OMICS Journal of Radiology

Sharma et al., OMICS J Radiol 2014, 3:4
DOI: 10.4172/2167-7964.1000168

Research Article | Open Access

40 ml And 50 ml Contrast Volume Comparison in 256-Slice Craniocervical Computed Tomography Angiography

Sharma BR*, Timilsina M, Yuan QH and Liu D

Norman Bethune College of Medicine, Changchun, Jilin, China

Abstract

Objective: The main objective of this study is to reduce attenuation profiles and decrease the perivenous artifacts by decreasing the contrast amount used than used regularly.

Material and methods: Sixty six patients were randomly assigned into two groups (Group A and B), each comprising 33 patients. Group A (21 men, 12 women) received the department's standard protocol of 50 ml intravenous contrast volume, whereas Group B (19 men, 14 women) received 40 ml of contrast volume and underwent craniocervical CTA (computed tomographic angiography). Quantitatively, mean attenuation values for both groups were measured in arteries and veins of the craniocervical region. Attenuation values of veins and arteries were measured at four points. Qualitatively, two radiologists independently evaluated the axial source and maximum intensity projection (MIP) images for the occurrence of artifacts at the subclavian vein using a four-point scale. Probability values less than 0.05 were considered statistically significant.

Results: Although there were no statistically significant differences in mean arterial attenuation profiles (aorto-carotid artery (p=0.87) and vertebra-basilar artery (p=0.72)) in Group A versus Group B, mean venous attenuation values were lower in Group B than in Group A (110 ± 19.61 HU vs. 188.27 ± 57.4 HU; p<0.001). When compared with Group A qualitatively, the perivenous artifacts in the subclavian veins were evaluated as less prominent (p<0.001) in Group B, whereas there was no significant difference during the qualitative assessment of the arterial images.

Conclusion: Use of 40 ml contrast medium on cervical CTA can reduce venous attenuation profiles and decrease perivenous artifacts in the subclavian veins when compared with 50 ml.

Keywords: 256-MDCT; Perivenous artifacts; Computed tomography angiography; Contrast volume

Introduction

With the advent of modern 256-slice multidetector computed tomography (MDCT) scanners, the scan acquisition time has greatly reduced and the image quality has further improved owing to its high spatial as well as temporal resolution. Craniocervical CTA has become an important tool for the assessment of the extracranial and intracranial vessels. However, artifacts are common place in CTA, are distracting and may compromise accurate diagnosis. Perivenous artifacts are well reported concerned on CTA [1]. Hence, the goals of this prospective study were to study the attenuation values of craniocervical vessels and the perivenous artifacts at the subclavian vein using different volumes of contrast m edia (40 ml versus 50 ml) with 256-slice craniocervical MDCT angiography.

Materials and Method

This prospective study was approved by institutional review board (IRB) and the informed consent was obtained from all the patients. Sixty six patients were randomly assigned into two groups (Group A and B), each comprising 33 patients. All patients underwent craniocervical CTA examination. Group A (21 men, 12 women; mean age, 56.87 ± 11.53) received standard protocol of 50 ml intravenous contrast volume, whereas Group B (19 men, 14 women; mean age, 56.94 ± 11.51 years) received 40 ml of contrast volume.

The standard protocol was followed during the cervical CT angiography which includes fasting for at least 2 hour prior imaging. After obtaining written consent, vascular access using 20-gauge needle into the right antecubital vein was used as it provides shortest path (with least amount of dilution) and less streak artifact caused by flow in left brachiocephalic vein.

The contrast agent (Xenetix 350 (Iobitridol 350 mg of iodine/mL); Guerbet Asia Pacific, Shanghai, China) volume for CTA was 50 ml for group A and 40 ml for group B. In both groups, injection rate was 5 ml/s, followed by a 40 ml flush of saline. All studies were performed with same scanning parameters with 256-slice CT scanner using a real time-bolus tracking technique. Precontrast scout anteroposterior and lateral CT scans were acquired first, with a scan coverage range from the Circle of Willis (2 cm above the frontal sinus) to the aortic arch (2 cm below the aortopulmonary window). Scanning was performed in caudocranial direction. All scans were performed using the same parameters for both groups with tube voltage of 120 kV, rotation time of 0.5 second, an effective tube current-rotation time product (normalized to the pitch factor) of 800°C 1000 mAs, tube current was 495 mA, table feed speed of 158.7 mm/second, a pitch factor of 0.16 and a fixed detector collimation of 128x0.625 mm, field of view (FOV) was 220 mm, and the total scan time was 3.15 s. The scanning delay was predetermined by using a contrast agent bolus tracking method (Bolus Pro, Philips Healthcare, Cleveland, OH, USA) for assessment of the optimal time delay for CT scanning, to optimize contrast material enhancement in carotid arteries; the region of interest (ROI) indicator was placed on a reference image obtained from the aorta. The initiation of the scan was after a post-threshold delay of 5 seconds after the signal

***Corresponding author:** Sharma BR, Norman Bethune College of Medicine, Changchun, Jilin, China, Tel no: +86-431-85166885; E-mail: bhojrajsharma2@gmail.com

Received July 17, 2014; **Accepted** August 04, 2014; **Published** August 11, 2014

Citation: Sharma BR, Timilsina M, Yuan QH, Liu D (2014) 40 ml And 50 ml Contrast Volume Comparison in 256-Slice Craniocervical Computed Tomography Angiography. OMICS J Radiol 3: 168. doi:10.4172/2167-7964.1000168

attenuation reached a predetermined threshold of 110 HU in the ascending aorta.

Image analysis was performed on a digital image workstation (Extended Brilliance Workspace (EBW) Version V4.5.2.40007, Philips Healthcare, Cleveland, Ohio, USA). Xres Standard filter (XCB, Philips Healthcare, Cleveland, Ohio, USA) was used for the purpose of image reconstruction with axial, coronal and MIP images. Raw data reconstruction was acquired by using 0.9 mm slices. For the qualitative analysis, source axial and coronal MIP with the slice thickness of 3.0 mm was reconstructed for the study of the subclavian vein and the aorto-carotid and vertebro-basilar arteries. Arterial and venous enhancement patterns were measured objectively. All axial source images were interpreted by a radiologist, blinded to patient data. Between the aortic arch (AA) and internal carotid artery (ICA), venous and arterial attenuations in HU were measured within a maximal circular region of interest (ROI) that would fit within the lumen excluding the wall of the vessel. The typical size for such ROIs was10-20 mm. For the arterial attenuations, the ROIs were placed at the seven points, between the aortic arch and ICA. These include 1) aortic arch, 2) proximal common carotid artery, 3) distal common carotid artery, 4) proximal ICA, 5) distal ICA, 6) ICA at cavernous sinus, 7) ICA at communicating segment. Similarly, the ROIs were placed at three locations in the vertebro-basilar artery and attenuation values were measured as follows: 1) proximal vertebral artery (VA), 2) distal VA, and (3) distal basilar artery. In the presence of severe artifacts or obscuration or severe narrowing of vessels, attenuation profiles of affected vessels at that scanning level were not measured. Also, venous attenuations were measured at four points: 1) subclavian vein, from the junction of the cephalic vein and axillary vein at the lateral border of the first rib, 2) subclavian vein, between the first rib and the clavicle at the costoclavicular space, 3)brachiocephalic vein, between the junction of the right internal jugular vein and the junction of the bilateral brachiocephalic veins, and 4) superior vena cava, between the junction of the bilateral brachycephalic veins and the right atrium.

Similarly as quantitative analysis, qualitative assessment was also done. Initially, the quality of the axial source images was evaluated and the contrast-related perivenous artifacts at the right subclavian artery were graded on a 4-point scale [1,2]. A score of 1 indicated no dense contrast medium within the venous lumen and clear anatomic detail without perivenous artifacts; 2, dense contrast medium within the venous lumen (<50%) with minimal streak artifacts; 3, dense contrast medium within the venous lumen (>50%) with moderate perivenous artifacts; and 4, dense contrast medium fills the venous lumen with severe perivenous artefacts (Figure 1).

Subsequently, coronal MIP images were assessed for any overlap between the subclavian artery and the subclavian vein with sliding thin slabs (0.9 mm) in the right subclavian vein. A four-grade scale was used; [1] 1), dense contrast medium did not persist, and there was only slight attenuation (less than in the subclavian artery) and the occurrence of a minimum overlap of venous structures; 2) a small volume of dense contrast medium remained with mild attenuation (close to that in the subclavian artery) with the occurrence of overlap of venous structures; 3) a moderate volume of dense contrast medium remained with high attenuation (greater than that in the subclavian artery) with the occurrence of moderate overlap of venous structures; and 4) a massive volume of contrast medium remained with markedly high attenuation (much greater than in the subclavian artery) with the occurrence of severe overlap of venous structures (Figure 1). The concluding step of qualitative analysis was accomplished by assessment of arterial enhancement in the aorto-carotid and vertebro-basilar arteries using

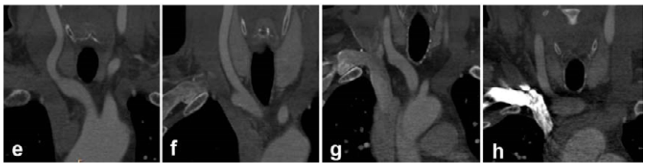

Figure 1: Qualitative assessment of perivenous artifacts at the subclavian artery. Axial source images (a-d) were grade using a 4-point scale: a) A score of 1 indicated no dense contrast medium within the venous lumen and clear anatomic detail without perivenous artifacts; b) 2, dense contrast medium within the venous lumen (<50%) with minimal streak artifacts; c) 3, dense contrast medium within the venous lumen (>50%) with moderate perivenous artifacts; and d) 4, dense contrast medium fills the venous lumen with severe perivenous artefacts. MIP images (e-h) were assessed also using a 4-point scale: e) a score of 1, dense contrast medium did not persist, and there was only slight attenuation (less than in the subclavian artery) and the occurrence of a minimum overlap of venous structures; f) 2, a small volume of dense contrast medium remained with mild attenuation (close to that in the subclavian artery) with the occurrence of overlap of venous structures; g) 3, a moderate volume of dense contrast medium remained with high attenuation (greater than that in the subclavian artery) with the occurrence of moderate overlap of venous structures; and h) 4, a massive volume of contrast medium remained with markedly high attenuation (much greater than in the subclavian artery) with the occurrence of severe overlap of venous structures.

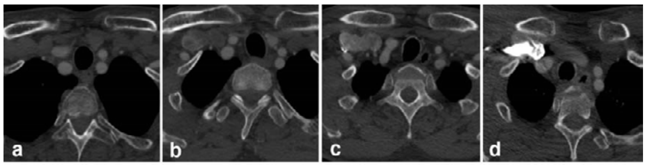

Figure 2: Coronal maximum intensity projection (MIP) images of internal carotid, vertebral and subclavian veins using 50 ml (a-d) and 40 ml (e-f) of contrast medium. Note: there is no significant difference in the quality of images with the use of 50 and 40 ml of contrast medium, however, the perivenous artifacts are less prominent with 40 ml.

coronal MIP and a four-point scale: (1) poor, (2) acceptable, (3) good and (4) excellent. When 40 ml contrast medium protocol was compared to 50 ml, the arterial and venous enhancement were comparable and the perivenous artifacts at the subclavian vein were less prominent (Figures 2 and 3). Qualitatively, two radiologists independently evaluated the axial source and maximum intensity projection (MIP) III images for the occurrence of artifacts at the subclavian vein using a four-point scale. Attenuation profiles were calculated using unpaired student's t-test, and the Mann's Whitney U test was used for qualitative analysis. Probability values less than 0.05 were considered statistically significant.

Result

For both groups, Group A (21 men, 12 women; mean age, 56.87 ± 11.53; age range, 29-73 years) and Group B (Table 1) (19 men, 14 women; mean age, 56.94 ± 11.51 years; age range, 37-87 years), the patient characteristics between the above groups had not revealed a significant difference. An unpaired Student's t-test revealed no significant differences between the two patient groups regarding age (p=0.66), sex (p=0.27), body weight (p=0.46), height (p=0.90), or body mass index (BMI) (p=0.17). Also, a chi-squared test showed no significant differences between sex distribution between two groups; male (p=0.66) and female (p=0.61) (Table 2).

While assessing the carotid artery images subjectively, three patients in Group A (n-2 partial occlusion, n-1 complete occlusion) and four patients in Group B (n-3 partial occlusion, n-1 complete occlusion) had obstruction of the internal carotid artery. Therefore,

Citation: Sharma BR, Timilsina M, Yuan QH, Liu D (2014) 40 ml And 50 ml Contrast Volume Comparison in 256-Slice Craniocervical Computed Tomography Angiography. OMICS J Radiol 3: 168. doi:10.4172/2167-7964.1000168

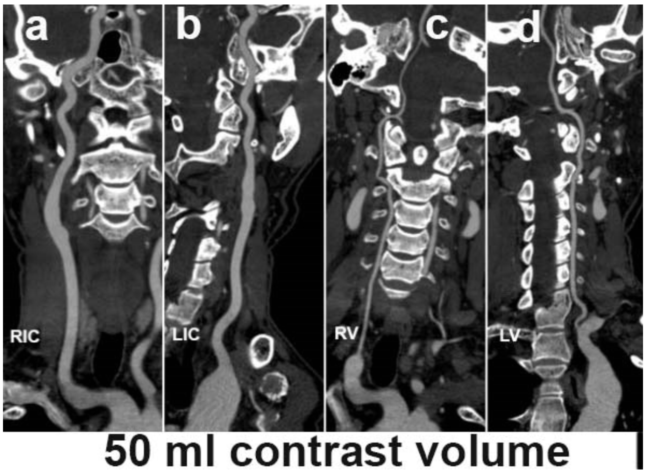

Figure 3: Comparison of axial images volume rendered images using 50 ml (A) and 40 ml (B) contrast material volume on 256-slice craniocervical computed tomography angiography.

	Group A (50 ml contrast)	Group B (40 ml contrast)
Scanner parameters		
Tube voltage (kV)	120 kV	120 kV
Pitch	0.99	0.99
mA (modulation)	495	495
Field of view (FOV, mm)	220	220
Gantry Rotation Time (sec)	0.5	0.5
Direction/range	Caudocranial	Caudocranial
Slice thickness (mm)	0.9	0.9
z-axis coverage (mm)	80	80
slice Increment (mm)	0.45 mm	0.45 mm
Detector Collimation (mm)	128x0.625	128x0.625
Contrast bolus geometry		
Bolus tracking	Dynamic	Dynamic
Region of interest	Ascending aorta	Ascending aorta
Threshold for bolus tracking (HU)	110	110
Contrast parameters		
Contrast volume (mL)	50	40
Saline volume (mL)	40	40
Injection rate (mL/s)	5	5

Table 1: Functional scanner and contrast material injection parameters.

the measurement of arterial enhancement in six segments in images of Group A and seven segments in images of Group B was hindered due to occlusion or severe narrowing of the arterial lumen. Severe motion artifacts hampered analysis in 0.93% (4/429) of all measurements in Group A and in 0.69% (3/429) of all measurements in Group B. Dental metal artifacts hampered analysis in 1.86% (8/429) of all measurements in Group A, while 1.16% (5/429) of all measurements in Group B. When vertebro-basilar artery was assessed, no patients had basilar artery occlusion in both groups. Unilateral vertebral occlusions were present in 2 of 33 patients in group A and 3 of 33 patients in group B; however, we measured the lumen of the unaffected side.

Quantitative and qualitative assessments of arterial enhancement

Quantitatively, there were no statistically significant differences in the mean arterial attenuation profiles of aorto-carotid artery in Group A versus Group B (334.84 ± 46.98 HU vs. 332.64 ± 61.49 HU; p=0.87). Likewise, the mean arterial attenuation profiles of vertebro-basilar artery revealed no significant difference in Group A versus Group B (393.02 ± 45.34 HU vs. 288.64 ± 52.01 HU; p=0.719) (Table 3). Similarly, qualitative assessment of arterial enhancement in the aorto-carotid (p=0.644) and vertebro-basilar arteries (p=0.552) showed no differences between Group A and Group B (Table 4).

Quantitative and qualitative assessments of venous enhancement at the central and subclavian vein

Quantitative assessment demonstrated that there was a statistically significant difference in venous attenuation between Group A and Group B at four points (Table 3). Furthermore, the mean venous attenuation profile in the central vein was significantly lower in Group B (188.26 ± 57.40 HU), as compared to Group A (110.06 ± 19.61 HU, p<0.001).

Qualitative assessment of both axial or MIP images showed that the perivenous artifacts at the subclavian vein in Group B was significantly less prominent in Group B when compared to Group A (p<0.001) (Table 4).

Discussion

CTA is a widely available, relatively safe, fast, and reliable method, and considered as first line diagnostic modality for the triage and evaluation of the patients of the patients suspected of cerebrovascular events in the setting of emergency. It can rapidly and precisely assess the patency of the intracranial vessels, evaluate for carotid atherosclerosis

	Group A (50 ml contrast)	Group B (40 ml contrast)	P value
No. of patients	33	33	
Age (range) (years)	56.87 ± 11.53 (35-77)	56.94 ± 11.51 (24-80)	0.66
Male/Female	21/12	19/14	0.657
Weight (kg) (range)	63.63 ± 10.84 (45-89)	61.83 ± 9.99 (40-85)	0.465
Height (cm) (range)	165.39 ± 8.48 (150-180)	165.15 ± 7.60 (149-180)	0.903
Body mass index (range) [kg/m^2]	23.21 ± 3.43 (18.6-24.9)	22.62 ± 2.98 (19.1-24.7)	0.46

Table 2: Baseline demographic characteristics of patients using two different volumes (50 and 40 ml) of contrast medium.

	Group A (50 ml contrast)	Group B (40 ml contrast)	P value
Arterial system			
Aorto-carotid system			
Aortic arch	338.98 ± 46.86	337.81 ± 52.41	0.925
Proximal CCA	328.72 ± 50.93	327.09 ± 57.76	0.122
Distal CCA	353.51 ± 51.97	350.12 ± 70.14	0.824
Proximal ICA	351.15 ± 60.12	349.26 ± 75.16	0.911
Distal ICA	343.93 ± 66.44	340.90 ± 80.37	0.868
ICA at the cavernous sinus	323.75 ± 51.78	321.74 ± 92.18	0.913
ICA at the communicating segment	303.84 ± 75.23	301.51 ± 74.46	0.90
Vertebro-basilar artery	273.93 ± 59.77	269.09 ± 64.09	0.752
Proximal VA	331.36 ± 62.12	328.85 ± 78.35	0.886
Distal VA	273.75 ± 47.80	268.10 ± 43.66	0.618
Venous system			
Superior vena cava	115.42 ± 79.64	72.74 ± 25.12	0.005
Right brachiocephalic vein	136.39 ± 123.08	82.89 ± 25.22	0.017
Right subclavian vein at the costo-clavicular space	267.15 ± 73.13	123.22 ± 50.97	0.0001
Right subclavian vein lateral the first rib	234.09 ± 65.38	161.36 ± 51.51	0.752

Table 3: Attenuation by locations.

	Group A (50 ml contrast)	Group B (40 ml contrast)	P value
MIP images			
Arterial images			
Carotid artery	3.91 ± 0.29	3.94 ± 0.24	0.64
Vertebro-basilar artery	3.91 ± 0.29	3.73 ± 0.52	0.552
Venous images			
Overlap between subclavian vein and subclavian artery	3.27 ± 0.67	2.15 ± 0.79	0.0001
Axial images			
Perivenous artefact at subclavian vein	3.27 ± 0.87	2.33 ± 0.85	0.0001

Table 4: Qualitative assessment of the arterial and venous images.

as a potential embolic source, and provide information about vessel occlusion that is essential before treatment with thrombolysis or even embolectomy is considered [2,3].

For the high quality CTA images, high concentration of contrast medium in the vessels is required. Technique-related factors such as contrast material volume and concentration, rate type of injection, saline bolus chase, and patient-related factors such as body weight, and cardiac output may affect CT contrast enhancement [1,2,4]. With the advent of modern 256 MDCT scanners, the scan acquisition time has greatly reduced and the image quality has further improved due to its high spatial as well as temporal resolution. However, perivenous artifacts are well reported concerned and can be caused due to flow of high contrast into the brachiocephalic, superior vena cava, subclavian veins, retrograde fill from the superior vena cava to the brachiocephalic vein and internal jugular veins during carotid CTA [2,5-8]. These artifacts can obscure origin of carotid arteries as well as important vessels of the head, neck and chest. The occurrence of perivenous artifacts continues to be a significant problem [9-12]. In the previous studies, different methods have been employed to reduced perivenous artifacts and enhanced image quality of CTA. The use of saline flush, following the contrast material administration helps to decrease perivenous artifact in the brachiocephalic veins, superior vena cava, and subclavian veins without a subsequent decrease in arterial attenuation. Schuknecht et al. demonstrated that the appropriate contrast agent volume and administration of saline chaser using of dual barrel injector have shown to decrease the perivenous artifacts and increase arterial enhancement. Although saline flush may result in increase in the mean and maximal attenuation of arteries, but for the reduction of perivenous artifact, the optimization of scan timing and the administration of saline flush is critical; the scan starts after the CM injection ends [1,5]. Multiple studies have shown that administration of contrast material into the right arm resulted in significant reduction in the jugular veins reflux and decrease in the perivenous artifacts. The venous system is longer in the left arm, and frequency and severity of artifacts increase as the venous system is longer in the left arm. Dilution of contrast material may decrease perivenous artifacts; however, for the optimal visualization of arterial enhancement on craniocervical CTA, high concentration of iodine is desirable [10]. There have been reported cases, in which, the comparison of vascular enhancement with reduction of contrast material volume, Yoon at el. determined the effect of two different volumes (80 and 60 ml) of contrast material and examined the contrast enhancement of head and neck with and without a saline chaser on 16-slice MDCT. They found that 60 ml contrast volume result in significantly lower mean attenuation and thus not acceptable for vessel contrast and use of saline bolus had no additional benefits except for reduction of perivenous artifact [13]. Saade et al. demonstrated the decrease in perivenous artifacts and increase arterial enhancement with reduced volume contrast regimen and craniocaudal scan acquisition with optimum bolus timing [1].

Modern 256 MDCT scanners are fast and shorter scanning times in MDCT may further reduce the volume of contrast material compared with single-detector row CT scanners [10]. The main hazards associated with CT scanning are radiation dose and contrast material use. Radiation dose attributed to medical radiation dose has risen drastically. CT scanning accounts for 49%, of all medical patient radiation doses [14]. In this study, we evaluated the possibility of reducing the volume of contrast material from 50 to 40 ml, as 50 ml of contrast material has been the standard dose for craniocervical CTA in our department. This decrease in contrast material volume has several potential advantages. Firstly, the high cost of contrast material may have significant financial burden on the patient and cost saving from decrease contrast material is apparent because of the increasing number of CT examinations. In the present study with the reduction of 10 ml of contrast material volume, there was 20% reduction of contrast material per CTA examination. secondondly, contrast-induced nephropathy (CIN) is directly related to the volume of the contrast material and reduction in contrast material volume may influence subsequent CIN [15,16]. Lastly, our study demonstrated and validated the use of the 40 ml contrast on 256-slice craniocervical CTA in terms of arterial enhancement of craniocervical vessels and perivenous artifacts at the subclavian artery. However, large-scaled studies are still required for the further evaluation of use of low volume contrast material and compare its diagnostic accuracy with standard protocols.

Till date, this was the first prospective study, comparing two different volumes of contrast materials in the assessment of perivenous artifact at the subclavian vein using 256-slice craniocervical MDCT angiography. The major findings in this study were as follows: First, 20% decrease in the contrast material volume (i.e. 40 ml) can produce very good arterial opacification and was comparable with the standard volume of 50 ml contrast volume. There was no significant difference between two groups (p=0.87). secondond, there was overall reduction in the mean venous attenuations (p<0.001). Third, both quantitatively and qualitatively, perivenous artifacts at the subclavian veins were less prominent at the subclavian veins with 40 ml of contrast material volume (p<0.001).

Conclusion

Owing to widespread availability, fast acquisition scan timing and highly diagnostic precision, MDCT angiography is a fast, reliable method, with low morbidity and has become a key diagnostic modality for the assessment of both intracranial and extracranial vasculature. However, careful measures should be taken to reduce the hazard associated with CT angiography such as contrast medium and radiation, without compromising image quality. In the current study, with the used of 40 ml contrast agent, there was a significant reduction in the perivenous artifacts at the subclavian vein, overall decrease in venous attenuation and the arterial image quality was comparable with 50 ml of contrast material in 256 slice craniocervical MDCT angiography, resulting in reduction of both cost and risks of contrast induced Nephrotoxicity.

References

1. Saade C, Bourne R, Wilkinson M, Evanoff M, Brennan P (2013) A reduced contrast volume acquisition regimen based on cardiovascular dynamics improves visualisation of head and neck vasculature with carotid MDCT angiography. Eur J Radiol 82:e 64-69.
2. Takeyama N, Ohgiya Y, Hayashi T, Takahashi T, Takasu D, et al. (2011) Comparison of different volumes of saline flush in the assessment of perivenous artefacts in the subclavian vein during cervical CT angiography. Br J Radiol 84: 427-434.
3. Koelemay MJ, Nederkoorn PJ, Reitsma JB, Majoie CB (2004) Systematic review of computed tomographic angiography for assessment of carotid artery disease. Stroke 35: 2306-2312.
4. Yamashita Y, Komohara Y, Takahashi M, Uchida M, Hayabuchi N, et al. (2000) Abdominal helical CT: evaluation of optimal doses of intravenous contrast material-a prospective randomized study. Radiology 216: 718-723.
5. de Monyé C, Cademartiri F, de Weert TT, Siepman DA, Dippel DW, et al. (2005) Sixteen-detector row CT angiography of carotid arteries: comparison of different volumes of contrast material with and without a bolus chaser. Radiology 237: 555-562.
6. Cademartiri F, Mollet N, van der Lugt A, Nieman K, Pattynama PM, et al. (2004) Non-invasive 16-row multislice CT coronary angiography: usefulness of saline chaser. Eur Radiol 14: 178-183.
7. Fujikawa A, Tsuchiya K, Imai M, Nitatori T (2010) CT angiography covering both cervical and cerebral arteries using high iodine concentration contrast material with dose reduction on a 16 multidetector-row system. Neuroradiology 52: 291-295.
8. Kim JJ, Dillon WP, Glastonbury CM, Provenzale JM, Wintermark M (2010) Sixty-four-section multidetector CT angiography of carotid arteries: a systematic analysis of image quality and artifacts. Am J Neuroradiol 31: 91-99.
9. Tseng YC, Hsu HL, Lee TH, Chen CJ (2007) Venous reflux on carotid computed tomography angiography: relationship with left-arm injection. J Comput Assist Tomogr 31: 360-364.
10. Lell MM, Anders K, Uder M, Klotz E, Ditt H, et al. (2006) New techniques in CT angiography. Radiographics 26 Suppl 1: 45-62.
11. Schuknecht B (2004) Latest techniques in head and neck CT angiography. Neuroradiology 46 Suppl 2: 208-213.
12. Demirpolat G, Yüksel M, Kavukçu G, Tuncel D (2011) Carotid CT angiography: comparison of image quality for left versus right arm injections. Diagn Interv Radiol 17: 195-198.
13. Yoon DY, You SY, Choi CS, Chang SK, Yun EJ, et al. (2006) Multi-detector row CT of the head and neck: comparison of different volumes of contrast material with and without a saline chaser. Neuroradiology 48: 935-942.
14. Mettler FA Jr, Huda W, Yoshizumi TT, Mahesh M (2008) Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology 248: 254-263.
15. Rudnick MR, Goldfarb S, Wexler L, Ludbrook PA, Murphy MJ, et al. (1995) Nephrotoxicity of ionic and nonionic contrast media in 1196 patients: a randomized trial. The Iohexol Cooperative Study. Kidney Int 47: 254-261.
16. Rosovsky MA, Rusinek H, Berenstein A, Basak S, Setton A, et al. (1996) High-dose administration of nonionic contrast media: a retrospective review. Radiology 200: 119-122.