Subtraction CT Angiography of the Lower Extremities:

Single Volume Subtraction versus Multi-Segmented Volume Subtraction

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Rationale and Objectives: To validate the hypothesis that a multisegmented approach during subtraction computed tomography (CT) angiography of the lower extremities can improve bone removal efficiency by suppressing regional motion.

Materials and Methods: The institutional review board of our hospital approved this retrospective study. One hundred and one consecutive patients that had undergone the lower extremity CT angiography were included in this study. Subtraction CT angiography was performed using two different methods, namely, by single volume subtraction and by multisegmented volume subtraction. Multisegmented volume subtraction was conducted by dividing the whole volume of the CT data into three segments along the z axis of the lower extremities, performing a subtraction process for each segment, and combining segments to form as single subtracted volume. The bone removal efficiencies of the two methods was assessed by analyzing bone subtraction scores on maximum intensity projection (MIP) images for each bone segment in a blinded fashion. In addition, overall MIP image qualities were compared by displaying MIP images produced using the two methods side by side. Differences between bone subtraction scores were tested using Wilcoxon's signed rank test.

Results: Multisegmented volume subtraction MIP images demonstrated significantly better bone removal for the following bone segments: pelvis ($P < .0001$), hip ($P = .0002$), thigh ($P = .0258$), knee ($P = .0004$), ankle ($P = .0008$), metatarsal bone ($P < .0001$), and toes ($P < .0001$). Overall bone subtraction score and subjective image qualities determined by performing side-by-side comparisons were better for the multisegmented volume subtraction method.

Conclusion: Bone removal performance and overall MIP image quality can be increased by adopting multisegmented volume subtraction during subtraction CT angiography of the lower extremities.

Key Words: Lower extremity; CT angiography; bone removal; bone subtraction.

Digital subtraction angiography (DSA) is currently the standard imaging reference method for the lower extremities in case of the peripheral arterial occlusive disease, because of its high temporal and spatial resolutions. However, DSA is also invasive, has a small risk of complications, and incurs high costs because of the need for hospitalization (1,2).

Technical advances in multidetector computed tomography (CT), which include improvements in spatial and temporal resolutions and scanning of the lower extremity arteries, mean that contrast-enhanced CT angiography is now considered noninvasive potential alternative to conventional DSA for evaluations of lower extremity arteries. Furthermore, several studies have demonstrated that CT angiography is comparable to conventional DSA in terms of performance and accuracy (2–8).

When postprocessing CT angiographs of the lower extremities, it is essential to remove bones from acquired volume CT data (9,10). This can be done by performing by subtraction CT angiography by registering unenhanced CT scans to contrast-enhanced CT scans (11–16). According to this method, the appropriate registration between two volume CT datasets is important for bone subtraction and if a patient moves significantly between the two CT acquisitions, especially if this movement involves complex regional motion, bone residues may remain in variable extent even after bone subtraction because of inappropriate registration.

We hypothesized that the multisegmented approach during subtraction CT angiography of the lower extremities is more efficient at bone removal than the single volume approach. To validate this hypothesis, we retrospectively evaluated the bone removal performance of multisegmented volume

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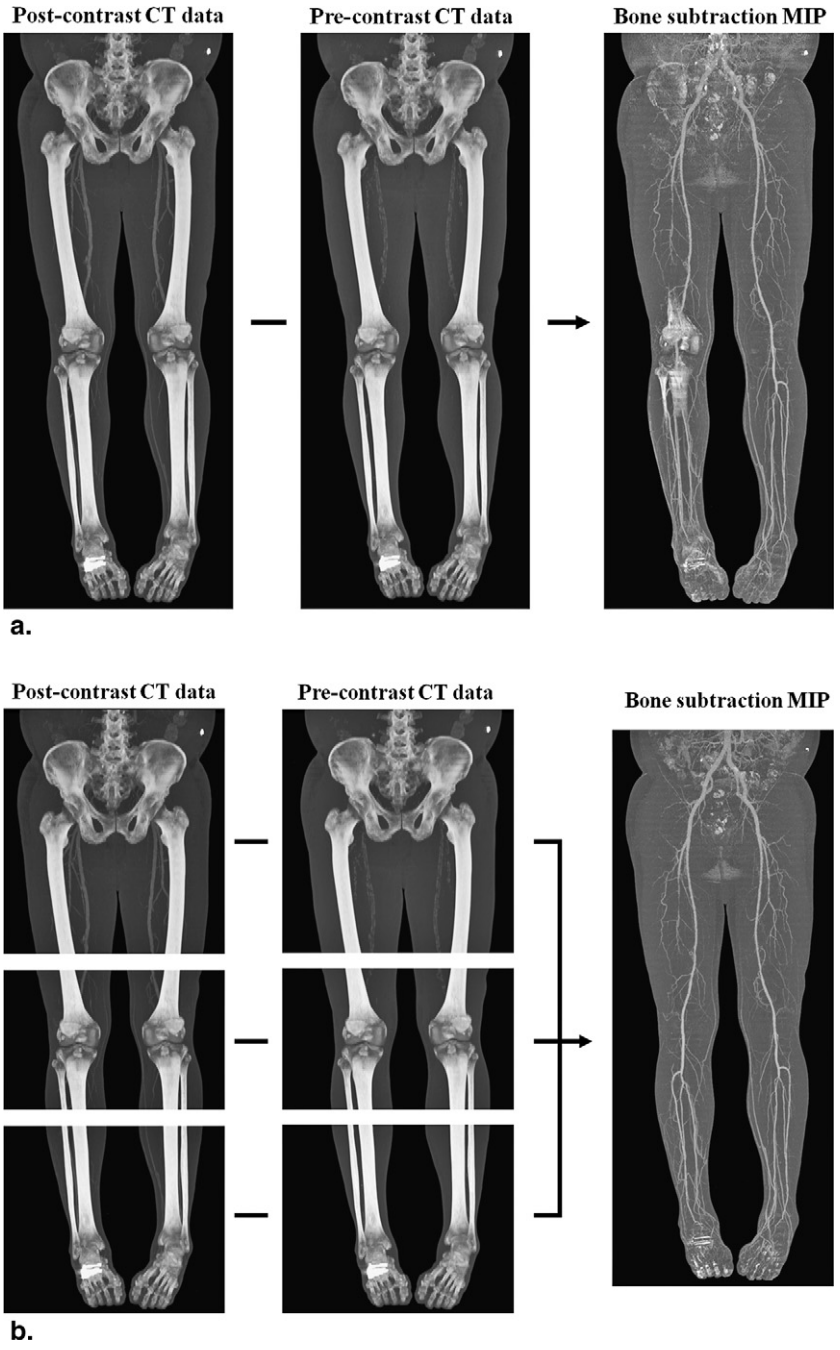

Figure 1. Schematic diagram of the concept behind the two bone subtraction methods. **(a)** Single volume subtraction. **(b)** Multisegmented volume subtraction.

subtraction of the lower extremities and compared this with that of single volume subtraction CT angiography.

MATERIALS AND METHODS

Patients

This retrospective study was approved by our institutional review board, which waived the requirement informed consent. Between May 2006 and December 2006, 321 patients underwent CT angiography of the pelvic and lower extremity arteries using one of four CT machines at our hospital. One hundred and one consecutive patients from among these 321 patients, without the previous history of lower limb amputation surgery or of joint prosthesis implantation, who had undergone CT scanning on a 64-channel multidetector row CT scanner (Somatom Definition; Siemens Medical Solutions, Forchheim, Germany) were finally included in this study. The 101 study subjects had a mean age of 63.6 ± 14.4 years (range 19–90 years), and there were 81 men (mean age 65.0 ± 13.3 years; range 19–90 years) and 20 women (mean age 57.8 ± 17.4 years; range 24–82 years).

CT Angiography

All patients underwent CT using a 64-channel multidetector row CT scanner (Somatom Definition). The following