The Use of Multidimensional Modeling of the Aorta in Planning the Resection of an Aortic Angiosarcoma

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Purpose. **We report a technique of finite-element multidimensional modeling that was used to help with the planning of and the resection of an angiosarcoma in a single patient.**

Description. **A patient was referred to our department with suspected aortic angiosarcoma. We visualized and reconstructed the computed tomography and magnetic resonance imaging scans of this patient to create finite-element multidimensional models of his diseased aorta.**

Evaluation. **This technique and the multidimensional models were very helpful in assessing the tumor size and its extension. It also facilitated preoperative planning of the aortic resection and repair.**

Conclusion. **Finite-element multidimensional modeling is a useful technique for preoperative planning of aortic operations in patients with angiosarcoma.**

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Aortic angiosarcoma is an exceedingly rare tumor, with most cases only being diagnosed by postoperative histology [1]. Recent improvements in computed tomography (CT) and magnetic resonance imaging (MRI) technology and three-dimensional (3D) rendering have provided additional tools to aid in the preoperative diagnosis of this condition [2]. The production of high-quality multidimensional images may also aid surgical planning and allow virtual simulation of aortic repair preoperatively. Virtual multidemensional reconstructions are already being used routinely in diagnostic and interventional roles across many fields of clinical medicine [3].

Technology

The aim of this study was to create a patient-specific virtual model of the aorta based on CT and MRI scans of a patient with suspected aortic angiosarcoma. With the help of stereolithography technology [4], we developed a new finite-element multidimensional model (FE-MDM) of the aorta in our patient. The use of FE-MDM technology in cardiac surgery enabled our aortic team to analyze the aortic lesions more precisely, allowing better preoperative planning and decision making. To our knowledge, this is the first report of the use of FE-MDM in a patient with aortic angiosarcoma planned for surgical intervention.

Technique

A 51-year-old man, who was active and healthy, presented with sudden-onset persistent left-sided limb weakness. MRI of the brain identified 3 cerebral lesions with associated edema. He also had 3 unidentified painful subcutaneous lesions in the right calf. A biopsy specimen of these lesions revealed metastatic nodular deposits of a malignant tumor suggestive of a high-grade angiosarcoma.

Staging CT picked up a dilated ascending aorta (4.2 cm) with a filling defect and thickening of the wall focally, raising the suspicion of an angiosarcoma of the ascending aorta. After positron emission tomography scanning, MRI scanning, and multidisciplinary team discussion, we decided to proceed with aortic resection.

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Fig 1. (A) Lateral view of scan data shows the tumor in the distal ascending aorta. (B) Processing the scan data by thresholding the tumor, aortic lumen filled with blood, and the aortic wall, respectively.

To plan an optimal surgical strategy, CT scan and MRI data were used to create multidimensional virtual models of the tumor. We imported 64-slice CT and MRI data set from our patient into 3D Slicer 3.3.6 image processing software (Kitware Inc, New York, NY; Fig 1A). This software identifies the individual components of the aortic tumor (tumor, blood, and aortic wall) automatically and represents them virtually in different colors. The individual components are then reunited to form one 3D model (Figs 1 and 2). The components are segmented automatically by thresholding and region growing. Segmentation requires transformation of voxels/pixels into objects. The 3D image segmentation makes it possible to create 3D rendering for multiple objects and enables quantitative analysis of the size, density, and other variables of detected tissues.

Final manual segmentation corrections were performed to eliminate irrelevant artifacts. The model was then meshed volumetrically using the open-source MeshLab V1.30 meshing software (ISTI–CNR, Pisa, Italy), which allowed recognition and differentiation between components of the diseased aorta and the extension of the tumor (Figs 2 and 3).

Clinical Experience

The multidimensional models enabled us to have a better visualization of the mass, such as its fusiform nature, size (3×4 cm), location (distal ascending aorta), and extension (brachiocephalic artery; Fig 3). This facilitated our preoperative surgical planning, in which the patient underwent resection of the mass under deep hypothermic circulatory arrest (18°C) with supracoronary and hemiarch aortic replacement using a size 28 Vascutec aortic graft (Terumo, Leeds, United Kingdom). Intraoperative findings confirmed the preoperative models of the mass

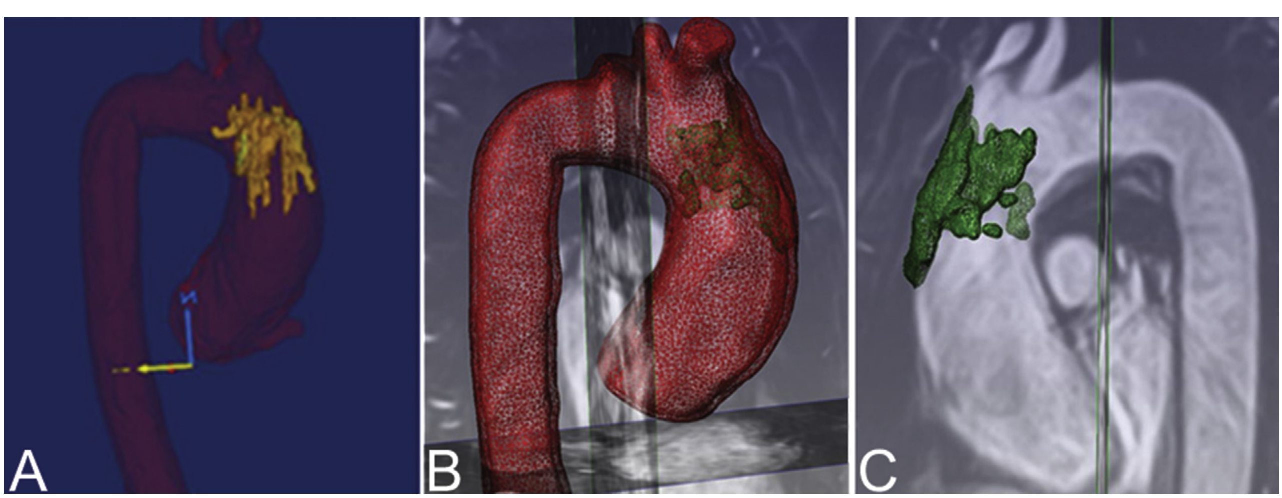

Fig 2. (A) Segmentation of aortic tumor components: aorta, blood, and tumor showing fusiform tumor in the distal ascending aorta. (B) Surface and volume meshing of the segmented models. (C) Volume meshing of the tumor, which enable measurement of the size and extension.