Neck CTA with deformable registration and subtraction method: evaluation in stent cases

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Purpose

Carotid artery stenosis is a major cause of cerebral infarction. Previous prospective multicenter studies have demonstrated the superiority of surgery in patients with symptomatic severe stenosis, and carotid artery endarterectomy is commonly performed. In addition, stenting is performed in patients with restenosis following endarterectomy, in elderly patients, and in patients in whom the stenotic region is located high in the artery. Ultrasound, CT, MRI, and angiography are used to evaluate the carotid arteries. Although CT requires the administration of contrast medium and involves radiation exposure, it is very useful for acquiring volume data in a short time. However, in some patients with severe calcification or with stents, artifacts generated by the calcification or stents may interfere with diagnosis. Contrast-enhanced CT images and non-contrast-enhanced CT images can be subtracted to eliminate calcification or stents and display only the carotid artery lumen. However, if standard image subtraction methods are employed, diagnostically useful information cannot be obtained in most cases due to positional shift resulting in misregistration between the contrast-enhanced and non-contrast-enhanced CT images. The standard linear position matching subtraction method is also unsuitable for eliminating stents. In the present study, we investigated the effectiveness of subtraction software based on deformable position matching for the evaluation of patients with stents.
Methods and Materials

Patients

This study was performed after approval was obtained from our institutional review board. Written informed consent was waived. We retrospectively selected 20 consecutive patients (19 men and 1 woman, 54-83 years of age, mean age 72 years) who underwent Carotid CT angiography. Carotid artery stenting was performed for carotid artery stenosis (n=19) or carotid artery dissection (n=1).

CTA protocol

CTA examinations were performed using a 320-row MDCT system (Aquilion ONE, Toshiba Medical Systems, Japan). The scan parameters were peak tube voltage 120 kV, tube current 150 mAs, rotation time 0.75 s, collimation 0.5 mm, and slice increment 0.5 mm using a standard kernel for a field of view of 120 mm. Z axis lengths were 10cm, 12cm, 14cm, or 16cm.

Contrast medium (350 mgI/ml) was injected over 20 s via an antecubital vein, followed by a 25-ml saline flush. The contrast dose and injection rate were adjusted according to the patient's weight: 50 ml at 2.5 ml/s for a patient weighing 50 kg, 60 ml at 3.0 ml/s for a patient weighing 60 kg. The delay time from contrast injection to the start of CT data acquisition was determined using bolus-tracking software with the scan triggered automatically when contrast was above 160H.U. in the CCA.

Image processing and analysis

Software employing a deformable registration and subtraction method (SURESubtractionTM, Toshiba Medical Systems, Japan) installed in our CT system was used to generate subtraction images from contrast-enhanced and non-contrast-enhanced CT volume data.

Two readers blinded to all clinical information of the patients independently assessed the CTA findings by viewing maximum intensity projection (MIP) images at a 3D workstation. Any disagreements in the assessment results of the two readers were resolved by consensus.

Deformable Registration and Subtraction Method

SURESubtractionTM processing consists of two main steps.

Step 1: Global registration and subtraction
Position matching and subtraction processing is performed for the entire volume.

Step 2: Local registration and subtraction

High-precision position matching and subtraction processing can be performed for a local region where positional shift has occurred.

Stent subtraction score (Fig. 1)

Stent removal was rated according to a four-point scale (1 = excellent, 2 = good, 3 = moderate, 4 = unevaluable). "Excellent" was defined as clearly visible vessels containing no stent remnants or containing only tiny stent remnants, "good" as visible vessels containing mild stent remnants, "moderate" as vessels containing larger stent remnants that did not prevent visualization of the vessels, and "unevaluable" as vessels containing large stent remnants or artifacts obscuring parts of the vessels.

Bone subtraction score (Fig. 2)

Bone removal was rated according to a four-point scale (1 = excellent, 2 = good, 3 = moderate, 4 = unevaluable). "Excellent" was defined as clearly visible vessels containing no bone remnants, "good" as visible vessels containing only tiny bone remnants, "moderate" as vessels containing larger bone remnants that did not prevent visualization of the vessels, and "unevaluable" as vessels containing large bone remnants or artifacts obscuring parts of the vessels.

The kappa statistic was used to assess inter-observer reliability. Kappa values greater than 0 were considered to indicate positive agreement, with a kappa value of >0.80 defined as excellent agreement, 0.61-0.80 as good agreement, 0.41-0.60 as moderate agreement, 0.21-0.40 as fair agreement, and <0.20 as poor agreement.
**Fig. 1:** Stent subtraction score Stent removal was rated according to a four-point scale (1 = excellent, 2 = good, 3 = moderate, 4 = unevaluable).

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Fig. 2: Bone subtraction score Bone removal was rated according to a four-point scale (1 = excellent, 2 = good, 3 = moderate, 4 = unevaluable). Score 3 image and score 4 image are conventional subtraction images.

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Results

Inter-observer reliability was good, $\# = 0.71$ for stent subtraction, $\# = 0.79$ for bone subtraction (Fig. 3).

Three carotid arteries were classified as unevaluable, and no vertebral arteries were classified as unevaluable. The mean image quality score was $2.4 \pm 0.9$ for stent subtraction and $1.5 \pm 0.5$ for bone subtraction (Fig. 4).

Two cases are shown in Fig. 5 and Fig. 6.
Fig. 3: Inter-observer reliability

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Fig. 4: Stent subtraction score and bone subtraction score

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Fig. 5: Case 1. Post carotid artery stenting for carotid stenosis. Left side image is conventional subtraction MIP. Right side image is deformable registration and subtraction MIP. Stent subtraction score is 1 (excellent) and, bone subtraction score is 3 (good) for deformable registration and subtraction.

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Fig. 6: Case 2. Post carotid artery stenting for carotid stenosis. Left side images are conventional subtraction images. Right side images are deformable registration and subtraction images. Upper images are axial images, and lower images are MIP. Stent subtraction sore and bone subtraction score are 3 (good) for deformable registration and subtraction.

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Conclusion

Bone elimination could be performed almost perfectly in carotid artery CTA by employing this newly developed method.

Satisfactory subtraction to eliminate stents could also be achieved in most patients.

This new subtraction software is a useful tool for assessing the carotid arteries in patients with stents as well as the vertebral arteries.
References


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