

Automatic scan triggering software “confused”: Computed tomography angiography in foot arteriovenous malformation!

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Abstract

Multidetector computed tomography angiography (MDCTA) has become a well-established modality for limb angiography for a variety of indications. The technique of MDCTA depends on the scanner features including the number of detector rows, rotation speeds and single or dual source energy. Integral to a diagnostic quality CTA is the acquisition timing. Various techniques are available for determining the appropriate timing of scan acquisition which includes fixed delay, test bolus and the bolus tracking technique. The transit times of contrast from the aorta to the peripheral arteries shows a wide variability and is dependent upon the inter individual hemodynamic states. The bolus tracking technique is the most preferred one which allows reliable scan timing with acceptable contrast volume and radiation dose. Pitfalls with all these techniques are well described and we report one such technical pitfall in a case of left foot arteriovenous malformation (AVM) where the bolus tracking technique employed for scan triggering failed to initiate acquisition.

Key words: Arterio-venous malformation; bolus tracking; computed tomography angiography; contrast injection

Introduction

Computed tomography (CT) angiography is an established modality for evaluation of a variety of peripheral vascular disorders including peripheral arterial diseases (PAD) and peripheral vascular malformations. Besides increasing detector rows allowing shorter acquisition time, an equally important component of this success is the evolution of techniques to trigger the scan at an appropriate time.^[1] Over the years, bolus tracking technique in CT has become the most popular and is a time-tested technique. In patients

with asymmetrical PAD, variable transit time of contrast through the diseased vessels can render their opacification inadequate.^[2] Such pitfalls can also occur in patients with vascular malformations of the extremities which has not been highlighted in the literature to the best of our knowledge. We present a case of lower limb arteriovenous malformation (AVM), where bolus tracking technique failed to trigger the scan acquisition as the threshold Hounsfield value (HU) could not be attained.

Case Report

A 27-year-old female, a diagnosed case of left foot AVM, presented with asymmetrical enlargement of the left lower limb since childhood and recent onset bleeding from the foot following trivial trauma. On examination, there was swelling of left lower limb, predominantly of the left foot and leg. Oozing of fresh blood was noted from a small ulcer over the lateral aspect of foot. Cardiovascular system examination as well as chest radiograph was normal. A CT

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angiography (CTA) was planned to evaluate the AVM and contemplate angioembolization. CTA was performed on a 64-detector CT scanner (LightSpeed® VCT; GE Healthcare, Buckinghamshire, UK) at 120 kVp, 250 mA, collimation of 0.625 mm, and reconstruction interval of 1.25 mm, pitch of 0.5, and scan time of 9 sec. One hundred milliliters of iohexol (Omnipaque®300; GE Healthcare, Princeton, NJ, USA) was injected without a saline flush at a rate of 4 ml/sec through an 18-gauge cannula placed in the right antecubital fossa. A circular region of interest (ROI) was placed covering approximately two-thirds of the abdominal aortic diameter below the level of renal vessels. Serial scans were acquired at this level following injection of contrast. Real-time HU versus time plot revealed gradual increase in enhancement that reached a maximum HU value of 150 at 20 sec after which the plot showed a falling trend, failing to reach the desired HU of 200. Manual triggering of scan was done at 40 sec [Figure 1]. Evaluation of CTA images revealed early opacification of veins in the left lower limb [Figures 2 and 3]. A fall in the enhancement value following initial increase to a peak of 150 HU was noted, causing a critical lapse in the functioning of automatic triggering of scan acquisition.

Discussion

Contrast detection and appropriate timing of scan acquisition is a critical component of CTA and an error of a few seconds can render the study non-diagnostic. Amongst the various methods of contrast timing (fixed scan delay, test bolus technique, and bolus tracking technique), bolus tracking technique is the most efficient for optimizing contrast enhancement in the peripheral arteries.^[3] This technique employs a single low-dose non-contrast CT

image at the level of abdominal aorta. A circular ROI, 10-15 mm², is placed inside the aortic lumen. Following a delay of 10 sec after IV contrast injection, serial low-dose monitoring CT scans are acquired at the same table position as the non-contrast scan at a pre-determined interval (usually 2 sec). When the preset enhancement level is achieved within the ROI, the table is moved into position for beginning the scan and automatic triggering of scan occurs. This allows a real-time assessment of contrast enhancement characteristics leading to a highly precise timing of scan acquisition with a secondary advantage of reduced contrast requirement compared to the test bolus technique.^[4] Cademartiri *et al.* suggested that the bolus tracking technique yields more homogeneous enhancement than does the test bolus technique.^[5] Others, however, have found that with the use of appropriate timing, test bolus technique can yield similar results to bolus tracking.^[6]

There are several limitations and pitfalls in CTA. The threshold for triggering the scan is rather arbitrary and ranges anywhere between 50 and 150 HU depending on the CT scanner and the operator.^[7] However, the mean arterial attenuation values ranging between 232 HU and 281 HU have been found in patients with augmented peripheral arterial flow due to vascular grafts.^[8] An arterial attenuation of 200 HU or more has also been suggested for better differentiation of arteries and veins on multidetector CTA (MDCTA).^[9] Another issue is the additional delay required between the detection of optimal contrast enhancement and actual initiation of scanning.^[7] This delay, varying from 2 to 9 sec, depends on the table position and the CT scanner capabilities. A remedy to long delay in scan initiation is using a lower enhancement threshold. Yet another problem with this method of contrast timing is the need for a larger vessel caliber for placing the ROI. If the ROI is not placed properly in the center of the vessel,

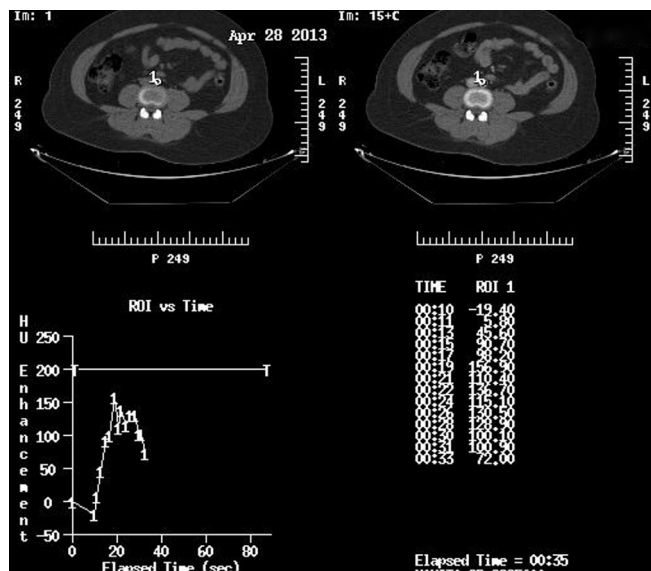


Figure 1: Image from the monitoring phase of CTA shows the ROI placed in the lumen of abdominal aorta (upper panel). Plot of enhancement (y-axis) versus time (x-axis) in the lower panel reveals initial rise followed by a fall in the peak enhancement

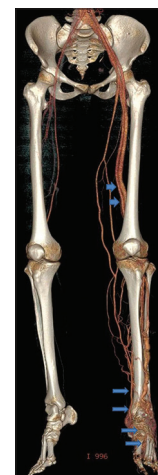


Figure 2: Subtracted coronal volume-rendered (VR) image reveals the abnormal tangle of vessels on the dorsum of foot (arrows) and dilated, tortuous early filling veins (short arrows, compare with the right lower limb)

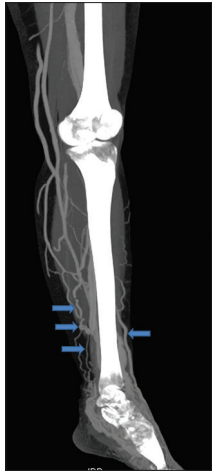


Figure 3: Sagittal maximum intensity projection (MIP) image reveals a large number of vessels in the leg (arrows) suggestive of early filling veins

erroneous triggering occurs, yielding non-diagnostic studies. Adequate contrast opacification is also dependent on patient-related factors like weight, gender, height, and cardiac output,^[7] injection rate and duration, iodine concentration, anatomical area of scan coverage, as well as scanner specifications and duration of scanning.^[10] Bolus tracking, as employed in our case, substantially overcomes the individual variability of cardiac output.^[11] However, the failure to reach the threshold value in the absence of cardiac compromise can be due to various factors. The peripheral high-flow AVM can result in a localized hyperdynamic circulation with a rapid run off from the arteries into the arterio-venous-precapillary anomalous connections. This would lead to decrease in local circulation time as well as greater mixing of contrast with unopacified inflowing blood in the volume of interest in the absence of cardiac function derangement, both leading to inability to attain predetermined threshold values.^[12] Methods to overcome these drawbacks have been described by Kitai *et al.*, where two separate ROIs are placed over the abdominal aorta for bolus tracking.^[13] Exponential bolus shaping has also been described by Bae *et al.*, where instead of a uniphasic or biphasic rate of contrast injection, an exponentially decreasing rate is used.^[14] The authors claim this to give a more uniform contrast enhancement. However, this needs to have an inbuilt commercially available tool for implementation at the time of data acquisition. Optical sensor based tracking of the contrast bolus has also been recently described which offers the possibility of radiation-free monitoring of contrast kinetics.^[15] Saline chase is a standard technique in CTA as it has been shown to decrease the contrast volume and reduce artifacts.^[16,17] Monye' *et al.* reported slightly higher attenuation with the addition of bolus chaser to 80 ml of contrast material in carotid CT angiography.^[18] Thus, in the present case, lack of saline chase may have contributed to the inadequate CTA.

In the present case, an interesting pitfall of bolus tracking technique is documented. AVM of lower limb causes early filling of the deep veins with rapid mixing of the fresh contrast bolus with unopacified arterial inflow during first-pass flow. The resultant fall in the HU value in the ROI leads to erroneous interpretation and failure of scan triggering. Unnecessary delay due to such a technical lapse can cost a CTA study as arterial washout occurs during this period. We suggest that in case of suspected AVM of the periphery where CTA is planned, test bolus technique may be a better method of scan timing, though at the cost of a greater contrast and radiation dosage.^[19] However, experience with a large number of patients is required.

Conclusion

Modification in CTA scan timing technique is required in patients with peripheral AVM as the bolus tracking technique may fail to achieve adequate scan timing in these patients. The purpose of highlighting this case is to bring to the forefront the often unreported or glossed over suboptimal scans due to suboptimal vascular opacification. Close visual monitoring is needed during acquisition to detect a fall in peak enhancement early so that scanning can be immediately initiated manually. The threshold value also needs to be kept low as a localized decrease in circulation time would allow rapid mixing of unopacified blood and contrast dilution. Automatic triggering methods should ideally be in place to initiate the scanning in case a fall in peak enhancement is present before reaching the threshold value.

Instead of a "one size fits all" approach, each scan must be tailored with meticulous attention to each of the variable factors like patient age, sex, weight, and cardiac output, and the area of interest. There is a need for a commercially available algorithmic approach inbuilt into the scanners, which takes into account these factors before scanning is initiated.

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