Magnetic resonance imaging based three-dimensional modeling of a complex vulvar tumor as a component of presurgical planning

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Abstract

We report on the presurgical evaluation of an aggressive vulvar angiomyxoma using MR based three-dimensional (3D) modeling. A graphics computer was used to outline the tumor and other soft tissue structures on axial T2-weighted MR images of the pelvic floor. Specialized software was then applied to the edited images to build a 3D model. The model was viewed and manipulated on the computer screen, and 3D photographs were taken to the OR. This allowed the surgeon to see the tumor and associated structures from multiple angles. Visualization of the tumor in a 3D setting gave the surgeon valuable insight into the shape and extent of the tumor, which was not available from the physical exam and two-dimensional MRI data alone. Improved pre-operative planning allowed for an effective and efficient surgical intervention.

Key words: vulva, angiomyxoma, MRI

Learning objectives: After reading this article and completing the post-test, the physician should be able to
-describe the MR imaging features of vulvar angiomyxoma
-understand the steps required to form a 3D model
-identify the pelvic organs on 3D models

Introduction

Aggressive angiomyxoma is a poorly circumscribed tumor of the vulva with a gelatinous or myxoid gross appearance. It is difficult to identify on T1- and T2-weighted MR images because its signal intensity is very close to adjacent structures (1). Histologically, it is a paucicellular tumor composed of bland spindle and stellate shaped cells with delicate cytoplasmic processes set within a copious myxoid matrix. Medium sized vessels, many being thick-walled and hyalinized, characterize the vascular component. Margins can be difficult to assess histologically, due to this tumor’s infiltrative nature and the almost imperceptible merging with normal vaginal/perineal tissue (2).
Case report

The patient is a 24-year-old nulliparous woman. She underwent surgery for what was thought to be a left Bartholins cyst in 1993. The pathology returned as an aggressive angiomyxoma, a locally invasive, non-metastatic tumor (1, 2). It is singularly treated by surgical excision (3). The patient had a recurrence of the tumor in 1994, at which time a wide local excision of the left vulva was performed. She did well until 1997 when she noted pain with intercourse, which radiated to her buttocks. Up to that time her Papanicolau smears and rectovaginal exams had been normal, and she had experienced no constitutional symptoms. Upon presentation, a rectovaginal exam was performed and found to be without evidence of tumor. Because of her history, a MRI study was obtained.

The standard MR malignancy protocol was performed using a pelvic multi-coil array and a 1.5T magnet (General Electric Medical Systems, Milwaukee, WI). Axial, sagittal, and coronal T2-weighted fast spin-echo images (TR 5000/TEeff 90) were obtained followed by axial T1-weighted images (TR 500/TE 60) and finally by axial fast multi-planar spoiled gradient echo images (TR 260/TE in phase/flip angle 75\(^\circ\)) before and immediately after intravenous administration of 20cc Gadolinium DTPA. In all pulse sequences, a 16cm field of view and 5mm slice thickness were employed. The 2D source images were read by a senior radiologist to determine tumor extent, and to evaluate for invasion. The MRI demonstrated enhancing areas in the left vulva that were consistent with tumor recurrence. Based on the two-dimensional (2D) MRI data, the tumor appeared to be poorly defined, complex in shape, and lacking a defined capsule. It extended both within and beyond the puborectalis muscle and between the rectum and vagina, but did not invade the latter two structures. Because of these factors, there was concern about damage to the anal sphincter and incomplete resection at surgery.

MR based 3 dimensional (3D) tumor reconstruction was considered because it had been performed successfully at our institution on other organ systems and had aided visualization in those cases. Also, our research team had considerable experience in 3D representation of the pelvic floor (4-6). Further, the angiomyxoma had proven difficult to distinguish from surrounding normal tissue on gross inspection, but was well defined on contrast enhanced MRI, likely due to its vascularity. Therefore, it was thought that 3D visualization of this tumor would give the surgeon a mental map of the tumor, thereby enhancing his
presurgical planning, and increasing the likelihood of complete surgical resection, without damage to vital surrounding structures.

The tumor was most conspicuous on the Gadolinium-DTPA enhanced images and these were used for construction of the model. The data were electronically transferred to a Sun UltraSparc-30 graphics computer workstation (Sun Microsystems, Mountain View, Ca.) and, under guidance from a senior radiologist, segmented into anatomically significant components, including tumor, bladder, urethra, uterus, vagina, rectum, muscles, and bones. The intervening fatty tissue did not contain any vital structures, and was not segmented. The structures were then labeled using a combination of semi-automated and manual editing. From these images, 3D renderings of the pelvic viscera as well as supporting muscle, fascia and bones were reconstructed using the marching cubes algorithm and a surface rendering method (6). Three-dimensional surface models were generated using a pipeline consisting of dividing cubes, triangle reduction, and triangle smoothing. Using the workstation, the model could be rotated in space and the color and opacity of organs changed at will. The total segmentation time was approximately 6 hours. The computer time for model generation was 1.5 hours. The reconstructed 3D images were reviewed with the surgeon preoperatively, on the computer workstation together with the superimposed 2D source images. Color photographs (8.5” x 11”) of several views of the 3D model were made and carried to the operating room for intraoperative review.

Results

A representative axial source image and resulting 3D model are show in Fig. 1. On the axial fast spoiled gradient echo image, the gadolinium-enhanced tumor has two components which surround the levator ani muscle. A 3D model of the same pelvis in the dorsal lithotomy position demonstrates the size and lateral extent of the tumor. Finally, a sagittal 3D projection shows interposition of the tumor between the rectum and vagina.

Surgical exploration ensued via a left labial “J” incision, and proceeded along the path depicted by the 3D model. The surgeon consulted the color images frequently during the procedure to guide his approach. Tissue excision was directed by the expected tumor location and dimensions identified on the 3D model. Intraoperative frozen section confirmed that the excised tissue contained the tumor, with negative margins. Next, histological specimens were taken from the deep incisional margins and were negative for
tumor. The procedure was completed without disruption of the vagina, rectum, or levator sling. An excellent cosmetic result was achieved. Six months after surgery, the patient was evaluated by contrast MRI, and there was no evidence of tumor regrowth.

Discussion

The reconstructed 3D model correctly demonstrated the shape and extent of this oddly shaped tumor. By allowing the surgeon to view the tumor and surrounding tissues from arbitrary angles, the 3D model permitted him to make a visual map of the tumor, enhanced by intraoperative reference to color 3D still images. This led to a directed surgical exploration, which yielded excellent results, with no disruption of critical adjacent structures. It is emphasized that the 3D reconstruction was based entirely upon information from the T2 weighted source images. What is unique about 3D is that it afforded the surgeon a view of the tumor in a familiar anatomic context. Accordingly, in the surgeon’s eyes, the 3D model elucidated a segment of tumor, which infiltrated the recto-vaginal septum. This portion of the tumor was not appreciated clinically, and would likely not have been resected without pre-operative imaging, and an appreciation of its 3D extent. Also, to the surgeon, the 3D model showed that the tumor did not invade the anal sphincter, and this knowledge allowed him to perform the excision in a way that preserved fecal continence. It is believed that the likelihood of a good surgical outcome increases with the level of the surgeon’s preparation. The benefit of this 3D pre-surgical visualization was to increase the surgeon’s preparedness and thus confidence. This enabled him to focus the surgical approach, leading to a shorter, more effective surgery, which maximally preserved the patient’s rectovaginal anatomy and function. The drawback of segmentation and reconstruction time has since been reduced with the redesign of our model-building tools, which have shortened the turnaround time to less than 3 hours. As we develop improved automatic segmentation tools, we expect that this delay will be reduced to less than one hour.

Bibliography


**Legends**

![Figure 1. Axial T2-weighted MR image (A) and dorsal lithotomy (B) and sagittal (C) displays of the 3D model of aggressive angiomyxoma of the pelvic floor. Color legend is as follows: bones – white, bladder/urethra – yellow, levator ani – red, rectum – blue, vagina – pink, tumor – green. A, Arrows mark tumor extension above and below the levator sling. B, Dorsal lithotomy projection simulates surgical approach, facilitating operative planning. C, Sagittal projection shows extension of tumor into rectovaginal space.](image)

**CME questions**

Aggressive angiomyxoma of the vulva is easily identified on axial T2-weighted MR images

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The use of fat suppression and Gadolinium DTPA were required to better demonstrate the tumor margins
The major processes required for formation of 3D models are 1) data acquisition, 2) segmentation and labeling organs of interest, and 3) surface rendering.

In this case, the 3D model was particularly valuable because it demonstrated extension of the tumor into the space of Retzius.

In this case, pre-operative planning was critical because of the tumor’s proximity to the anal sphincter.