Seminars in ULTRASOUND CT and MRI

Computed Tomography Angiography of the Extremities in Emergencies

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Computed tomography angiography (CTA) of the extremities offers a noninvasive, rapid means of evaluation of the extremities in vascular emergencies. CTA is now the first-line investigation for this purpose, offering high sensitivity and specificity in diagnosis. The learning objectives of this review article include reviewing normal arterial anatomy and variants of the upper and lower extremity, illustrating CTA findings in traumatic vascular injuries, and exploring the range of vascular pathologies that may cause acute ischemic symptoms in the extremities.
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Introduction

Extremity vasculature emergencies presenting to the emergency department have different management and outcomes depending on the cause and nature of injury. They range from symptoms of chronic claudication to critical limb ischemia with risk of loss of limb and life. Characterizing them with a noninvasive test is essential before the decision for intervention and to plan the approach. Digital subtraction angiography (DSA) has long been the gold standard for evaluation of the vasculature of the extremities. However, screening DSA for every person who presents to the emergency department with suspicion of vascular injury or limb ischemia is not practical, safe, or cost-effective.

Rise of the CTA

The role of computed tomography angiography (CTA) in evaluation of peripheral vascular trauma has been documented since 1999 with the earliest study noting a sensitivity and specificity between 90% and 100%.[1]

Subsequently, a number of studies have demonstrated the efficacy of CTA in evaluating trauma, with the majority of studies published after 2005 (Table). A series by Colip et al evaluated the role of CTA in penetrating injuries to the extremities. Out of 446 patients evaluated, 131 patients showed evidence of vascular injury, a subset of which required surgical intervention. Of note, none of the patients who had a negative examination needed surgical intervention during their hospital stay.[7]

Current Guidelines

Eastern Association for the Surgery of Trauma (EAST) practice management guidelines[8] from 2012 state the following:

(1) Level 1 evidence.
(A) CTA may be used as the primary diagnostic study for the evaluation of penetrating lower extremity vascular injury.
(2) Level 2 evidence.
(A) Patients with hard clinical signs of arterial injury (pulse deficit, pulsatile bleeding, bruit, thrill, and expanding hematoma) should be surgically explored without the need for an arteriogram unless there is an associated skeletal or shotgun injury.
(B) Patients with abnormal physical examination findings (outside of the hard signs) or ankle brachial index <0.9 or both should have further evaluation.
(C) Patients without concerning physical examination signs and ankle-brachial index >0.9 can be discharged from the vascular standpoint.

Current standard of care in many emergency departments across the country is to use CTA to rule out clinically significant vascular pathology within the framework set by the aforementioned guidelines.

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Table Studies Evaluating Efficacy of CTA in Evaluation of Vascular Injuries

	No of Patients	Sensitivity (%)	Specificity (%)
Soto et al[1]	45	90 and 100 (2 observers)	90 and 100
Soto et al[2]	139	95.1	98.7
Inaba et al[3]	59	100	100
Rieger et al[4]	87	99	87
Seamon et al[5]	21	100	100
Babar et al[6]	51	100	98

Anatomy

Upper Extremity

The arterial supply to the upper extremity begins as the subclavian artery that arises from the aortic arch on the left and the brachiocephalic artery on the right. The subclavian gives off 5 branches (vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk, and dorsal scapular artery) before becoming the axillary artery at the lateral margin of the first rib. The axillary artery gives off the superior thoracic, thoracoacromial, lateral thoracic, subscapular, anterior, and posterior circumflex humeral arteries. The axillary artery becomes the brachial artery at the lateral margin of the teres major muscle. The brachial artery gives off the deep brachial artery and divides into the radial and ulnar arteries in the antecubital fossa. The superficial and deep palmar arch are formed with contributions from radial, ulnar, and interosseous arteries.

The common interosseous artery arises from the ulnar artery and bifurcates into anterior and posterior interosseous arteries (Figs. 1 and 3A).

Lower Extremity

The aorta bifurcates into common iliac arteries that in turn give off external iliac and internal iliac (hypogastric) arteries. The external iliac artery becomes the common femoral artery as it passes under the inguinal ligament. The common femoral artery continues as the superficial femoral artery after giving off the deep femoral artery (profunda femoris or deep artery of the thigh). Both vessels traverse the anterior compartment. The deep femoral artery gives off medial and lateral circumflex femoral arteries and terminates as perforating arteries in the thigh.

The superficial femoral artery becomes the popliteal artery as it traverses the adductor hiatus, an opening along the insertion of the adductor magnus muscle, marking the transition from the anterior compartment of the thigh to the popliteal fossa. The vast majority (89%-92%[9,10]) of patients have a classical branching pattern with the popliteal artery bifurcating into an anterior tibial artery and the tibioperoneal trunk. The tibioperoneal trunk divides into the posterior tibial artery and peroneal artery (aka fibular artery), both in the posterior compartment of the leg. Other branching patterns include a 2-vessel runoff with hypoplastic or aplastic posterior tibial artery (3.5%) and trifurcation of the popliteal artery in the popliteal fossa (2.5%). There are at least 10 different branching patterns described, with the rest occurring far less frequently (Figs. 2, 3B, and 4).[10]

The anterior tibial artery passes through the interosseous membrane in the upper leg to enter the anterior compartment and becomes the dorsalis pedis artery as it crosses the ankle. The dorsalis pedis contributes to the formation of the plantar arch through the deep plantar artery. The posterior tibial artery gives off medial and lateral plantar arteries, with the latter anastomosing with the deep plantar artery to form the plantar arch. The peroneal artery terminates near the ankle, dividing into calcaneal branches.

Approach to the CTA

The image reconstruction protocol at our institution consists of axial soft tissue windows in 5 mm and 1 mm reconstructions, 5 mm thick coronal and sagittal plane maximum intensity projection (MIP) reconstructions, whole-image surface-shaded and rotating MIP reconstructions, and curved planar reformats (CPR). CPR and surface-shaded 3-dimensional (3D) reconstruction images are created at an outside 3D laboratory but may be made on site during image review.

There are various ways to approach the CTA based on personal preference. We describe a systematic approach that offers a rapid and comprehensive review of the study whose image count may run into the thousands.

Start off with the thick axial slices and whole-thickness MIP images to get a global idea of the bolus quality, anatomy, major findings (e.g., occlusions or extravasation), and overall study quality. This can be followed by evaluation of the 3D reconstructions for similar information. Major pathologies will be revealed at this point and aid in evaluation of more subtle abnormalities while evaluating the source images.

Following each vessel, an evaluation of continuity, caliber, and extraluminal extension of contrast is the next step with a meticulous assessment of the major vessel runoff, and review of side branches as relevant. The opacification of smaller branches varies based on patient factors such as anatomy, circulation, and bolus timing.

Opacification of the distal vessels and vascular arches of the hands and feet is highly variable. Careful evaluation is necessary for patients with no proximal disease and symptoms of ischemia consistent with small vessel disease.

Systematic evaluation for plaque and stenoses is done using centerline CPR images. As needed, 3D postprocessing software available at the workstation can be used to create