A Binarization Preprocessing Method for the Three-Dimensional Reconstruction of Carotids

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The carotid bifurcation is one of the most common sites of atherosclerotic plaque [1]. It is widely accepted that hemodynamic forces (particularly wall shear stresses) play an important role in the development and progression of atherosclerosis [2].

The process of image acquisition is a key step for computational hemodynamic simulations. Many prior studies based on three-dimensional (3D) reconstruction of MR images studied a single sample in which the segmentation and smoothing tools of Mimics software were used to complete boundary segmentation and fill interior cavities [3]. The inadequacies of this method are time-consuming, and the results obtained greatly depend on the experience of the operators, so it is difficult to standardize analysis for bulk samples [3].

We present a preprocessing method for MR carotid images taken with a surface coil that can improve the accuracy of Mimics reconstruction and can carry out the standardized processing of large amounts of MR carotid images.

Experimental data were derived from a 62-year-old female healthy volunteer who signed an informed consent form. The study was permitted by the hospital ethics committee in compliance with the Declaration of Helsinki. The subject, in a supine position, received a 3.0 T MR (Trio-Tim; Siemens, Erlangen, Germany) scan with a surface coil (Machnet BV, Eelde, Netherlands) placed under the patient's neck. Left and right carotid scanning was performed. First sagittal and coronal scanning were carried out to judge carotid morphology and bifurcation location, and then, within 2 cm of the carotid artery bifurcation site, the scanner performed a 3D-TOF sequence scan with a slice thickness 1 mm, obtaining a total of 50 scanning sequence diagrams[4].

The MR image obtained was 320×320 pixels, and the MR TOF images were converted to PNG images using DicomWorks [5]. The left and right carotid artery segments were converted to BMP image sequences with a resolution of 51×51 pixels by MATLAB 7.0 (The MathWorks Inc., Natick, MA, USA).

Binarization consists of the following steps in MATLAB: (1) The "im2bw" function is used to binarize the region of interest (ROI) images, (2) The ActiveX "actxcontrol" function calls Excel as an ActiveX automation server, then the "invoke" function generates a new Excel workbook, (3) The "actshrng" function obtains the handle of the designated area in the current table, (4) The "set" function is used to transfer the binarization values of the ROI area into the workbook, (5) The binarization values of the ROI area are manually modified in the Excel workbook, and (6) The "get" function transfers the binarized values of the Excel workbook back into MATLAB.

In the Excel workbook, the binarized ROIs of the carotid artery are segmented, the boundaries are smoothed, and any cavities are filled. For image segmentation, the noncarotid portion of the artery can be deleted. To smooth edges on the carotid artery boundary, the pixels on any row or column containing only one pixel of value "1" are set to "0". To fill holes, the "0" pixel values of regions that are surrounded by "1" pixel values are changed to "1" values, and the "1" pixel values of regions that are surrounded by "0" pixels are changed to "0" as well. Pixels on the diagonal are set to "1" if the row and column neighbor pixels are also "1".

After image processing, the binarized pixels whose values are "0" and "1" are set to 20 and 230, respectively. The images are

Figure 1 Carotid reconstruction from different angles.

saved as BMP files and imported into Mimics to complete 3D reconstruction.

Fifty layers of 3D MR TOF images were processed in this manner. Every ROI image was obtained at a resolution of 51×51 pixels automatically by our program. The BMP files were saved after binarization. With the binarization preprocessing method, the tops of vessels were automatically cut to a cross section, suitable for use by other software if the vessel images were needed for further analysis, such as anatomic or hemodynamic analysis.

The 3D reconstruction of the carotid is shown in Figure 1. The image after the mesh procedure with binarization preprocessing is shown in Figure 2(A). The resulting image from the Mimics method, which includes boundary extraction, 3D reconstruction, smoothing, and a mesh procedure is shown in Figure 2(B).

The conventional method uses Mimics software and its 3D reconstruction tools to segment the required tissues from surrounding tissue and fill cavities manually[6,7]. However, this manual procedure is time-consuming and difficult to standardize

Figure 2 Quality comparison of the mesh procedure with binarization preprocessing (A) and without binarization preprocessing (B). There are no cavities or low quality patches (marked by colors), and the top is cross section when binarization preprocessing is used.

when mass processing images. Our approach saves time and could carry out the standardized processing appropriate for MR carotid images and easily generates cross sections for carotids when needed for further hemodynamic analysis.

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Conflict of Interest

The authors declare no conflict of interest.

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