Jeffery S. Klein, MD  Hi. I’m Jeff Klein, Editor of RadioGraphics and today I’m pleased to have with us Dr. Aaron Rutman from the University of Washington, Department of Radiology who is the author of one of our featured papers in the current March 2018 issue of RadioGraphics. His paper is entitled “The Imaging and Management of Blunt Cerebrovascular Trauma.” Aaron thank you for joining us today.

Aaron Rutman, MD  Yep, thank you.

J.S.K.  So Aaron your paper on the imaging of blunt cerebrovascular trauma deals primarily with injuries to the carotid and vertebral arteries which as you state in the paper are pretty uncommon even in trauma patients. Nevertheless, the sequela of missing these injuries could be pretty significant given their importance. Can you give us some background on how these serious injuries occur, what other injuries are most often associated with cerebrovascular injuries, and what the pathophysiology is behind the arterial injuries themselves?

A.R.  Sure. Yeah so blunt cerebrovascular injuries which I’ll just refer to as BCVI are pretty rare but they’re likely not as rare as we once thought. Over the last 20 years or so we found that the more we look and the better we are at looking with more advanced CT technology, the more we find. So in the age of screening, studies have shown you know higher incidences of BCVI and blunt force trauma in patients compared to earlier studies. Back in the 90s or so they were finding around a 10 percent of patients were having these injuries and then more recent studies more like 1 to 2 percent so a whole order of magnitude and of course the incidence is even higher in an appropriately selected screening population. So, how do they occur? Obviously it’s gonna be most common in cases of high energy trauma. Motor vehicle collisions not surprisingly account for more than 50 percent of injury mechanisms. Other mechanisms include falls from heights, assaults, hanging suicide attempts, other direct head and neck trauma. And it’s poorly understood, but much more rarely you can see these types of injuries with low energy mechanisms or with rapid head movement, a classic example being chiropractic manipulation. What injuries associated with BCVI, the most important association is cervical spine injury. In particular upper C spine fractures, from C-1 to C-3 and any ligamentous injury or fracture subluxation. Any fracture which extends to include the transverse foramina as well. In this population the incidence has been reported as high as 8 percent. So lots of other injuries have been identified as risk factors, including diffuse axonal injury, unexplained stroke on CT or MRI, forward facial fractures, basilar skull fractures, occipital condyle fractures, lots of other fractures that we can discuss. And the pathophysiology you asked about, vessel trauma is usually related to longitudinal stretching or twisting or compression forces to the vessel, so that can tear and disrupt the intimal layer of the vessel. And when the intima is injured, luminal blood can dissect into the wall at the site of the defect and propagate cranially. Of course this can cause problems in a couple ways. As the false lumen expands it can narrow and even occlude the true lumen of the vessel, plus the exposure of luminal blood of the thrombogenic subendothelium materials can lead to thrombosis and subsequent embolizations to intracranial vessels and stroke. Alternatively, the adventitia and media of the vessel can be injured without involvement of the intima and thus can lead to intramural hematoma from injury to the vasa vasorum of the vessel and then you have traumatic pseudo aneurisms which occur when there’s disruption of some of the layers of the vessel and the blood dissects through the breach and there’s an outpouching contained by the adventitia or the outer walls of the vessel. And then finally, direct laceration to the vessel usually by fractured bone fragments can injure the vessel and even transect it which is obviously is a devastating injury.

J.S.K.  Sure. Well thanks for that. So Aaron in the early part of your paper you detail the screening of these injuries. Can we talk a little bit about the various screening recommendations that you describe in the paper? And we’ll also take a look at Table 1 which details some of the signs and symptoms and risk factors that are associated with these cerebral vascular injuries.

A.R.  Yeah, so it gets a little confusing. Over the last 20 years several professional organizations and research groups have put forth some identified criteria. The original Denver criteria that most people are familiar with and the subsequent modified Denver criteria are based on studies conducted in the late 90s and early 2000s by the University of Colorado group and then the Western Trauma Association published official screening recommendations in 2009 based on the Denver criteria. So the criteria are separated into signs and symptoms and objective risk factors in asymptomatic patients, and so you can see in Table 1 signs and symptoms include: arterial hemorrhage from the neck, nose, and mouth; expanding cervical hematoma; cervical bruit in a younger patient under 50-years-old; a focal neurological deficit; ischemic stroke on CT or MRI; and then neurologic deficit inconsistent with a head CT. So all these things might prompt you to get some screening. And then as opposed to the identified risk factors in asymptomatic patients and so those are going to be the things we find on the
initial imaging. So like displaced II and III fractures, basilar skull fractures with carotid canal involvement, diffuse axonal injury with a low Glasgow Coma score, and then additionally, like we discussed earlier, the cervical spine fractures and subluxations especially the upper C spine with ligamentous injury or involving the transverse foramen. And then there’s a few things that we should probably screen when it has to do with the injury mechanism like a near hanging with anoxia or a clothes line type injury. And then there’s a little bit of controversy, but some people think a seat belt abrasion with swelling is enough to get screening whereas one paper showed that it probably wasn’t something that should prompt you to get screening. And then over the course, even in the last few years, there have been more papers showing that there’s a few other things that should probably be added which you can see at the bottom of the table there, things like mandible fractures, complex skull fractures, scalp degloving, thoracic vascular injuries, and TBI with thoracic injuries. So we’re probably not done as far as finding things that are gonna be on the list for screening. And then another important set of guidelines is from the Eastern Association for the Surgery of Trauma, which you can just call EAST, E-A-S-T, which established recommendations based on the level of evidence. So they have a level I, I, and III recommendations based on how good the evidence is. And notably most studies on BCVI are based on cohort studies and case control studies, uncontrolled retrospective studies, so EAST actually can’t make any level I recommendations. There are no good level I recommendations for screening and for BCVI. But they do give a level II recommendation for screening a trauma patient in the event of an unexplained neurologic symptom or arterial epistaxis after trauma. And then a few level III recommendations for cases of DAI, so the diffuse axonal injury with a low Glasgow Coma score less than 8, petrous bone fracture, upper cervical spine fracture, transverse foramen fracture, cervical subluxation with II and III fracture. As you can see, the EAST recommendations don’t quite cover everything that the WTA does and that the Denver group advocates. Not to mention the particulars in wording is a little different. So for example the WTA says skull based facture involving the carotid canal, while EAST says petrous bone fracture. And obviously the idea is the same, but in practice the actual patients included in screening using the different wording will be slightly different. So you know it’s up to the institution whether they’re gonna have to decide how they want to implement the guidelines based on their own experience and patient population and where they want to fall in the ROC curve.

J.S.K. Great. Well thanks for that. So Aaron, you reviewed the various imaging modalities that can be utilized to evaluate patients with potential blunt cerebrovascular injury. Can you address the relative roles of angiography, CT angiography, MR angiography and give us some details on the current role in particular of CT angiography in this particular study?

A.R. Sure. Historically catheter angiogram has been the gold standard for BCVI detection. It arrives at the highest spatial resolution and the highest sensitivity, but of course it’s invasive and carries some inherent risks. So if we can do just as well or nearly as well with non-invasive imaging, we should be doing that for our screening tool. Early on CTA was simply not adequate. It performed poorly when compared to the DSA gold standard. In fact EAST provides a level two guidelines specifically stating that four slice and less CTA are inadequate for screening. But as CT technology has improved with more detectors allowing for more rapid acquisition, better spatial resolution, the sensitivity and specificity for BCVI detection has improved a lot. So on a 16 to 64 channel CT, sensitivity has been shown as high as 98% and specificity as high as 100%, some studies lower obviously. But the majority of mixed injuries are low grade injuries in those cases so. And EAST gives a level three recommendation for the use of an A+ eight or greater slice CTA as a screening modality. So it is the recommended tool for screening modality as long as you have a fairly current CT scanner to do the screening. As for MRI, of course it’s great for diagnosing brain infarction. That’s where it’s gonna come in, in these cases most handily. But standard time of flight MRA has performed poorly for detecting BCVI with sensitivity between 50 and 75%. So standard MRI that most of us are doing is simply not adequate as a screening tool. However, I will say that in recent years high resolution vessel wall imaging has been developing and these technologies can play an important role. So they’re more likely to be used in conjunction with luminal imaging like CTA or MRA to really get a good look at the vessel wall itself. So perhaps MRI at the moment is not a great screening tool, but there’s a ton of potential as a follow-up tool or to help differentiate equivocal findings from the CTA or DSA you know to get a good look not just at the vessel lumen but the injured vessel wall itself.

J.S.K. Sure. Terrific. Well thanks. So let’s go ahead and discuss the specific imaging findings that are associated with arterial injury and we’ll review the Denver rating scale, you’ve touched on that, we’ll also look at Table 2 and at figure 6 as you detail the findings in this particular example.

A.R. Okay, great. Well let’s start with figure 6 so we can see the spectrum of vessel injuries. In A, so called minimal intimal injuries, you can see focal or segmental wall thickening with minimal luminal narrowing. And then in B, a thrombus or focal hematoma can develop at the site of intimal injury causing luminal narrowing. And C, this shows a classic dissection in which you have a raised displaced intimal flap and dissection with a false lumen. In D, the intima is intact and there’s a long segment of intramural hematoma and wall thickening with narrowing of the lumen. E shows a pseudo aneurism, like I said it’s a contained focal out pouching through a disrupted vessel wall. F shows a dissection which has progressed to occlusion. So the false lumen or intramural hematoma expands to the point of occluding the true lumen. And then finally in G, this is rare, but the entire vessel wall can be transected allowing for free extravasation. So let’s put these in the Denver grading scale now in table 2. When you see vessel wall injury with less than 25% stenosis of the lumen, this is a grade I injury. So there’s often called minimal intimal injury where you have a small hematoma or injury to wall, but the narrowing of the lumen is less than 25%. So if the stenosis is greater than 25%, it automatically becomes a grade II injury. And additionally the presence of a raised intimal flap or the presence of any intraluminal thrombus automatically qualifies it for a
grade II injury regardless of the degree of stenosis. A pseudo aneurism is a grade III injury. When the vessel is occluded it’s grade IV. And finally arterial transection is grade V. And then in addition the presence of any arterial venous fistula qualifies as a grade V injury.

J.S.K. Great. So let’s go ahead and look at a couple of cases that illustrate some of these findings. We’ll begin with dissection with a raised intimal flap and we’ll put up figure 11 which I think nicely demonstrates some of the findings you’ve just described.

A.R. Sure. So this case shows the typical findings of intimal dissection with raised intimal flaps. So this is a 30-year-old male. He was brought in with two facial fractures after being hit in the face with a boulder and there’s a linear feeling defect you can see on the right common carotid artery with a false lumen. Note that although the appearance is typical, the location in the common carotid is not. It’s much more common to see dissections in the internal carotid artery. And note also that the presence of a displaced intimal flap automatically makes this a grade II injury even though there’s really no significant luminal narrowing.

J.S.K. Right. Let’s go ahead and move to figure 19 which is a case of vertebral artery transection with anterior venous fistula formation after trauma.

A.R. Yeah this is a really interesting case; a really bad poly trauma with fracture dislocation at C4-5. On the CTA you can see extravasation and hematoma set in a transverse foramen at C4-5. The patient went to catheter angiography and the middle image there shows a right vertebral artery injection with contrast spilling out at the level of the fracture dislocation and so this represents transection, a grade V injury. And when the left vertebral artery is injected you can see the retrograde flow goes to the level of the transection and no further. It can’t get past the transection obviously. And then in the next part of the image, the digital subtraction images, there’s three subsequent phases in the right vertebral artery injection and you can see even in the earliest arterial phase on the left, you can start to see some venous filling in the vertebral venous plexus which becomes more obvious on the subsequent phases as the high arterial flow fills the entire vertebral venous plexus system on both sides and drains into the internal jugular system. So this is an arterial venous fistula and transection, so both of those things qualify it as a grade V injury.

J.S.K. Great, thanks for that. You know an important component of your paper reviews some of the mimics and the imaging pitfalls and artifacts that can mask or can simulate a vascular injury in these patients. Figure 21 shows a case of a subtle injury to a redundant portion of the cervical ICA. Can we review this case and its findings?

A.R. Sure. Yeah this is a difficult thing because diagnosing BCVI can immediately change the treatment trajectory for a patient. So it creates treatment decisions where you might have to weigh treating with aspirin or heparin in a patient who has fractures and may be bleeding somewhere else. So we want to be as sure as possible when we call it, and artifacts and things like atherosclerosis and spasm can make it tricky and this particular case illustrates another tricky thing, a fairly common entity, coiled or looped vascular segments which we often see in the distal cervical internal carotid arteries especially in hypertensive patients. And the loops can mimic a pseudo aneurism especially when viewed on axial, where you can see the same artery twice in cross section, but it can also conceal injuries and make them more difficult to distinguish like in this case. So here you see a bump of a pseudo aneurism directed medially from the coiled segment, and if you’re not careful and don’t look at it in multiple planes, it’s pretty easy to lose it among the other vessel segments. And the myth reconstructions are also quite helpful in these types of cases.

J.S.K. Right. Terrific. So after a discussion of a medical, interventional, and surgical management treatment of these conditions, you review some of the imaging follow-up issues particularly for low-grade injuries. Can we look at two cases here which are figures 24 and 25 which show different outcomes in two different patients each of whom sustained a low-grade injury?

A.R. Yeah. So follow-up imaging is an important part of continued evaluation of BCVI. The injuries often evolve one way or the other and the changes in imaging appearance will serve to guide the changes in treatment. These are two examples of low grade injuries usually defined as grade I or grade II injuries. And as a general rule, low grade injuries are more likely to heal or improve than high grade injuries. So up to 75% of grade I injuries will heal, and over a third of grade II injuries will heal or improve to grade I over the first month; whereas only 11% of grade III injuries improve so not nearly as many. On image 24 here, on the left you can see an oblique sagittal CTA MIP of the right carotid. There’s a focal intimalm plexus which becomes more obvious on the subsequent phases as the high arterial flow fills the entire vertebral venous plexus system on both sides and drains into the internal jugular system. So this is an arterial venous fistula and transection, so both of those things qualify it as a grade V injury.