Computed Tomography Angiography of the Upper Extremities

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KEYWORDS

• CTA • Upper extremity • Arterial anatomy • Vasculitis • Penetrating trauma • Dissection • Vascular malformation • Arteriovenous fistula

KEY POINTS

- Upper extremity CTA is a powerful tool in the evaluation of acute and nonacute arterial pathology; however, certain technical principles including patient positioning, choice of contrast injection site and rate of administration, and physiologic considerations must be optimized to achieve a high-quality angiographic study.
- The utility of CTA in the setting of trauma has been recognized; however, it's less well-known and varied clinical applications in the subacute setting are also important and include presurgical anatomic mapping including identification of variant arterial anatomy, evaluation of connective disorders, vasculitis, overuse syndromes, arteriovenous fistula/grafts, vascular malformations, compression syndromes, and assessment of perivascular pathology.
- Volume-rendered, maximum intensity projection, and multiplanar reformat images are indispensable for evaluating the data set.

INTRODUCTION

In an era where noninvasive imaging has formed the cornerstone of medical triage, computed tomography angiography (CTA) has found its niche. Better-known uses of CTA include evaluation of the central vasculature for aortic dissection, pulmonary embolism, and aortic aneurysm. However, CTA of the upper extremity has been gaining popularity over the last decade with the advent of faster multidetector scanners yielding improved spatial and temporal resolution. In our institution, upper extremity CTA is one of the last territories where CT has replaced conventional angiography because of improvements and increasing availability of high-end scanners that have adequate spatial resolution and anatomic coverage. Compared with MRI or other modalities, CT has widespread availability and fast acquisition times, strengths especially critical in the setting of acute trauma. Several authors have described the role of CTA of the upper extremities in the setting of acute vascular and extravascular injury over recent years.[1–4] We have also have previously illustrated a variety of acute clinical applications of upper extremity CTA.[5] However, the use of CTA in the subacute setting is less well defined. Examples of subacute roles of CTA include presurgical anatomic mapping and delineating the vascular manifestations of connective tissue diseases; vasculitis; overuse syndromes; arteriovenous (AV) dialysis fistulas; AV malformations (AVM); compression syndromes; and perivascular pathology, such as abscesses and neoplasms. CTA can readily identify thromboembolic phenomena, aneurysms, and stenoses associated with these disease entities.

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SCAN PROTOCOLS AND PHYSIOLOGIC CONSIDERATIONS

Patient Positioning

Appropriate patient positioning is critical for upper extremity CTA image quality. The guiding principle is to position the anatomy of interest close to the isocenter of the scanner, unobstructed by nonrelevant anatomy, such as the contralateral arm, shoulders, and abdomen, while keeping the patient comfortable. Patients can be positioned headfirst either in the supine or prone position on the scanner table with the arm to be scanned placed above the patient's head. The fingers should be spread out and taped down. The laser light of the scanner should be used to align the arm and fingers as close as possible with the isocenter of the scanner where spatial resolution is best. Younger and mobile individuals can easily tolerate a prone or oblique prone position with the entire upper extremity, thoracic inlet, and aortic arch close to the isocenter. The contralateral arm is positioned next to the patients' body, which also moves the shoulders out of the same transverse plane. Less mobile patients are typically scanned supine, with tape and pillows supporting the upper extremity.

In immobile patients or in the setting of trauma, the upper extremity is scanned at the side of a patient's body. Again, every attempt should be made to place the anatomy of interest as close to the isocenter as allowed under the circumstances, for instance by adjusting table height or putting the hand and forearm on the patient's abdomen rather than next to the pelvis.

Scanning Parameters

Contrast medium injection

Proper choice of injection site is critical when imaging the upper extremity. Injection of contrast into the extremity contralateral to the side of interest should be chosen whenever possible to avoid masking pathology by streak artifact. However, if radiographic evaluation of both extremities is desired, contrast injection via a central AV catheter is preferred for optimal data acquisition. This is typically the case in preprocedure imaging obtained for dialysis fistula planning purposes.

Injection protocols at our institution are based on patient weight and injection of contrast is typically performed in a biphasic manner. **Table 1** lists our institution's upper extremity contrast injection protocol based on patient weight.

Scan time plus the diagnostic delay should equal the injection duration. It is critical to select the scanning range first and then set the scan time to 30 seconds in all patients. Additionally, the injection duration is set to 30 seconds for all patients assuming the diagnostic delay is essentially zero. This is done to avoid outrunning the contrast bolus. Automated bolus tracking is performed at the ascending aorta, with the trigger set at the 100 HU level with a minimum user delay of 2 seconds. A normal monitoring delay is 8 seconds with injection of the upper extremity. If injection is performed via the foot, the monitoring delay is set to 15 seconds. The scan time should be chosen based on the injection duration to avoid outrunning the contrast bolus. Scan times are chosen with the assumption that upper extremity scan times can be extrapolated from known lower extremity scan times. A saline flush of 40 mL is performed after injection of contrast, set at the same flow rate as the phase 2 contrast injection. Of note, slower acquisition/scanning protocols allow for adequate filling of small peripheral arteries.

Physiologic considerations that affect contrast injection include blood flow at rest; presence of inflow obstruction as can be seen in the setting of atherosclerosis; physiologic states with increased blood flow, such as with activity or during reperfusion after an ischemic event; and presence of high-flow lesions or conduits, such as AVM

Table 1
Weight-based upper extremity CTA injection protocol

Body Weight (lb)	Body Weight (kg)	Phase I	Phase II	Total Contrast Medium Volume (mL)
<121	<55	20 mL @ 4.0 mL/s	80 mL @ 3.2 mL/s	100
121–143	<65	23 mL @ 4.5 mL/s	90 mL @ 3.6 mL/s	113
143–187	~75	25 mL @ 5.0 mL/s	100 mL @ 4.0 mL/s	125
187–209	>85	28 mL @ 5.5 mL/s	110 mL @ 4.4 mL/s	138
>209	>95	30 mL @ 6.0 mL/s	120 mL @ 4.8 mL/s	150

Adapted from Lippert H, Pabst R. Arterial variations in man: classification and frequency. Wurzburg (Germany): J. F. Bergmann Verlag Munchen; 1985.