That's basically any patient who presents with hemorrhagic blisters or really any kind of blisters whether they're hemorrhagic or just have fluid in them or who have obviously tissue necrosis, discoloration, and gangrene. Each of the phases of bone scan provides really valuable functional information about tissue viability. So the first phase or the blood flow phase provides information about macrovascular perfusion. The second phase or the soft tissue phase provides information about the microvascular perfusion and soft tissue perfusion. The third phase, what we call the delayed phase, provides really critical information about bone viability. When you take a look at the patterns of these three different phases and how they present together you can not only tell the depth on injury but you can actually determine the fate of those tissues and whether or not they need to be resected and then patients who've undergone intravascular thrombolysis you can use these bone scans to not only see the response to treatment, but actually go on to tell whether or not they'll need further surgical management. And so that's really actually demonstrated really well in one of our figures, Figure 6, which is a patient who is a 22 year-old male who came in with frostbite of his toes, and you can see that in the figure this patient had really hemorrhagic blisters over both of his toes and he presented within 24 hours of his injury and so we got him directly to the cath lab and he had a DSA and you can see on Figure b how incredibly compromised the perfusion to his toes are. He's really not getting arterial flow to any toes and after just 24 hours of TPA you can see that perfusion is basically restored throughout all his toes and so TPA for him really made a dramatic difference. He subsequently went on to have the multiphase bone scan which is shown in 6 d, e, f, and g and he had a SPECT/CT as well and this basically confirmed that there were no photopenic defects, there were no areas of dead tissue that needed to be further resected and it showed another pattern which is described in the article that he received basically increased uptake in his heels, in his mid feet and in his primarily his great toes around primarily the soft tissue and the late phases and so basically that's just reactive hyperemia from the injury and rather than any signs of underlying tissue necrosis and he subsequently went on to do great, he made a full recovery. So this is just a great example of how incredibly powerful a tool TPA is and how multiphase bone scans can really show whether or not there's any tissue that needs further addressing with surgical management after these patients are treated.

J.K. Great. Let me move to Ben for a moment and ask about the surgical management of these patients. So clearly you evaluate each of these individuals based upon the specifics of their presentation. As a plastic surgeon who cares for patients with frostbite, can you explain how you use the results of the SPECT/CT studies to aid you in your surgical approach to these patients?

B.L. Yeah again I think it really has changed the way I practice and I think has led me to have improved ability to tell where these patients need their amputation. So I think I'm able to preserve more tissue now than I used to be able to because of this imaging modality. So historically we used to just get a bone scan and the bone scans aren't as easy to interpret, it's certainly not as anatomic as having the entire SPECT/CT image, it doesn't have as much data. So by having the SPECT/CT image, you may see a hand or a foot, so for example in Figure 11 you look at what it looks like and how much tissue looks like it's dead and you look at the skin, you may think the patient in Figure 11 might need a below the knee amputation because you can't even salvage a transmetatarsal amputation. But then you look at the SPECT/CT scan and you see that actually he has blood flow primary to the end of the metatarsal so I could do a limb sparing operation and so I think what it allows me to do now is the algorithm that I use is I get the SPECT/CT and wherever the bone is dead in the SPECT/CT that is where I'll go in my first operation and perform my amputation because I know anything distal to there is not going to survive. But anything proximal, even if the skin looks horrible, I will give it more time because I know I have a live bone under there and so I could always do a free tissue transfer or a local tissue transfer to get that bone covered. And so similarly with Figure 10 if you look at on one side of the patients hand the skin looks really bad almost to the NCP joint and you'd have to do a complete amputation of the small, ring, middle and index fingers, but because SPECT/CT scan showed that there was actually viable tissue beyond that I was able to preserve longer length of her digits on that hand. So I think really the key thing it helps me do is decide where I can go and remove the dead tissue and so I'm not cutting out too much tissue and taking away tissue from the patient that shouldn't be removed, at the same time I'm able to remove the necrotic tissue so I'm not leaving behind you know again the frostbite in December and amputation in June. A lot of those patients between December and June get an infection because they're sitting around with dead bone. Now that dead bone is gone and I know where to cut it off because of the SPECT/CT.

J.K. Right, sounds really to be crucial in making those decisions. Let me just finish up by asking both John and Ben any recommendations for those medical centers who care for patients with frostbite? Obviously you folks in Michigan have had a fairly extensive experience and you've shared that with us in this particular paper and into these podcasts, but I wonder about those institutions that perhaps deal with patients in cold climates who encounter these patients who maybe don't have the resources or the experience that you've had in Michigan. Any recommendations as far as the imaging or surgical management that you could impart to folks who are looking to implement these techniques at their institution?
J.D.M. Sure well two recommendations come to mind for me. One is that really time is of the essence with these injuries, especially the more severe frostbite injuries. TPA given to these patients within the time window of 24 hours from the time point of injury really can make a huge difference as far as tissue salvage and subsequently long term functional mobility in these patients. These can be debilitating injuries and the more tissue you can save the better. And so making sure that these patients get triaged to a place that has a 24 hour interventionalist that can administer intraarterial TPA can make a huge difference for them. I think appropriate triage is definitely one important thing to remember. And then the other thing that’s highlighted throughout the article is just how incredibly valuable SPECT/CT can be in addition to the multiphase bone scintigraphy for evaluating these injuries and as Ben was saying that we can really determine the exact level of tissue necrosis which can really contribute to making a much finer amputation if an amputation is needed making exactly where we know where the bone is viable and really prevent having to take more tissue than is needed. If SPECT/CT is available obviously I’d recommend using it or hopefully getting these patients imaged at a center where there is SPECT/CT capabilities in addition to multiphase bone scintigraphy.

J.K. Terrific. John Millet and Ben Levi I want to thank you for your time today and joining us for today’s podcast. Thank you for a terrific contribution to our journal and to the radiology literature on the issue of frostbite. Thanks very much.

B.L. Thank you.

J.D.M. Thanks so much. Pleasure to be here.