

PERIVENOUS ARTIFACT IN THORACIC CT ANGIOGRAPHY: EFFECTIVENESS OF LOWER EXTREMITY INJECTION

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ABSTRACT:

Purpose: Perivenous artifacts in the vena cava superior may cause obscuration of adjacent great vessels in thoracic computed tomography (CT) angiography. Our goal was to determine the image degrading effects of perivenous artifacts and determine the effectiveness of lower extremity injection as an alternative contrast delivery method.

Materials and Methods: Fifty patients with suspected pulmonary thromboembolism (PE) or aortic dissection were included in this study. Contrast material was administered via an upper extremity vein in 25 patients (group 1) and via a lower extremity vein in 25 patients (group 2) with a power injector. CT angiography was performed with bolus tracking. Contrast attenuation of vessel segments was calculated. Images were analyzed for artifacts and interpretability by using a four-level scaling method (1: intense and 4: no artifact).

Results: Artifacts were observed in all but one patient in group 1. Artifacts were intense in 17 patients (68%). The mean artifact score was 1.52. Among the evaluated vessel segments, the most prominent image degrading effects of artifacts were observed in the ascending aorta and right pulmonary artery. The lower extremity injection totally eliminated the perivenous artifact. This method resulted in statistically significantly lower attenuation numbers in vessels compared to upper extremity injection ($p < 0.05$), but adequate contrast enhancement was achieved.

Conclusion: Perivenous artifacts cause obscuration of adjacent great vessels. Lower extremity injection prevents perivenous artifacts and good lesion depiction is achieved.

Key words: Thorax, Computed Tomography, Contrast Material, Artifact

TORAKS BT ANJİOGRAFİDE PERİVENÖZ ARTEFAKT: ALT EKSTREMİTE ENJEKSİYONUNUN ETKİNLİĞİ

ÖZ:

Amaç: Perivenöz artefakt, superior vena kavada kontrast madde varlığına bağlı olarak ortaya çıkan ve komşu büyük damarları örterek değerlendirme güçlüğüne yol açabilen bir durumdur. Bu durum bilgisayarlı tomografi (BT) anjiyografilerde önemli tanısal zorluklara neden olabilmektedir. Bu çalışmanın amacı, perivenöz artefaktın görüntüyü bozucu etkisini ortaya koymak ve alternatif bir enjeksiyon yöntemi olarak alt ekstremitte enjeksiyonunun etkinliğini belirlemektir.

Gereç ve Yöntem : Hastalar (n=50) esit iki gruba ayrılmış, otomatik enjektör aracılığıyla 1. gruba üst ekstremitte veni, ikinci gruba alt ekstremitte veni yoluyla esit hız ve miktarda kontrast madde verilmiştir. İnceleme 'bolus tracking' programı kullanılarak baslatılmıştır. Mediastinal ana damarların dansite-kontrastlanma değerleri ölçülmüştür. Görüntüler artefakt ve değerlendirilebilirlik açısından dörtlü sistem üzerinden derecelendirilmiştir (1: yoğun artefakt ve 4: artefakt yok).

Bulgular: 1. gruptaki hastaların biri dışında tümünde artefakt saptandı. 17 hastada (%68) artefakt belirgin derecede yüksekti. Ortalama artefakt derecesi 1,52 idi. Değerlendirilen damar segmentleri arasında perivenöz artefaktın görüntüyü bozucu etkisi çıkan aorta ve sağ pulmoner arterde en belirgin olarak gözlemlendi. Alt ekstremitte enjeksiyonu yöntemi ile perivenöz artefakt görülmedi. Dansite ölçümü yapılan damar segmentlerinde ikinci grupta ortalama dansite değerleri birinci gruba kıyasla daha düşük ($p < 0,05$) ancak kontrast düzeyi değerlendirme için yeterliydi.

Sonuç: Perivenöz artefakt toraks BT anjiyografilerde çıkan aorta ve sağ pulmoner arter basta olmak üzere mediastinal büyük damarların değerlendirilmesinde tanısal zorluklara yol açmaktadır. Alt ekstremitte enjeksiyonu yöntemi aortik disseksiyon ve pulmoner emboli şüphesiyle incelenen hastalarda kullanışlı ve güvenli bir yöntemdir. Bu yöntem perivenöz artefaktı önlerken, lezyon saptanabilirliği konusunda da etkindir.

Anahtar Kelimeler Artefakt, Toraks, Bilgisayarlı Tomografi, Kontrast Madde

INTRODUCTION

Contrast enhanced chest computed tomography (CT) examinations make up a considerable proportion of all CT examinations. Contrast material is generally administered via an upper extremity, preferably the antecubital vein. Effective and faster usage of contrast material has become a necessity with the introduction of helical CT technology. Today with MDCT technology proper usage of contrast material has become much more important. Recently multilevel dual head power injectors with up to 10 ml/s injection rate capacity have come into use for sophisticated CT angiographic or multiphase perfusion imaging. This causes two major problems: extravasation and perivenous artifacts. Generally, contrast material is given via an antebrachial vein or another large caliber upper extremity vein. Perivenous artifacts are streak or blooming artifacts that occur due to the presence of undiluted contrast material in the subclavian vein, brachiocephalic vein, or superior vena cava. These artifacts may cause obscuration of adjacent great vessels. Loss of information occurs, especially in the ascending aorta and right pulmonary artery. This gives rise to major diagnostic problems when performing CT angiography in patients with suspected pulmonary thromboembolism or aortic dissection.

Our goal was to determine the image degrading effects of perivenous artifacts and determine the effectiveness of lower extremity injection as an alternative contrast delivery method for CT angiography.

MATERIALS AND METHODS

Patients:

Fifty patients (24 male, 26 female; mean 57 years, 26-86 years) who underwent thoracic CT angiography with suspicion of pulmonary thromboembolism or aortic dissection were included in this study and were evaluated for perivenous artifacts. Indications for CT angiography were pulmonary thromboembolism (PE) (n=38) and aortic dissection/aneurysm (n=12). Contrast material was administered via an upper extremity vein (preferably the antecubital vein) in 25 patients (group 1) and via a lower extremity vein in the remaining 25 patients (group 2). Patients in the lower extremity injection group underwent a lower extremity venous Doppler examination to exclude thrombus formation before the CT examination. Our institutional review board approved the study. All patients gave informed consent.

Imaging:

All examinations were performed with a third generation helical CT device (HiSpeed CTi General Electric Medical Systems, Milwaukee, WI, USA). The commercially available bolus tracking software 'Smart prep' (General Electric Medical Systems,

Milwaukee, WI, USA) was used to determine the time to start the scan. Patients were imaged in the supine position with their arms above their heads. Scanning was performed in the craniocaudal direction. After a scout scan was performed (120 kVp, 50 mA), a localizer graphic was placed from the superior level of the aortic arch to the inferior level of the cardiac ventricles. A precontrast image was taken from the level of the ascending aorta and pulmonary trunk for smart prep application. A round ROI was placed on the pulmonary trunk in the patients with suspected pulmonary thromboembolism and on the ascending aorta in the patients with suspected aortic dissection. The size of the ROI was adjusted according to the size of vessel. Then the contrast injection and bolus tracking program were initiated synchronously. The scanning parameters were 120 kVp, 40 mA, and 0.8 s rotation time. The first scan was taken 10 s after the initiation of the contrast injection and sequential scans were taken from the same level every 3 s. The selected threshold value was 50 HU above the baseline. When the threshold value was reached, scanning was initiated manually. The scanning parameters were 120 kVp, 240 mA, 3 mm collimation, 1.5 pitch, and 0.8 s rotation time. Images were reconstructed retrospectively with 1 mm thickness.

Contrast injection protocol:

The contrast material was given via a superficial lower extremity vein in 25 patients.

In the remaining 25 patients, upper extremity veins were used for contrast administration as in our routine protocol. A total of 120 cc nonionic iodine contrast material, iodixanol (Visipaque 320 mg I/mL; Amersham Health, Ireland), was given. The contrast material was administered with a power injector (MedRad CT injector, Pittsburgh, PA, USA), through a 20 gauge IV cannula. The injection rate was 3 ml/s. The venous access was tested with 20 ml of isotonic saline bolus injection before contrast material administration. After the examination was completed, venous access was washed with saline solution.

Image evaluation:

All examinations were reviewed on a workstation by two radiologists unaware of the injection method and experienced in thoracic imaging. Before interpreting the images separately, they worked together to establish a consensus on qualitative assessment and determine basic definitions. The optimal window settings for optimal visualization of vessel segments were also determined in the first four patients by consensus as follows: window width: 400, window level: 80 HU. These settings were used for all patients. The images were analyzed both qualitatively and quantitatively. Attenuation values (Hounsfield unit) of great vessels were measured by drawing a round region of interest (ROI) in the lumen of the following great vessels: superior vena cava, ascending aorta, aortic arch, proximal descending aorta, pulmonary trunk, right main pulmonary artery, and left main pulmonary artery. The ROI was drawn as large as the diameter of the lumen allowed in the axial slice. Care was taken to cover the

majority of the vessel lumen without including vessel walls (Fig 1). The degree of perivenous artifact and interpretability of adjacent major mediastinal vessels were evaluated using a four-level scoring method (Table 1). Contrast material-related perivenous artifacts were graded as follows: 1- Intense, completely obscuring adjacent structures; 2- Moderate, partially obscuring adjacent structures; 3- Mild, artifact exists but causes minimal or no undesired effects on image quality; 4- No artifact (Fig 2). Scoring of interpretability of great mediastinal vessels was as follows: 1- poor, discrimination of vessel contour and lumen is impossible; 2- marked loss of data, poor perception of vessel border and lumen; 3- good, minimal data loss of anatomical details that do not have a great impact on interpretation; 4- excellent, clear anatomic detail. The artifact and interpretability scores were assessed by two observers independently.

Table 1: Four-level grading system for perivenous artifact and interpretability

Score	Perivenous Artifact	Interpretability
1	Intense, completely obscuring adjacent structures	Poor, discrimination of vessel contour and lumen is impossible
2	Moderate, partially obscuring adjacent structures	Marked loss of data, poor perception of vessel border and lumen
3	Mild, artifact exists but causes minimal or no undesired effects on image quality	Good, minimal loss of anatomical details that do not generate a great impact on lesion depiction and interpretation
4	No artifact	Excellent, clear anatomic detail

Table 2: Attenuation values of vessel segments

Location	Attenuation values (mean±SD)	
	Upper extremity injection (group 1)	Lower extremity injection (group 2)
Superior vena cava	665.44±241	102.56±36
Ascending aorta	248.48±60	177.52±46
Descending aorta	238.48±59	173.52±58
Pulmonary trunk	278.56±62	177.04±58
Right main pulmonary artery	257.36±59	162.96±55
Left main pulmonary artery	264.36±64	169.32±61
p <0.01 for all vessel segments		

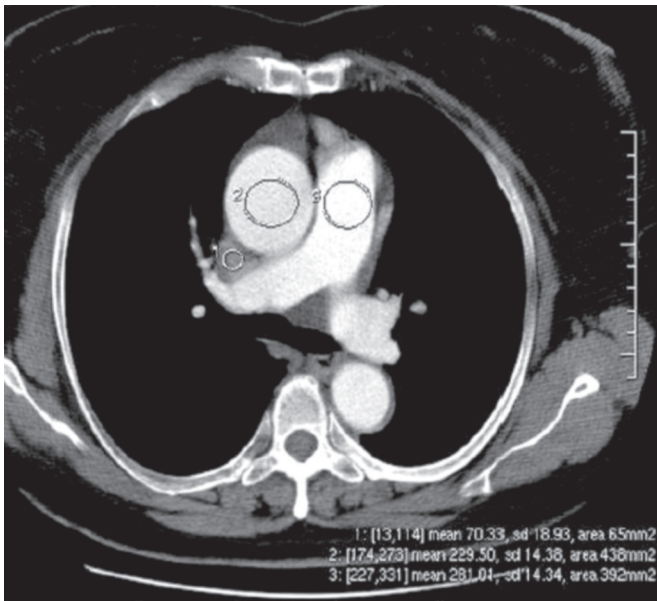


Figure 1: Measurements of contrast enhancement and placement of ROI in a patient with lower extremity injection.

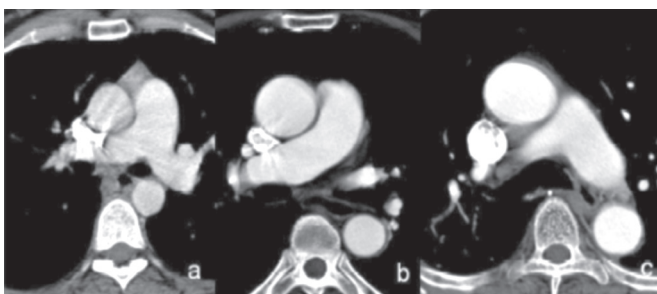


Figure 2: Artifact grading: a. Intense artifact, b. Moderate artifact, c. Mild artifact

Statistical Analysis:

Mean and standard deviation of venous and arterial attenuation values were calculated. Attenuation values, and artifact and interpretability scores in the two groups were compared using Student's *t* test and *p* values were calculated. Statistically significant differences were defined as *p* less than 0.05. Pearson's correlation test was used for assessment of the agreement between the two observers. Intraclass correlation coefficients greater than 0.5 were accepted as indicative of good agreement.

The software SPSS for Windows v 11.0 (SPSS Inc. Chicago IL, USA) was used for statistical analyses.

Results:

Perivenous artifacts and grading of interpretability:

Perivenous artifacts were not found in group 2 patients. Artifacts were observed in all but one patient in group 1. Artifacts were intense in 17 patients (68%), moderate in 4 patients (16%), and mild in 3 patients (12%). No artifact was found in one patient. The mean artifact score was 1.52. There was a strong relationship between the perivenous artifact score and the density calculated from VCS ($p < 0.01$). The

mean attenuation values measured from VCS in groups 1 and 2 were 665.4 HU (min. 180, max. 1139) and 102.5 HU (min. 29, max. 175), respectively. The difference is statistically significant ($p < 0.01$) (Fig 3).

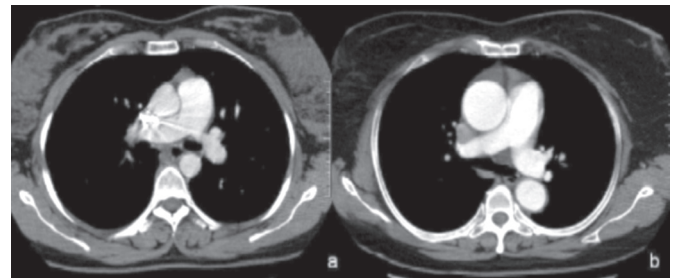


Figure 3: Upper extremity injection (a) with intense perivenous artifacts vs. lower extremity injection (b) without any artifact

Interpretability scores of vessel segments were 4 for all vessel segments in all patients in group 2. The mean scores in group 1 were 1.72 for the ascending aorta, 2.2 for the arcus aorta, 4 for the descending aorta, 3.8 for the pulmonary trunk, 1.68 for the right pulmonary artery, and 4 for the left pulmonary artery. A strong correlation was found between the two observers both for the artifact and the interpretability grading. Correlation coefficient values were between 0.669 and 0.967.

Attenuation of vessels:

Mean attenuation values of evaluated vessel segments were 248.48 ± 60 (153-393) HU in the ascending aorta, 238.48 ± 59.6 (156-397) HU in the descending aorta, 278.56 ± 62 (146-372) HU in the pulmonary trunk, 257.36 ± 59.6 (150-347) HU in the right pulmonary artery, and 264.36 ± 64.2 (156-354) HU in the left pulmonary artery in group 1. The attenuation values were 177.52 ± 46 (90-258) HU in the ascending aorta, 173.52 ± 47.6 (89-260) HU in the descending aorta, 177 ± 58.6 (84-273) HU in the pulmonary trunk, 162.96 ± 55 (72-258) HU in the right pulmonary artery, and 169.32 ± 61.7 (67-293) HU in the left pulmonary artery in group 2. The lower extremity injection resulted in significantly lower attenuation numbers in all vessel segments ($p < 0.05$).

The mean number of monitoring scans was 3 in group 1 and 6 in group 2. The time interval between the beginning of the injection and starting the scan was 16 and 28 s in groups 1 and 2, respectively.

Abnormal CT findings were observed in 26 patients. Pulmonary embolism was seen in 8 patients, aortic dissection was found in 1, and aneurysmatic dilatation was found in 4. Non-vascular findings were depicted in the remaining 14 patients (pleural effusion and compressive atelectasis in 11, malignancy in 1, consolidation in 1, and pulmonary edema in 1). The lower extremity injection was well tolerated by all patients. No complication was observed in either group related to the contrast injection.

No venous thrombus was found in patients in the lower

extremity injection group on the venous Doppler examination.

DISCUSSION:

The use of intravenous contrast materials, especially for the evaluation of vessels and mediastinum, is indispensable in thorax CT examinations. Since the introduction of spiral and multidetector CT systems, the administration of contrast material has been done by multilevel power injectors. The amount of contrast material used for thoracic helical CT varies between 75 and 150 ml depending on the indication for scanning and institution.^{1,2} Many institutes have begun using high injection rates up to 10 ml/s for CT angiography. Contrast material is generally administered via an upper extremity (preferably antecubital) vein. The occurrence of perivenous artifacts in VCS due to the inflow of undiluted contrast material is an important problem in thoracic CT angiography. These artifacts are frequently seen when the start of scanning occurs before the end of the contrast material injection. Many techniques and injection protocols have been proposed and determined to overcome this problem in the literature.^{2,3-6,7}

Scanning the thorax in the caudocranial direction has been used in many institutions for general purpose chest CT examinations and may reduce or prevent intense perivenous artifacts. With this technique breath-holding problems and intense artifacts secondary to respiratory movements may occur towards the end of the examination that includes superior mediastinum and great vessels, especially in seriously ill or dyspneic patients as with PE. It is also necessary to finish the injection before the examination ends in this technique to prevent artifacts; therefore, higher contrast material injection rates are generally required.

Saline flush or chaser bolus is another well described and widely used technique.⁵ This technique is also suggested for reducing the contrast material dose³ and needs relatively high injection rates. It may reduce but cannot always prevent artifacts.

Reduced iodine concentration appears to diminish perivenous artifacts; however, higher injection rates and higher volumes are generally required with this technique. Rubin et al. concluded that dilution of 15 g of iodine to 150 mg/ml iodine resulted in superior thoracic CT scans by diminishing perivenous artifacts and improving arterial enhancement.²

Two phase CT angiography is a method described for effective detection of hilar pulmonary thromboembolism, and exhibited good opacification especially in the right pulmonary artery without major perivenous artifacts.⁶ Although it allows improved image quality, this technique increases the effective radiation dose to which the patient is exposed.

Nakayama et al. concluded that doing hand exercises during contrast delivery can reduce perivenous artifacts.⁷ Cooperation with patients is the critical point of this technique, which is not always possible.

Hara et al. tested the effectiveness of ankle vein contrast injection in routine purpose thorax CT examinations with fixed 60 s scan delay time and found it useful in situations such as mediastinal abnormalities near the great vessels.⁴

We tested the image degrading effects of perivenous artifacts that arose from undiluted contrast material in VCS on thorax CT angiography when upper extremity veins were used as the contrast delivery route. We found that the most prominent image degrading effects of perivenous artifacts occurred in the ascending aorta and the right pulmonary artery. This can be an important problem in patients suspected of having PE or aortic dissection, as in our study population (Fig 4, 5). We also tested the efficiency of lower extremity injection in thorax CT angiography with bolus tracking. The results of our study indicate that the lower extremity injection eliminates perivenous artifacts totally while assuring adequate image quality and is well tolerated by patients.

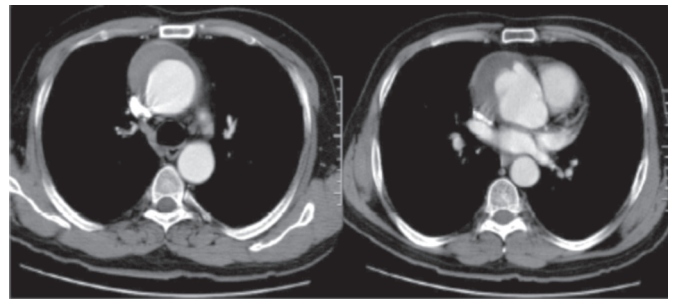


Figure 4: Moderate artifact partially obscuring the vessel wall and the true extension of the intimal flap in a patient with aortic dissection.

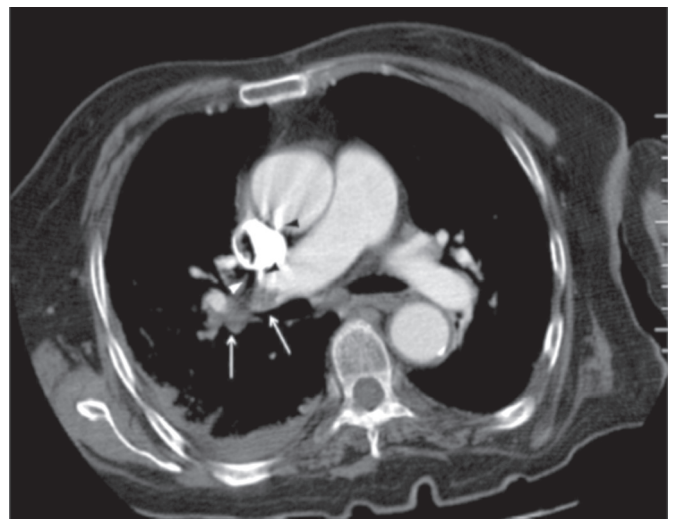


Figure 5: Emboli in right main and lobar pulmonary artery branches (arrows) and intense perivenous artifacts obscuring the vessel wall and lumen (arrowheads).

Many authors consider lower extremity injection to be a method for contrast delivery that has a potentially high risk of complications. This general belief depends on observations and the results of previous studies on conventional venography

with ionic iodinated contrast materials. However, it should be kept in mind that the endothelial contact duration of contrast material may extend for several minutes and venous drainage is blocked by compressing the femoral vein during venography for adequate imaging of the veins. Jacobs et al. reported the contrast reactions and extravasation rate of 6660 patients. They analyzed the relationship between extravasation and many technique and patient dependent factors. They found no correlation between the extravasation rate and catheter location, catheter size, or catheter type.⁸ In addition, systemic and local contrast reactions occur less frequently with nonionic contrast agents as used in our study than with ionic contrast agents.

We found significant differences in the mean attenuation values of vessels between the two groups. The lower extremity injection resulted in lower enhancement. This was probably related to further dilution of the given contrast material via the lower extremity by a large amount of venous blood returning from the opposite lower extremity and abdomen compared to with the upper extremity injection. Actually, the lower attenuation values depicted from the great vessels of the patients in group 2 did not affect our assessment. When considering pulmonary embolism, according to data from animal and human studies, emboli have a mean intrinsic CT attenuation of about 50 HU.^{9,10} After contrast administration, this level must be exceeded for depiction of any thrombus in a vessel lumen. Cham et al. investigated venous thrombosis in PE patients and the efficacy of CT venography. They rated the technical quality of the examination as “excellent” when the main pulmonary artery had an attenuation level greater than 200 HU and “good” when attenuation values were 150 to 199 HU.³ Moreover, 150-200 HU of vessel enhancement was accepted as optimal according to the results of another study.¹¹ Using different window settings is as important for effective depiction of PE in thoracic CT examinations as good contrast attenuation.⁹ Aortic arrival times and threshold reaching times depend on intrinsic parameters of patients such as cardiac output and circulation rather than injection protocol as described by Kim et al.¹² Our study population consisted of seriously ill patients to a great extent. Most of them had various degrees of hemodynamic problems. This may also have affected our results.

On CT angiography, the main objective of acquisition timing is to maximize the imaging covering during the period of highest contrast enhancement. Bae concluded that for longer injection durations (more than 20 s) time to peak enhancement occurs shortly after completion of the injection.¹³ The magnitude of aortic enhancement increases proportionally to an increase in injection duration. An adequate contrast enhancement level can be achieved by setting the injection duration the same as the imaging duration. Our results showed that the lower extremity injection allows the injection of contrast material during the whole examination, without any perivenous artifacts and with adequate vessel enhancement. This injection method might be an alternative way especially in patients in

whom proper venous access in both upper extremities is not possible (for example patients who have undergone bilateral mastectomy or with thrombophlebitis in the upper extremities due to recent chemotherapy).

In conclusion, perivenous artifacts in the superior vena cava degrade the image quality in CT angiography of the chest. The most prominent effects of these artifacts occur in the ascending aorta and the right pulmonary artery. Lower extremity contrast injection is a useful and safe method in patients suspected of having PE or aortic dissection. This technique totally eliminates perivenous artifacts and good lesion depiction is achieved. While it prevents perivenous artifacts and assures clear anatomical detail, it also allows sufficient vessel attenuation when used with a bolus tracking program.

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