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Original Article

Use of low-dose contrast agent in cerebral angiography produces high-quality diagnostic images

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Abstract: The present study was aimed to study feasibility of low-dose contrast agent in cerebral CT angiography (CTA) to alleviate some side effects and costs associated with routine doses of contrast agent. Sixty patients suspected to have cerebral artery disease were randomly selected to receive either low-dose (60 mL) contrast agent or routine-dose (100 mL) contrast agent. CTA included transverse images, volume rendering (VR), and maximum intensity projection (MIP) images. Developing strength, image noise, and structure display effects of the cerebral artery were compared between groups. The developing strength and image noise of the cerebral artery were equivalent between groups (*P* > 0.05). No statistical differences were observed in structure display effects of the cerebral artery or in radiological diagnosis between groups (*P* > 0.05). Application of the low-dose contrast agent is feasible and offers comparable diagnostic capabilities in cerebral CT angiography.

Keywords: Tomography, X-ray computed, cerebral angiography, radiation dosage

Introduction

The use of contrast agent in computed tomography (CT) has provided clinicians with clearer, sharper images, along with more accurate and detailed diagnostic tools. In the last ten years, advances in CT technology have allowed for the development of CT angiography of the head, neck, and coronary artery, abdominal aortography, and limb arteriography protocols to be incorporated into routine clinical examination. As a result, conventional angiography has been widely replaced by non-invasive CT angiography [1, 2]. CT angiography entails the use of iodine-based contrast agents to highlight the blood supply in blood vessels, tissues, and organs. Due to the high price of iodine-containing contrast agents, as well as contraindications and unfavorable side effects of its use, it is essential to explore ways in which contrast dosage can be reduced while ensuring that CT angiography can still be widely used and meet diagnostic standards [3-6]. Here, we evaluated the use of low doses of contrast agents in cerebrovascular CT angiography.

Materials and methods

Study design

Sixty patients suspected of having cerebral artery disease underwent brain CT angiography (CTA) in the Department of Radiology, Harbin Medical University Cancer Hospital (Harbin, China) between January 2011 and December 2012. Patients were randomized into two groups: one group received low-dose contrast agent and another received routine-dose contrast agent. The low-dose group consisted of 30 patients: 18 males and 12 females, aged 40 to 82, with a mean age of 61.5 ± 8.2 years and a mean weight of 70.8 ± 9.4 kg. The routine-dose group included 30 patients: 20 males and 10 females, aged 38 to 81, with a mean age of 61.1 ± 7.8 years and a mean weight of 71.2 ± 10.2 kg. There was no statistical difference in gender, age, or weight (*P* > 0.05) between the

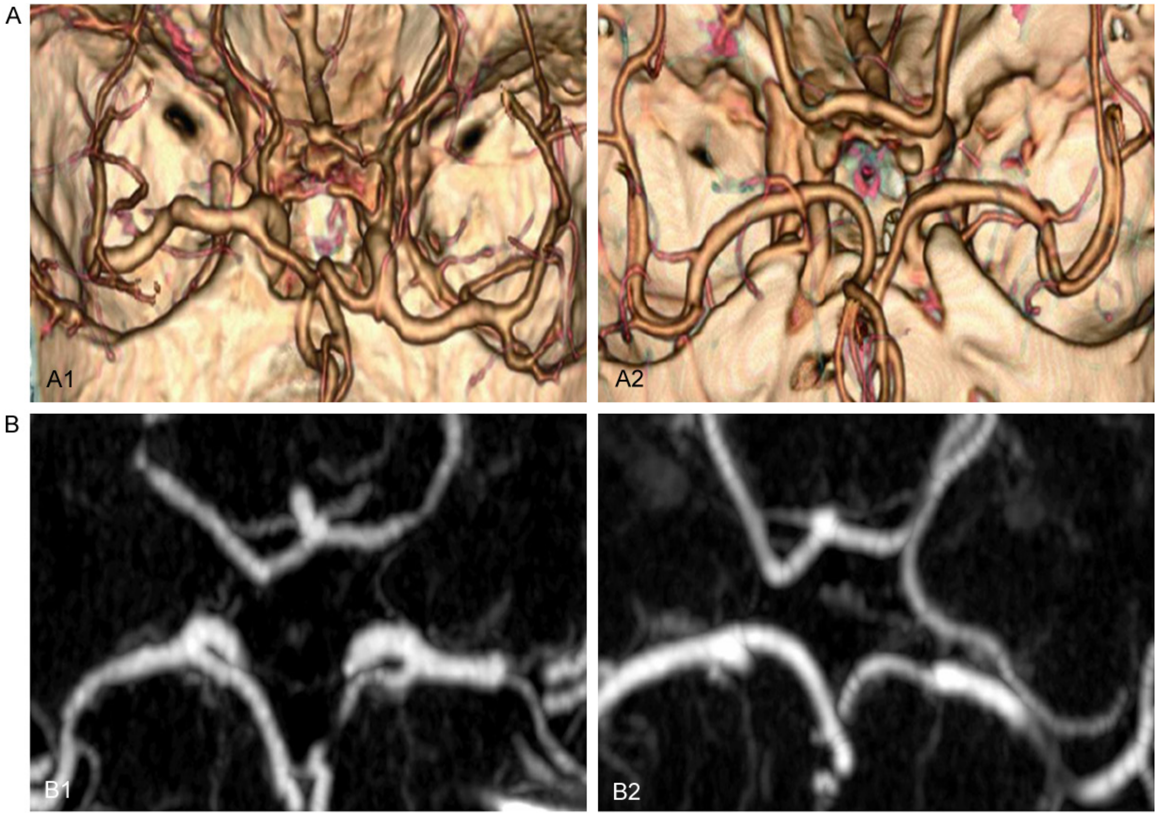

Figure 1. Image of VR (A) and MIP (B) in cerebral CTA. (A1\B1) Low-dose group; (A2\B2) Routine-dose group.

Table 1. Scores for display effect of cerebral artery structure between groups [*n* (%)]

Dosage Group	Case numbers	Score		
		5	4	3
low-dose group	30	17 (56.7)	12 (40.0)	1 (3.3)
Routine-dose group	30	14 (46.7)	12 (40.0)	4 (13.3)
Total	60	31 (51.7)	25 (40.0)	5 (8.3)

X^2 = 2.090, P = 0.352.

two groups. All patients gave informed consent for the use of contrast agent.

CT imaging

A 16-slice spiral CT (Lightspeed Pro16, GE Medical Systems, Milwaukee, USA) was used to collect CT images. The base of each patient's skull was scanned 22 to 25 s after injection of contrast agent. Scanning parameters were as follows: 0.562:1 pitch, 0.8 s tube revolution time, 1.25 mm thickness, 1.25 mm interval, 200 mA current, 120 kV tube voltage in the routine-dose group and 80 kV tube voltage in the low-dose group, 3.5 mL/s injection speed (both groups), 100 mL Iopamidol (Shanghai Bracco Sine Pharmaceutical, Shanghai, China) injection for the routine-dose group and 60 mL for the low-dose group. Low-dose group members received 40 mL saline following Iopamidol injection to control for injection volume. Images were reconstructed using standard methodology, with a reconstruction thickness of 0.625 mm. Workstation AW412 (Advantage workstation) was used to perform three-dimensional (3D) post-processing and analysis, including volume rendering (VR) and maximum-intensity-projection (MIP). Two experienced radiologists observed the horizontal, VR, and MIP images of patients in the two groups separately, and made diagnoses based on the anatomical structure of the cerebral artery (**Figure 1**).

Evaluation of CT contrast [7]

Development strength was determined using CT scans of the internal carotid artery. The skull base was imaged at the level of the sella turcica and the region of interest was set to 2 mm^2. The average CT value of the bilateral internal

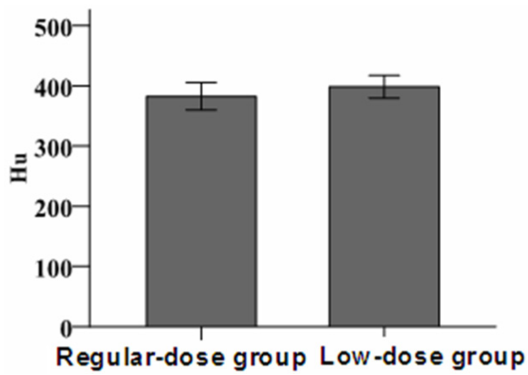

Figure 2. Developing strength of cerebral artery between groups.

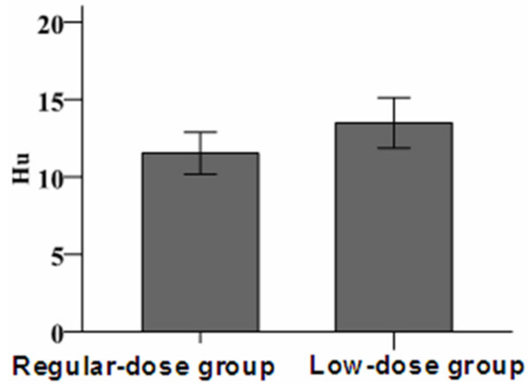

Figure 3. Evaluation of image noise in CTA between groups.

Table 2. Radiological diagnosis for each group [*n* (%)]

Dosage Group	Cerebral arteriosclerosis	Cerebral artery stenosis	Cerebral artery occlusion	Cerebral aneurysm
Routine-dose group	14 (51.9)	10 (37.6)	2 (7.4)	1 (3.7)
Low-dose group	11 (42.3)	13 (50.0)	1 (3.8)	1 (3.8)
Total	25 (47.2)	21 (43.4)	3 (5.7)	3 (3.8)

$\chi^2 = 1.066$, $P = 0.785$.

carotid arteries was selected as the development strength. If only one unilateral carotid artery was displayed, then the CT value of the unilateral carotid artery was used. Image noise was evaluated in a similar fashion. The standard deviation of the highest CT values was selected; and average of standard deviations of CT values of the bilateral internal carotid arteries was selected. VR and MIP images were evaluated using the following scale: 1 (the image quality is poor, not able to make diagnosis), 2 (the image quality is not good; there are many image artifacts, thereby reducing reliability of diagnosis), 3 (fair average image quality, some image artifacts, still able to make radiologic diagnosis), 4 (good image quality, just a few artifacts, slightly blurred surface structure, but clearly displayed vascular structures, able to make diagnosis), 5 (very good image quality, no artifact, able to distinguish the fine structure in detail, able to make more accurate imaging diagnosis).

Statistical analysis

SPSS17.0 statistical software was used to conduct statistical analysis. All data are expressed as mean ± standard deviation ($\overline{x} \pm s$). Independent samples *t* test was used to analyze differences in development strength and image noise of cerebral artery imaging between the two groups; χ^2 test was used to compare the displaying effect and imaging diagnosis of the cerebral artery structures. The test was two-sided, at test level (α) of 0.05, and $P < 0.05$ was considered statistically significant.

Results

CTA image collection was successful in both groups of patients, without complications, side effects, or technical errors. Cerebral arteries in both groups were clearly visible and met diagnostic standards. No difference in cerebral artery structure display quality was seen between the two groups ($\chi^2 = 2.090$, $P = 0.352$) (**Table 1**).

The CT value of the internal carotid artery was 382.3 ± 61.0 Hu in the routine-dose group and 398.3 ± 50.4 Hu in the low-dose group, with no significant difference between the two groups ($t = 1.105$, $P = 0.274$) (**Figure 2**). The standard deviation of internal carotid artery CT was 11.5 ± 3.6 Hu in the routine-dose group and (13.5 ± 4.4) Hu in the low-dose group, with no statistically significant difference between the two groups ($t = 1.105$, $P = 0.274$) (**Figure 3**).

Diagnostic imaging

Diagnosis was made using CT results for each group: 23 (76.7%) patients in the low-dose group and 24 (80.0%) patients in the routine-dose group presented with abnormal cerebral artery morphology. The difference in image-based diagnosis between the two groups was not statistically significant (χ^2 = 1.066, P = 0.785) (**Table 2**).

Discussion

Recent advancement in the quality of contrast agents available for CTA has lead to an increase in their use by clinicians looking for non-invasive visualization of arterial structure. However, large doses of contrast agent have been shown to compromise renal function; specifically, the dose of contrast agent has been shown to be positively associated with contrast-induced nephropathy [8]. Therefore, it is vital to explore ways in which contrast agent can be used at as low a dose as possible. Many approaches have been considered to reduce dose of the contrast agent, including tube current, tube voltage, tube rotation time, pitch, and other parameters [9-11]. When the tube current is fixed, reducing tube voltage can further reduce the dose of contrast agent. Several studies [12-15] show that reducing tube voltage not only reduces the dose of contrast agent needed for imaging, but also can improve the vascular enhancement values and maintain comparable image quality to regular doses. During CT perfusion scans, 80 kVp and 100 mAs are routinely used to reduce the dose of contrast agent, as injection of iodinated contrast agent improves the tissue contrast ratio [16, 17]. Yang *et al.* [18] reported that application of low kV multi-stage to CTA scans increases image enhancement of the blood vessels, even though the image noise is increased and the resolution is reduced. Subsequently, low kV multi-stage CTA scanning is recommended primarily for observational purposes.

The purpose of this study was to evaluate the need for high doses of contrast agent. Low-dose brain CTA was performed alongside typical-dose brain CTA in visualizing cerebral arteries. No significant difference in development strength was seen between the low- and routine-dose groups, and only slightly higher image noise was observed in the low-dose group, without statistical significance. CTA displays of brain arteries were not significantly different between the two groups and both groups' image quality met with standard imaging diagnostic criteria. These results indicate that low-dose CT cerebral artery imaging is capable of generating high-quality images while greatly reducing the dose of contrast agent. Further studies will evaluate the use of low doses of contrast agent in the visualization of additional tissues and organs.

Disclosure of conflict of interest

None.

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