ORIGINAL REPORT

Dual energy CT angiography of the carotid arteries: Quality, bone subtraction, and radiation dosage using tube voltage 80/140 kV versus 100/140 kV


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KEYWORDS
Computed tomography; Dual source CT; Angiography; CT angiography; Supraaortic trunks; Radiation dose; Image quality; Bone removal

Abstract
Objective: To study the differences in vascular image quality, bone subtraction, and dose of radiation of dual energy CT angiography of the supraaortic trunks using different tube voltages.

Materials and methods: We reviewed the CT angiograms of the supraaortic trunks in 46 patients acquired with a 128-slice dual source CT scanner using two voltage protocols (80/140 kV and 100/140 kV). The "head bone removal" tool was used for postprocessing. We divided the arteries into 15 segments. In each segment, we evaluated the image quality of the vessels and the effectiveness of bone removal in multiplanar reconstructions (MPR) and in maximum intensity projections (MIP) with each protocol, analyzing the trabecular and cortical bones separately. We also evaluated the dose of radiation received.

Results: Of the 46 patients, 13 were studied using 80/140 kV and 33 with 100/140 kV. There were no significant differences between the two groups in age or sex. Image quality in four segments was better in the group examined with 100/140 kV. Cortical bone removal in MPR and MIP and trabecular bone removal in MIP were also better in the group examined with 100/140 kV. The dose of radiation received was significantly higher in the group examined with 100/140 kV (1.16 mSv with 80/140 kV vs 1.59 mSv with 100/140 kV).

Conclusion: Using 100/140 kV increases the dose of radiation but improves the quality of the study of arterial segments and bone subtraction.

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Introduction

Computed tomography angiogram (CTA) is an important diagnostic modality for the study of supra-aortic trunks and it can easily find stenoses, dissections, congenital abnormalities and various pathologies.\(^1\)

Even though the digital subtraction angiogram is still the standard of reference,\(^2\) it is an invasive modality that usually underestimates the degree of stenosis due to the limited number of projections. This is why it can fail when trying to establish the maximum stenosis caused by this or that plaque.\(^3\) Rotational angiography allows us to do a 3D evaluation of carotid stenosis which helps reduce this problem yet it is still an invasive modality which provides information of the lumen of the vessel only.\(^4\) This is why CTA is a good alternative because it is safer and more comfortable for the patient and because it allows us to study the neck wall and soft tissues with a greater cost-effectiveness ratio.\(^5\) The downfall is that while post-processing images we experience technical difficulties when trying to separate the contrast-agent calcium from the vascular lumen in vessels next to the bone (arteries at the base of the skull or vertebral arteries) and so they show artifacts with artificial suppression of some of the vascular lumen since it is not recognized as iodine.\(^6\)

Until recently when the time came to do a CT a single-tube X-ray scanner with which voltage (kV) could be varied was used. Later double-tube CT equipments appeared with both tubes working with the same voltage. Recently the market has welcome the arrival of CT equipments that allow us to use 2 tubes with different levels of energy,\(^7\) which is a good alternative to conventional modalities of bone-subtraction.\(^7\)

Since the early studies on dual energy back in the 1970s it is widely known that by changing the voltage (kV) of the X-ray tube and thus the beam of energy there is a modification in the attenuation of Hounsfield units (HU) of the studied materials\(^8\) in such a way that 80 kV voltages produce values of attenuation different to 140 kV loads in the same tissue.\(^9\) The extent of this change depends on the chemical composition of the studied material and it is unique for each change.\(^10,11\) Dual-energy computed tomography (DECT) can theoretically exploit this property and isolate the calcium (contained in bones) from the iodine (existing in the contrast agent).\(^12\) This ability enables the existence of post-processing tools capable of an automatic elimination of the bone. Also in dual-source CT equipments the potential (kilovoltage) to which each tube works can be varied and the current to be used in each case individualized. When varying the voltage the final quality of the image obtained can be different and the dose of radiation that the patient receives may vary given that the more the kilovoltages the greater the radiation. The goal of this study is to compare possible differences in the ability of eliminating the bone automatically in the subjective evaluation of the quality of image of vessels and the dose of radiation received when 2 tubes in different energy ranges are used (80/140 kV vs 100/140 kV).

Materials and methods

Patients

Between September 2009 and June 2011 46 studies of CTA of supra-aortic trunks were done and then revised retrospectively. These CTA studies were requested in 45 patients with suspicions of stroke to evaluate carotid atheromatosis and vertebral dissection in one patient.
The first 13 patients (group 1) were studied using 80/140 kV. The following 33 (group 2) were studied using 100/140 kV. All patients signed written informed consent to undergo CTA and since it was a retrospective study the license from the ethical committee was not requested.

CTA protocol

CTA was done using a 0.64 pitch-dual energy equipment (128 cuts Somatom Definition Flash, Siemens, Germany). Cut thickness was 1 mm with a 0.6 mm increase. After planning the study (from the aortic arch–skullcap included) 70 m of iodine contrast (300 mg I/ml) was administered at a flow of 5 ml/s and after 40 ml of saline solution via the antecubital vein using the dual-head Stellan D CT injection system (Medrad, Pittsburgh, USA). CTA was done using the Bolus Tracking modality (Siemens Medical Solutions, Erlangen, Germany) placing the ROI in the aortic arch at a peak of 100 HU.

Image post-processing

Images were then transferred to a working station (Multimodality, Siemens Medical Solutions, Erlangen, Germany) with a specific software available in the market for the post-processing of images through dual energy.

When a DECT is done we obtain 3 series of images (Fig. 1)–one corresponding to the lowest level of energy (80 or 100 kV), a 2nd one of the 140 kV tube and a 3rd series merged or "mixed" that is the result of combining both levels of energy. Its quality of image is similar to the one we would obtain with a 120 kV conventional acquisition.

For the post-processing of angio-DECT we used the specific software "head boneremoval" (Siemens Medical Solutions, Erlangen, Germany) (soft part density low kV and high kV, 50 HU; ratio 1.90, minimum 130 HU, maximum 700 HU; 2 pixel-range of filters; both "blooming reduction"

Analysis of images

The 3D evaluation was done using the In-Space software (Siemens Medical Solutions, Erlangen, Germany) to create maximum intensity projections (MIP) from data obtained from the "plaque and boneremoval" images (Fig. 2). Two skilled radiologists (ESA and GTF) evaluated the images obtained and analyzed the readings obtained under consensus. To that end the vascular tree was divided (Fig. 3) according to Bouthillier15 into: (1) Brachiocephalic trunk. (2) Right common carotid artery. (3) Right extracranial (segment C1) internal carotid artery (ICA). (4) Right C2–C5 segments of ICA. (5) Right C6–C7 segments of right ICA.

Figure 1 Series of images obtained through dual-energy carotid CT-angio. A series is obtained when using an 80 kV power range, another series when one 140 kV range is used and then a series of mixed image is obtained with an image quality similar to the one we would have obtained had a 120 kV-trial been done.

Figure 2 MIP (maximum intensity projection) image obtained after the automatic elimination of bone.

and "boneremoval" activated) in the working station. The automatic extraction of both bone and plaques was used without manual adjustments on the predefined algorithm.

Figure 3 Categorization of 15 segments of vascular tree.

All MIP images were studied in coronal and sagittal planes using one scale from 0 to 3 to assess the elimination of bone (1=poor: bone fragments >1 cm in diameter still exist; 2=sufficient: bone fragments <1 cm in diameter exist only; and 3=excellent: there are no traces of bones and the remaining traces are irrelevant) and another scale from 0 to 5 points to assess the quality of the vessels (1=poor: there is discontinuity inside the lumen of vessels unconfirmed by source images; 2=insufficient: there is an artificial reduction in the caliber of the lumen simulating a hemodynamically significant stenosis (>50%); 3=artificial alteration in the caliber of lumen simulating a >50% caliber reduction; 4=insufficient: the alterations of the lumen are <10%; and 5=excellent: no alterations of vascular lumen reported). To confirm the adequate elimination of bone and calcified plaques the original data of angio-DECT were used as a frame of reference.

Table 1: Outcomes of score obtained in the evaluation of the quality of vessels per segment.

<table>
<thead>
<tr>
<th>Arterial segments</th>
<th>Group 1 (80/140 kV)</th>
<th>Group 2 (100/140 kV)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQR range</td>
<td>Median</td>
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<tr>
<td>Segment 1</td>
<td>1</td>
<td>1-5</td>
<td>5</td>
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<tr>
<td>Segment 2</td>
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<td>Segment 5</td>
<td>5</td>
<td>3-5</td>
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<td>Segment 6</td>
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<td>1-4</td>
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<tr>
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<td>4.5-5</td>
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<td>4</td>
<td>3.25-5</td>
<td>5</td>
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<tr>
<td>Segment 12</td>
<td>5</td>
<td>4.25-5</td>
<td>4</td>
</tr>
<tr>
<td>Segment 13</td>
<td>2</td>
<td>1-4.5</td>
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<tr>
<td>Segment 14</td>
<td>4</td>
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<td>5</td>
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<tr>
<td>Segment 15</td>
<td>5</td>
<td>4-5</td>
<td>5</td>
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</tbody>
</table>

In the variables following normal distribution parametric tests were used (a Student’s t test). In those not following normal distribution both the median and the interquartile range (IQR) were used providing the median and the standard deviations as complementary data; also the non-parametric Mann–Whitney U test was used for comparison purposes. P value <0.05 was relevant.

Results

The range of age was between 24 and 85 years old (median 67.3±15 years). There were no statistically significant differences between the two groups when it comes to age or sex. In group #1 (80/140 kV) there were 13 patients (4 women and 9 men) with an age median and IQR of 71 years old (55.5–76.5). In group #2 (100/140 kV) there were 33 patients (12 women and 21 men) with an age median and IQR of 74 years old (64.5–78.5).

When it comes to the evaluation of the arterial quality of the 15 segments we obtained a greater quality in the 100/140 kV group than in the 80/140 kV group statistically significant in segments 1, 6, 9 and 13 (Table 1).

When the elimination of bone was evaluated there were statistically significant differences when it came to eliminating cortical bone in the MPR images and cortical and medullary bone in MIP images—with a greater score in the 100/140 kV group (Table 2).

There were also statistically significant differences between both groups in the dose of radiation—again with a greater score in the 100/140 kV group (Table 3).

Discussion

The differences in the image quality of vessels, the ability to eliminate bone and the dose of radiation of CTAs of supra-aortic trunks with the dual-energy modality using 2 different powers of tube have also been studied. Such modality showed the best quality of all in the evaluation of
vessels and in the elimination of bone using 100/140 kV vs 80/140 kV with an increase in the dose of radiation though. According to Krauss et al. in the clinical practice a dose-efficient low noise mixed image is as important as a good spectral resolution. This is why the combination 100/140 kV is better for large diameter-patients and the combination 80/140 kV is commonly used in small diameter-patients. When 60/140 kV is used the spectral separation is very good yet the mixed image obtain has poor quality.

In this study we tried to analyze the quality of images obtained using two different ranges of energy. We did not take into account the diameter of soft tissues of the neck since unlike it happens in the abdomen it is not as variable among patients yet the quality obtained has been greater using 100/140 kV.

However this improvement in the quality of the study led to a statistically significant increase in the dose of radiation. Lell et al. did 2 studies on the elimination of bone using the dual-energy modality and a 1–5 score scale for the evaluation of subjective quality. In one of these studies they compared modalities for the elimination of bone with dual-energy modalities vs conventional modalities using 80/140 kV. In the other study they also evaluated the subjective quality of vessels in this case with 100/140 kV. However they did not compare the difference in the quality of images of 80/140 kV vs 100/140 kV. In both studies the outcomes when it comes to both the evaluation of subjective quality and the automatic elimination of bone were pretty similar to those obtained in this article.

Some of the limitations of this trial are its retrospective study and the size of the sample which made us use non-parametric tests. In sum when it comes to doing a carotid CTA with dual-energy modalities when modifying the kilovoltage used with each and every tube we will also be modifying both the dose of radiation and the quality of images obtained.

Authors

1. Responsible for the integrity of the study: ESA

References