Minimizing Clip Artifacts in Multi CT Angiography of Clipped Patients

PURPOSE: To optimize the multi CTA (MSCTA) protocol, the influence of pitch, kilovoltage peak (kVp), reconstruction algorithm, type, and orientation of the clip on clip-induced artifacts was investigated in a phantom study. Also, the influence of kVp, concentration of contrast material, and clip orientation in clipped patients was studied.

METHODS: A phantom containing a clip was scanned with varying parameters. Artifact was quantified with 3D volumetry. Artifact volumes were compared for the different parameters. In addition, the number of artifact streaks was presented as a function of the pitch. Five clipped patients were scanned with 90 kVp and 120 kVp and 5 with 120 kVp and 140 kVp. The artifact area was compared. The visualization at the clip site was evaluated for different clip orientations in 50 patients, and for 140 kVp with 370 mg iodine/mL contrast (I/mL) compared with 120 kVp/300 mg I/mL in 7 patients.

RESULTS: Up to a pitch of 0.6, there was hardly an increase in artifact. Higher kVp and linear interpolation resulted in fewer artifacts. Alloy clips containing cobalt produced more artifact than did titanium clips. Clips positioned perpendicular to the scan plane led to significantly less artifact. In patients with clips, scanning with 140 kVp/370 mgI/mL led to a decrease of artifact area and a better visualization of the clip site. The visualization at the clip site was also better for clips perpendicular to the scan plane.

CONCLUSIONS: If clip artifacts are to be minimized, we suggest scanning with a pitch of 0.6, by using 140 kVp and 370 mgI/mL contrast.

Materials and Methods

All CT data were acquired on a 16-section CT scanner (MX8000 IDT, Philips Medical Systems, Best, the Netherlands). The study was approved by the ethics committee of the participating university medical center. Informed consent was obtained from all patients.

Phantom

A cylindrical polymethylmethacrylate (PMMA) phantom (thickness, 60 mm; diameter, 185 mm) was used. In the center of the phantom, a 5-cm PMMA cylinder could be inserted, into which a titanium or cobalt clip was placed (Sugita clip no. 2, Mizuho, Tokyo, Japan; volume, 25–26 mm³), positioned with its long axis either in the scan plane or perpendicular to the scan plane (Fig 1).

To investigate the influence of varying pitch, the phantom was scanned in high-resolution mode (small focal spot, quarter detector offset, resolution: 16 line pairs per centimeter) with a pitch (P) varying between 0.3 and 1 and in standard mode (large focal spot, no detector offset, resolution: 12 lp/cm) with a pitch varying between 0.3 and 1.5, both at intervals of 0.1. To investigate the influence of kVp, scans were acquired by using 90, 120, or 140 kVp with 450 (up to pitch of 0.7), 200 or 135 mAs, respectively, keeping the CT dose index (CTDI<sub>100</sub>): average local dose to a patient within the

Patients who survive subarachnoid hemorrhages and are surgically treated by means of clipping are at risk for mortality or morbidity in the postoperative period because of vasospasm-related delayed cerebral ischemia or rebleeding from an incompletely clipped aneurysm. Also, on long-term follow-up, these patients have increased risk for a new episode of bleeding, which may arise from either a regrowth aneurysm at the clip site or from a de novo aneurysm that develops at a location different than the clip site. To facilitate early diagnosis of vasospasm, incompletely clipped aneurysms, or regrowth and de novo aneurysms, follow-up imaging of the intracranial vessels is required.

Digital subtraction conventional angiography (DSA) is seen as the gold standard and carries a very low risk (0.07%) for developing permanent cerebrovascular complications, though it is time consuming as a screening tool. MR angiography (MRA) is not a reasonable alternative, because the clip-induced signal intensity loss precludes the evaluation in the vicinity of the clip. CT angiography (CTA) measures the vessel diameter accurately and is consequently useful for detecting vasospasm and seems promising for screening patients with clipped intracranial aneurysms, to optimize the CTA protocol for this specific subgroup of patients.

Received December 29, 2004; accepted after revision June 9, 2005.

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scan volume\textsuperscript{16} constant at 28 mGy. From pitch 0.8 to 1.5, it was not possible to scan with 450 mAs, and, with increasing pitch, the maximal kVp decreased to 245 mAs at pitch of 1.5. Thus, scanning was performed with lower CTDI\textsubscript{vol}.

The 120-kVp acquisitions were reconstructed with either linear interpolation or conebeam reconstruction (SP filter): data interpolation algorithm, correcting for effects of the conebeam geometry of the radiographic beam.\textsuperscript{16} The 90- and 140-kVp acquisitions were reconstructed by using only linear interpolation. All scans were acquired with the long axis of the clips in the scan plane. In addition, we performed acquisitions with the long axis of the clips perpendicular to the scan plane at 120 kVp. Other scan parameters were collimation, 16 × 0.75; rotation time, 0.75 seconds; pitch, 0.6; section thickness, 1.0 mm; reconstruction increment, 0.5 mm; slightly smoothing head filter (filter B for Philips scanner); field of view, 160 mm; matrix, 512 × 512.

**Patients**

We assessed the influence of clip orientation and kVp on the visualization of the clip site in clinical practice. Patients were selected from a CTA screening program for regrowth and de novo aneurysms in clipped patients. Patients were scanned with the following protocol: 120 kVp, 200 mAs; collimation, 16 × 0.75; rotation time, 0.75 seconds; pitch, 0.6; section thickness, 1 mm; reconstruction increment, 0.5 mm; filter B, by using 70 mL nonionic contrast of 300 mg I/ml (Iopromide, Ultravist 300, Schering, Berlin, Germany): 50 mL at a rate of 5 mL/s, 20 mL at a rate of 3 mL/s, and a 30 mL saline flush at a rate of 3 mL/s.

To assess the influence of clip orientation on clip-induced artifacts in clinical practice, we selected 50 patients who were treated with only one clip. Depending on aneurysm characteristics, different clips were used. Clip sizes and volumes were comparable with the clips used in the phantom study.

To study the effect of kVp on the amount of clip artifact, we also scanned the region of the clip with 90 kVp and 450 mAs in 5 patients and in another 5 with 140 kVp and 135 mAs. The CTDI\textsubscript{vol} was kept constant at 28 mGy for the 3 kVp/mAs combinations. On the basis of findings in the phantom study and the 10 patients in whom the region of the clip was scanned twice, we performed a follow-up scan of 7 patients, 1 year after screening, by using 140kVp/135 mAs. At 140 kVp, however, the attenuation of iodine-containing contrast, and thus arterial enhancement, is decreased compared with 120 kVp.\textsuperscript{17,18} To compensate for this loss of enhancement, we used contrast with an iodine concentration of 370 mg I/mL.

**Artifact Quantification**

All measurements were done on a workstation (MX View; Philips Medical Systems). The clip-induced artifact was composed of white and black components and was affected by the window width and the position of the clip to the scan plane. The white component consisted of a local halo surrounding the clip and a variable number of white streaks, radiating in all directions. The black component was bandlike and emanated on either side from the end of the clip (Fig 2).

**Phantom**

The amount of artifact was measured by means of 3D volumetry. When quantifying the clip-induced local image degradation, both positive (white) and negative (black) components need to be taken into account. The threshold values above and below the white and black components of the artifact were taken into account and were calculated by adding or subtracting 3 times the SD of the background to the attenuation value of the background. In addition, we quantified the radiating streak component of the artifact by counting the number of white streaks arising from the clip for both clips at 120 kVp in high and standard modes.

**Patients**

The amount of artifact in clipped patients was quantified by measuring the area of the white and black components at the level where the artifact was most pronounced, in the same scan position for both kVp values. Once again, the threshold values above which the white and below which the black components of the artifact were taken into account were calculated by adding or subtracting 3 times the SD of the background to the attenuation value of the background (Fig 3).

**Clinical Evaluations**

To study the influence of the orientation of the clip on the amount of artifact, the angle of the clip relative to the scan plane was measured on the sagittal scout view in 50 patients (by I.v.d.S.) and divided into 3 categories: (1) 0°–25°: in-plane to the scan plane; (2) 26°–65°: diagonal to the scan plane; and (3) 66°–90°: perpendicular to the scan plane). In addition, 2 of 3 readers (B.V., G.d.K., T.W.), blinded to the measurements of clip orientation, scored the grade of visualization of the vessel adjacent to the clip site in the following categories: (1) well-visualized: the vessel in the proximity of the clip can be followed along its whole length; (2) partly visualized: the visualization of the vessels in the proximity of the clip site is somewhat hampered by clip artifact, but no streaks ≥3 mm obscure the vessel; and (3) poorly visualized: the visualization at the clip site is obscured by the artifact. The visualization of the vessel adjacent to the clip site of the 7 patients in whom a second follow-up scan with 140 kVp/370 mg I/mL was performed was categorized in the same manner.

**Data Analysis**

**Phantom**

To compare the amount of artifact at different kVp/mAs combinations, for linear interpolation versus conebeam reconstruction, for
cobalt-containing alloy versus Titanium clips, and for the clips positioned in the scan plane compared with perpendicular to the scan plane, the mean volume of artifact for all pitches of each series was calculated and the ratio between mean artifact volumes assessed. The numbers of white radiating streaks, for both clips at 120 kVp, in the standard and high-mode series, were counted for each pitch value.
Patients

For the 50 patients in whom the angle of the clip to the scan plane was measured, we calculated for each category of clip orientation the proportion of patients with well-, partly, or poorly visualized vessels adjacent to the clip site and performed a $\chi^2$ test to study the relation between the orientation of the clip on the one hand and visualization at the clip site on the other. For the 10 patients in whom the clip site was also scanned at different kVp/mAs combinations, we calculated the percentage of increase or decrease in area of artifact at 90 and 140 kVp, with 120 kVp as the reference for comparison. In the 7 patients in whom a second follow-up scan was performed at 140 kVp, we compared the visualization at the clip site of the 120-kVp scan with the 140-kVp scan and calculated proportions of patients with well, partly, or poorly visualized vessels adjacent to the clip site for both the 120-kVp/300-mg I/mL and 140-kVp/370-mg I/mL scans.

Results

Phantom

Figure 4 shows the effect of increasing pitch for both clips and kVp/mAs combinations in high and standard modes. The minimum volume of artifact and clip at pitch 0.3 of approximately 1000 mm$^3$ constitutes of the volume of the clip itself, a white halo surrounding the clip and a black bandlike artifact (Fig 5). An increase in pitch led to an increase in total artifact volume, for both clips and for all kVp/mAs combinations in both high and standard modes. Up to a pitch of 0.6, there was hardly an increase in artifact volume for all kVp/mAs combinations and both clips. From pitch 0.6 to pitch 1.5, there was a gradual increase in artifact volume, which was more prominent for lower kVp and for the alloy clips containing cobalt and hardly present for the titanium clip scanned at 140 kVp. Both clips produced more artifacts for all pitches and all kVp/mAs combinations when scanned in standard mode. The influence of different kVp/mAs combinations, reconstruction algorithm, clip composition, and clip orientation to the scan plane are shown in Table 1. At all pitches, scanning with higher kVp resulted in fewer artifacts for both clips. When the cone-beam reconstruction algorithm (CBR) was used, the amount of artifact was slightly higher than with linear interpolation for both clips. For all kVp/mAs combinations, in high and standard mode, the cobalt-containing alloy clip produced more artifact than the titanium clip. The clip positioned perpendicular to the scan plane led to significantly less artifact compared with the clip positioned in the scan plane. The number of white radiating streaks increased with increase in pitch, starting at pitch of 0.4, though not in a linear fashion (Figs 5 and 6).

Artifact volume was higher in the standard mode than in the high mode over the whole range of pitches. This difference can be explained by the method of artifact quantification, which is based on the SD (noise) in the image. In the high mode, scan parameters are optimized for spatial resolution, whereas in the standard mode contrast and spatial resolution are more balanced, which results in a higher noise in the high mode over the whole range of pitches. Consequently, $\pm 3$ times the SD yields a narrower range of HU values in the standard mode, with a corresponding wider range of HU values incorporated into the artifact volume. When the artifact volume is evaluated subjectively by viewing the scans in high and standard mode side by side, this difference in amount of artifact was not of clinical importance, which confirms that the difference in volume can be explained by the method of quantification. The more prominent increase in artifact at 90 kVp from pitch 0.6 up to pitch 1.5 can be explained in the same manner (ie, above pitch 0.6 the maximal mAs decreased and scanning was performed with a lower CTDI$_{vol}$, resulting in more noise). The differences in artifact volume caused by the scan and clip pa-
rameters studied could not be explained by the difference in background noise.

**Patients**

The visibility of the vessels around the clip was scored better for patients with the clip positioned perpendicular to the scan plane, though this difference was not statistically significant ($P = .07$; Table 2). In the in-plane category, 6.3% of the clip sites were well-visualized, 52% were partly visualized, and 42% were poorly visualized. In the perpendicular category, 25% of clip sites were well-visualized, 67% were partly visualized, and 8.3% were poorly visualized. Overall, taking into account clips in all positions, the clip sites were well-visualized in 12%, partly visualized in 58%, and poorly visualized in 30%.

Compared with 120 kVp, scanning with 90 kVp led to an increase of 30%, and scanning with 140 kVp led to a decrease of 20% of artifact area.

Seven patients were scanned twice with the standard protocol (120 kVp/300 mg I/mL) and a second follow-up scan performed with 140 kVp with 370 mg I/mL. The clip site was well-visualized in one patient (14%) when scanned with 120 kVp versus 5 patients (71%) when scanned at 140 kVp. The clip site was partly visualized in 4 patients (57%) scanned at 120 kVp versus one patient (14%) scanned at 140 kVp. The clip site was poorly visualized in 2 patients (29%) scanned at 120 kVp compared with one patient (14%) scanned at 140 kVp.

The percentages of the degree of visualization at the clip site in these 7 patients scanned at 120 kVp/300 I/mL reflect the overall proportions of degree of visualization in the 50 patients in whom we measured the clip position who were scanned with the same protocol.

**Discussion**

The main problem in visualizing intracranial blood vessels in patients with clipped aneurysms is the clip-induced artifact, which frequently hampers the evaluation of the aneurysm.
neck and surrounding vascular structures. To understand and subsequently minimize the clip-induced artifact in this group of patients, we investigated the influence of pitch, kVp, reconstruction algorithm, clip composition, and orientation of the clip relative to the scan plane on the artifact volume.

The titanium clip produces less artifact than the cobalt-containing alloy clip, which is in accordance with the literature. Although titanium clips were already introduced in 1995, many patients are still treated with cobalt-containing alloy clips, because of familiarity with these clips and corresponding application material. Information about the artifact behavior of cobalt-containing alloy clips and optimization of the scan protocol for patients with cobalt-containing alloy clips is therefore still of clinical importance. Artifacts produced by endovascular coils are so severe that this precludes CTA screening and MRA is more suitable.

Increasing the pitch led to a gradual increase in artifact volume, which was more prominent for a pitch > 0.6, for lower kVp, and for cobalt clips. The increase in the number of white streaks started at pitch 0.4. The reduced amount of artifact can be explained by the fact that the projections (raw data) used for reconstruction of the final CT images lie closer together at low pitches compared with higher ones. This increased oversampling of data decreases the data inconsistency and hence decreases the artifact volume in the reconstructed images. The effect of reduced artifact at lower pitch should therefore hold independent of the number of detector rows in the neck and surrounding vascular structures. To understand and subsequently minimize the clip-induced artifact in this group of patients, we investigated the influence of pitch, kVp, reconstruction algorithm, clip composition, and orientation of the clip relative to the scan plane on the artifact volume.

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maximum artifact, with subsequent manual editing of adjacent high-attenuation anatomic structures. The agreement between the results obtained in the phantom and in patients support the chosen strategy.

Conclusion

If clip artifacts are to be minimized, we suggest scanning with a pitch of 0.6 and using 140 kVp and 370-I/mL contrast. This is applicable for clip artifact on different multisection systems. Visualization of vessels bearing multiple clips and cobalt-containing alloy clips remains problematic.

References