Received:
21 August 2019

Revised:
22 April 2020

Accepted:
29 July 2020

<https://doi.org/10.1259/bjr.20190731>

Cite this article as:

Ahmed S, Lee MH, Ahn H, Fishman EK. MDCT angiography of emergent, non-traumatic, upper extremity vascular lesions. *Br J Radiol* 2020; **93**: 20190731.

PICTORIAL REVIEW

MDCT angiography of emergent, non-traumatic, upper extremity vascular lesions

SAMEER AHMED, MEGAN H LEE, HANNAH AHN and ELLIOT K. FISHMAN

The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, Baltimore, Maryland

Address correspondence to: Dr Megan H Lee
E-mail: Mlee258@jh.edu

ABSTRACT

Timely, accurate diagnosis of upper extremity vascular pathology is critical for successful clinical and surgical management. Although the vast majority of upper extremity vascular injury is due to trauma, physicians in the emergency setting, including radiologists, must be familiar with vascular lesions from iatrogenic injury, thromboembolic disease, vascular malformations, and vasculitis. Non-invasive diagnostic imaging with multidetector CT (MDCT) angiography is often employed in the emergency department to evaluate patients with suspected vascular pathology of the upper extremity. Maximum intensity projection and volume rendering technique are two methods that are useful for evaluating vasculature. In addition, dual-energy MDCT is useful in that it allows for the generation of iodine-selective images and bone subtracted images. These techniques can be used to create images that simulate catheter angiograms. In this article, we will discuss the role of MDCT angiography in the diagnosis and management of emergent non-traumatic vascular lesions of the upper extremity.

INTRODUCTION

The utility of multidetector CT (MDCT) angiography of traumatic arterial vascular lesions to the upper extremity is well-described.¹ However, cases of iatrogenic injury, thromboembolic disease, vascular malformations, and vasculitis can also present emergently and should be further characterized with diagnostic imaging.

MDCT angiography is now established as a first-line imaging modality over catheter angiography due to its ease of access, rapid scanning protocols, and high spatial and temporal resolution.¹ While ultrasound can be valuable and avoids radiation and contrast, CT angiography offers a comprehensive assessment of the upper extremity arteries as well as providing additional soft tissue and bony information. Furthermore, CT is often required for pre-operative planning if there is a need for catheter angiography or surgery. Dual-energy CT and post-processing techniques can also aid in visualizing vascular lesions and pre-operative planning. While MRI is useful for additional soft tissue findings, its longer acquisition time makes it a less optimal choice in the emergent setting.

TECHNIQUE AND PITFALLS

The patient is typically placed supine with the arm of interest placed above the head. If there are physical limitations, the patient can be positioned prone or lateral decubitus with the arm down. 100–120 ml of non-ionic contrast are power injected through a peripheral, 18–20-gauge IV in a contralateral antecubital vein at a rate of 4–5 cc/s. Bolus tracking of the ascending aorta is performed using a 230 HU trigger setting. Scan coverage can be modified according to the clinical question. It is useful to include the aortic vessels for systemic disease such as vasculitis or connective tissue disease or a question of thromboembolic phenomenon. For localized questions or follow up of known lesions, coverage of the arm itself may be sufficient.

Due to the small size of the distal peripheral arteries, artifacts can significantly compromise a study. Patient positioning is critical as motion can be a limiting factor, especially in patients with severe pain. In addition, calcification in the arterial wall can cause overestimation of luminal stenosis, and artifact from metal can cause non-visualization of certain segments of the arteries.

Figure 1. Radial artery pseudoaneurysm after arteriovenous fistula ligation. 59-year-old male with a left radiocephalic arteriovenous fistula that was ligated following renal transplant. Following ligation, he noticed a growing mass in his lateral wrist over several years. Occasionally, the mass would increase in size and become painful, then decrease in size. He presented to the emergency room for what appeared to be an embolic event with pain and purple discoloration of the long, ring, and small fingers of the left hand. CT angiography showed a radial artery pseudoaneurysm (arrows). (a) Axial, (b) coronal, and (c) VRT images are shown. (d-e) MIP images and (f) VRT image with soft tissue and bone subtraction are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

Post-processing of MDCT angiography and advantages of dual energy CT

Current MDCT scanners with 128 slice acquisition provide high spatial and temporal resolution, and allow for multiplanar reconstruction, three-dimensional (3D) volume rendering, and maximum intensity projection (MIP) reconstruction. Each of these post-processing techniques, as well as dual energy CT, has certain advantages.

MIP reconstruction is a projection of the brightest voxel, is quickly and easily performed, and thus is a useful technique

Figure 2. Pseudoaneurysm after arteriovenous fistula ligation. 41-year-old male with end stage renal disease who presented with a large pseudoaneurysm (arrows) at a previously ligated arteriovenous fistula site. (a) VRT, (b) curved planar reconstruction, and (c, d) MIP images with bone subtraction are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

for evaluating vasculature. However, MIP reconstruction is also subject to limitations, such as the lack of depth perception and interference by other high attenuating structures such as bone and metal.

Dual-energy MDCT provides an added benefit of allowing for bone removal. In dual-energy CT, the use of two different voltages (80 and 140 kV) allows for material decomposition, which can be used for a variety of applications, including generating virtual non-contrast images, iodine-selective images, and bone subtraction images. When analyzing CT angiography images, bone subtraction is especially helpful as it allows for the creation of images that simulate catheter-based angiography. A study evaluating lower extremity peripheral arterial disease found that dual-energy MDCT with bone removal resulted in higher sensitivity, specificity, and accuracy compared to conventional CT with conventional bone removal techniques.² Virtual non-contrast images can also be helpful in delineating high attenuating surgical material from contrast opacification.

Volume rendering technique (VRT) is a 3D post-processing technique that is useful for CT angiography. One of its main advantages is that it allows for a better display of the 3D relationship between various structures, including between vessels, soft tissue and bone. In addition, bone removal is not mandatory with volume rendering, as the relationship of the vessels can be easily evaluated with respect to the bone.³

Cinematic rendering is a newer technique that creates realistic images using a complex lighting model. This technique takes into account a more realistic lighting pattern that includes more light rays from various angles and also considers scatter from adjacent tissues. The result is a more advanced, life-like representation of anatomy that can be especially useful for pre-operative planning. While initial work with cinematic rendering appears to have produced a greater level of anatomic detail and more realistic images, one of its limitations is that it is not currently widely available.⁴

Iatrogenic causes of arterial upper extremity injury

Iatrogenic causes of arterial injury in the upper extremity include complications from arteriovenous fistulas for hemodialysis, radial artery access, and line placement.

Access options for dialysis include arteriovenous fistula, arteriovenous graft, and central venous catheters. Arteriovenous fistula is the preferred access type, as it allows for better survival and fewer complications. Commonly placed fistulae include radiocephalic, brachiocephalic, and transposed brachiocephalic arteriovenous fistulae.⁵ The more common complications of arteriovenous fistula are thrombosis and stenosis, and this is more commonly evaluated with ultrasound and fistulagram. Other complications include steal syndrome and aneurysm or pseudoaneurysm (Figures 1 and 2).⁶ An aneurysm or pseudoaneurysm can develop at the anastomotic site or cannulation site, and can be of varying morphologies, including fusiform aneurysms and saccular aneurysms.⁷

Figure 3. Radial artery occlusion after cardiac catheterization. 59-year-old male with history of cardiac catheterization via the radial artery, who presented with a long segment occlusion of the right radial artery (white arrow) with distal reconstitution via the palmar arch (yellow arrow), which is supplied by the ulnar artery. (a) MIP and (b–d) VRT images with and without bone removal illustrate the segment of occlusion. MIP, maximum intensity projection; VRT, volume rendering technique.

Utilization of radial access for cardiac catheterization has become more common, as it has been found to have fewer access-related complications when compared to femoral access, and can be used for coronary procedures as well as interventional radiology procedures.⁸ In addition, the brachial artery and axillary artery may be used for access at some centers.^{9,10}

While arteriovenous fistulas occur more commonly with femoral access, complications from radial access include radial artery occlusion in 15–30% of cases (Figure 3).⁸ These often do not require intervention due to the dual blood supply to the hand. Use of a large sheath relative to the diameter of the radial artery is a well-known risk factor for radial artery occlusion. Patent hemostasis is the standard of care to reduce the risk of radial artery occlusion.¹¹

Figure 4. Radial artery pseudoaneurysm following cardiac catheterization. 52-year-old male with a history of cardiac catheterization via radial artery access who presented with a radial artery pseudoaneurysm at the wrist. (a) MIP image and (b) illustration are shown. MIP, maximum intensity projection.

Figure 5. Brachial artery injury after attempted catheter placement. 62-year-old male who presented with intramuscular hematoma (white arrow) and active arterial extravasation from the brachial artery (yellow arrow) after an attempted peripherally inserted central catheter placement. (a) Coronal, (b) MIP, and (c) VRT images are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

Other less common complications of radial access include hematoma and pseudoaneurysm (Figure 4). The risk of pseudoaneurysm is exceedingly small but is significantly less with transradial access compared to transfemoral access, occurring in 0.2% of transradial access patients compared to 0.7% of transfemoral access patients.¹²

Finally, other catheters such as peripherally inserted central venous catheters, midline catheters, and arterial access catheters can have similar complications (Figures 5–7).

Acute upper extremity ischemia due to thromboembolic disease

In contrast to the lower extremities, upper extremity ischemia due to atherosclerotic disease or thromboembolic disease is less common. Causes of acute embolic ischemia can include emboli from a cardiac source or atherosclerotic disease from a proximal artery. The brachial artery is the most common site of occlusion, and emboli more commonly lodge at bifurcations, such as the bifurcation of the brachial artery or at the take-off of the profunda brachialis artery. Upper extremity ischemia due to atherosclerotic arterial thrombosis is also less common in the upper extremities compared to the lower extremities, and is less common than ischemia due to embolic disease.¹³ A case of radial artery occlusion is shown in Figure 8.

Connective tissue and autoimmune diseases

A variety of connective tissue diseases and autoimmune diseases can cause vasculitis in the upper extremities, such as scleroderma, systemic sclerosis, systemic lupus erythematosus, Buerger disease, and other mixed or undifferentiated connective tissue diseases (Figure 9). A study of 22 patients with systemic sclerosis found that arterial involvement varied, ranging from involvement of the subclavian artery to involvement of the smaller arteries of the arm and hand, including non-opacification of the superficial palmar arch. In addition, arterial involvement in the upper extremity was associated with a higher pulmonary artery pressure.¹⁴ Overall, literature on upper extremity vascular imaging

Figure 6. Radial artery pseudoaneurysm after arterial line placement. 37-year-old male with an arterial line placed in the radial artery 2 months ago, who presented with a radial artery pseudoaneurysm (arrows). (a) MIP with bone removal and (b) VRT images are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

findings in the setting of connective tissue and autoimmune diseases is scant, and this is a viable area for future research.

MISCELLANEOUS CAUSES

Various other causes can also lead to vascular symptoms which may be evaluated with CT angiography. Figure 10 shows a radial artery thrombosis of unclear etiology in a patient with idiopathic

Figure 7. Radial artery occlusion in the setting of connective tissue disease. 26-year-old female with mixed connective tissue disorder on chronic steroids, who presented with left hand pain, duskiness, and decreased hand pulses after removal of a radial arterial line. (a) VRT and (b) MIP images show occlusion of the radial artery (white arrow) and mild adjacent soft tissue swelling. MIP, maximum intensity projection; VRT, volume rendering technique.

Figure 8. Radial artery occlusion due to thromboembolic disease. 69-year-old male with right wrist pain. (a) MIP and (b) VRT images show occlusion of the radial artery (white arrow). MIP, maximum intensity projection; VRT, volume rendering technique.

CD4 lymphocytopenia. Intravenous drug users are prone to infectious complications, such as cellulitis, subcutaneous abscesses, and mycotic aneurysms (Figure 11).

Figure 9. Vasculitis related to lupus and scleroderma. 26-year-old woman with lupus and scleroderma who presented with chronic pain in her distal fingertips. (a, b) MIP images with bone removal show occlusion of the ulnar artery (white arrow) and interosseous artery (yellow arrow) from the level of the proximal ulna. The superficial palmar arch is not well visualized, and a few digital arteries are faintly seen. These findings are consistent with vasculitis. (c) An illustration of ulnar artery occlusion, with flow to the superficial palmar arch provided by the radial artery. MIP, maximum intensity projection.

Figure 10. Radial artery thrombosis. 48-year-old male with idiopathic CD4 lymphocytopenia, who presented with radial artery thrombosis of unclear etiology (arrow). (a) Coronal multiplanar and (b) VRT images with bone and soft tissue subtraction are shown. (c) An illustration of radial artery occlusion, with flow to the deep palmar arch provided by the ulnar artery. VRT, volume rendering technique.

Figure 11. Brachial artery aneurysm in the setting of intravenous drug abuse. 35-year-old male with a history of intravenous drug abuse who presented with an elbow skin defect, hematoma, and cellulitis. A left brachial artery aneurysm is seen, most likely a mycotic aneurysm (arrows). (a) Coronal MIP and (b) VRT images are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

Figure 12. Venous malformation of the hand. 19-year-old man with a right thenar eminence venous malformation (arrows) presented with increased pain and clinical concern for hemorrhage into the hand. (a) VRT image and a (b) MIP image are shown. MIP, maximum intensity projection; VRT, volume rendering technique.

Lastly, some patients may present due to vascular malformations (Figure 12). Vascular malformations of the upper extremity can be classified broadly as slow flow, fast flow, or complex-combined lesions. In the slow-flow category, venous malformations are most common, with lymphatic, capillary, and combined malformations being less common. These are typically painless masses which are compressible. In contrast to slow-flow lesions, fast-flow lesions often do not compress easily and may have palpable thrills and bruits. There may be arteriovenous shunting due to fistula formation, with distal limb ischemia and congestive heart failure in severe cases. The complex-combined category includes those associated with various syndromes, which can have localized or diffuse involvement.¹⁵

CONCLUSION

CT angiography is often the preferred imaging modality in patients with emergent upper extremity vascular symptoms, and additional post-processing techniques such as MIP and VRT are particularly useful for vascular lesions of the extremities.

REFERENCES

1. Fritz J, Efron DT, Fishman EK. Multidetector CT and three-dimensional CT angiography of upper extremity arterial injury. *Emerg Radiol* 2015; **22**: 269–82. doi: <https://doi.org/10.1007/s10140-014-1288-z>
2. Brockmann C, Jochum S, Sadick M, Huck K, Ziegler P, Fink C, et al. Dual-Energy CT angiography in peripheral arterial occlusive disease. *Cardiovasc Intervent Radiol* 2009; **32**: 630–7. doi: <https://doi.org/10.1007/s00270-008-9491-5>
3. Fishman EK, Ney DR, Heath DG, Corl FM, Horton KM, Johnson PT. Volume rendering versus maximum intensity projection in CT angiography: what works best, when, and why. *Radiographics* 2006; **26**: 905–22. doi: <https://doi.org/10.1148/rg.263055186>
4. Rowe SP, Johnson PT, Fishman EK. Initial experience with cinematic rendering for chest cardiovascular imaging. *Br J Radiol* 2018; **91**: 20170558. doi: <https://doi.org/10.1259/bjr.20170558>
5. Sequeira A, Naljayan M, Vachharajani TJ. Vascular access guidelines: summary, rationale, and controversies. *Tech Vasc Interv Radiol* 2017; **20**: 2–8. doi: <https://doi.org/10.1053/j.tvir.2016.11.001>
6. Dix FP, Khan Y, Al-Khaffaf H. The brachial artery-basilic vein arterio-venous fistula in vascular access for haemodialysis--a review paper. *Eur J Vasc Endovasc Surg* 2006; **31**: 70–9. doi: <https://doi.org/10.1016/j.ejvs.2005.08.008>

7. Kakkos SK, Kouri AK, Tsolakis IA, Haddad GK, Lampropoulos GC, Karnabatidis D. Surgical and endovascular revision of brachio-basilic vein fistula. *J Vasc Access* 2016; **17** Suppl 1: S6–11. doi: <https://doi.org/10.5301/jva.5000516>
8. Wagener JF, Rao SV. A comparison of radial and femoral access for cardiac catheterization. *Trends Cardiovasc Med* 2015; **25**: 707–13. doi: <https://doi.org/10.1016/j.tcm.2015.03.012>
9. Harris E, Warner CJ, Hnath JC, Sternbach Y, Darling RC. Percutaneous axillary artery access for endovascular interventions. *J Vasc Surg* 2018; **68**: 555–9. doi: <https://doi.org/10.1016/j.jvs.2017.11.066>
10. Steve Lee K, Sos TA. Brachial artery access. *Tech Vasc Interv Radiol* 2015; **18**: 87–92. doi: <https://doi.org/10.1053/j.tvir.2015.04.006>
11. Arora V, Patel M, Shroff AR. Complications of Transradial cardiac catheterization and management. *Interv Cardiol Clin* 2015; **4**: 193–202. doi: <https://doi.org/10.1016/j.iccl.2014.12.004>
12. Jolly SS, Yusuf S, Cairns J, Niemelä K, Xavier D, Widimsky P, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (rival): a randomised, parallel group, multicentre trial. *Lancet* 2011; **377**: 1409–20. doi: [https://doi.org/10.1016/S0140-6736\(11\)60404-2](https://doi.org/10.1016/S0140-6736(11)60404-2)
13. Skeik N, Soo-Hoo SS, Porten BR, Graber J, Alden P, Cragg A, et al. Arterial Embolisms and thrombosis in upper extremity ischemia. *Vasc Endovascular Surg* 2015; **49**(5-6): 100–9. doi: <https://doi.org/10.1177/1538574415596740>
14. Emad Y, Al-Sherbeni H, Ragab Y, Abo-El-Youn I, El-Shaarawy N, Nassar DY, et al. Arterial vasculopathy in systemic sclerosis: computerized tomography (CT) angiographic features of macrovascular and microvascular upper limbs arteries. *Joint Bone Spine* 2014; **81**: 433–7. doi: <https://doi.org/10.1016/j.jbspin.2014.03.014>
15. Upton J, Coombs CJ, Mulliken JB, Burrows PE, Pap S. Vascular malformations of the upper limb: a review of 270 patients. *J Hand Surg Am* 1999; **24**: 1019–35. doi: <https://doi.org/10.1053/jhsu.1999.1019>