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INTERACTIVE 3D MODEL OF MR-BASED PELVIC SUPPORT ANATOMY OF NORMAL WOMEN IN PDF FORMAT

Hypothesis / aims of study

Anatomical errors are often found in drawings that are not based directly on actual dissections. The same can be true for 3D models used for education. Most of the available pelvic floor models are based on demonstrating concepts of anatomy and are not taken directly from data acquired from living women whose pelvic floor status is known. The aim of this study is to present detailed 3D models in a widely useable PDF interface made directly from high resolution MR scans of one nulliparous and one multiparous woman with proven normal support. These models include all 23 structures involved in pelvic organ support based on published descriptions of anatomical features as seen in MR images.

Study design, materials and methods

3D volumetric models were created from 1) the MR images of a 50th percentile 51 year-old healthy nulliparous woman and 2) a 50th percentile 45 year-old healthy multiparous woman recruited as normal controls in an IRB approved study. Multi-planar, two-dimensional, fast spin, proton density MR images were obtained using a 3 T superconducting magnet (Philips Medical Systems Inc, Bothell, WA) with version 2.5.1.0 software. The axial, sagittal and coronal fields of view were 20x20 cm, with slice thicknesses of 4 mm and a 1 mm gap between slices. MR images from all three planes were imported into 3D Slicer 3.4.2009-10-15 (Brigham and Women's Hospital, Boston, MA) [1] and aligned using auto registration and fixed landmarks. Each pelvic floor structure was traced from one most clearly visible axial or coronal plane and corresponding model was created. The degree of smoothing was adjusted to avoid artefacts. The models were compared to the original tracing to confirm fidelity to original scan. The 3D models generated by 3D Slicer were first imported into Adobe 3D Reviewer 9.0 (Adobe Systems Incorporated, San Jose, CA) [2] or Pro/Engineer Wildfire 4.0 (Parametric Technology Corporation, Needham, MA) and then exported as universal 3D file (U3D) after setting up the properties of the model. The saved U3D was then inserted into Adobe Acrobat 9 Pro (Adobe Systems Incorporated, San Jose, CA) with 3D tool under Tools menu. After activating the 3D model by clicking the picture, the 3D PDF was customized to set up a preview and several optional views for readers.

Results

Figure 1 shows the 3D pelvic supports PDF model of the 50th percentile 45 year-old healthy multiparous woman.

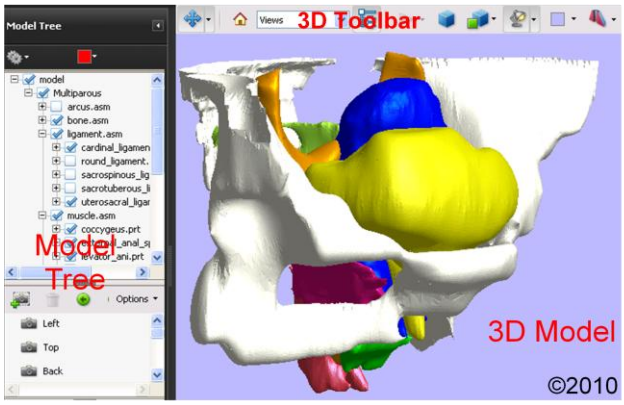

Figure 1. Interactive 3D PDF model of pelvic supports. The left side shows the model tree through which readers can hide or isolate parts, or make parts transparent, or choose custom view. Structures can be grouped by system (e.g. bones, muscles, organs). The right top side shows the 3D toolbar through which readers can zoom in and out, rotate, and pan across the object, make 3D measurements, or cut a cross section of the model. The PDF file can be downloaded from the internet (Download link, Open Password: ics2010) which has no any identification info.

The following manipulations can be performed after clicking the picture to activate the 3D model: 1) Display different combinations of structures, 2) Render any structure transparent, 3) Zoom in and out, rotate, and pan across the object, and 4) Cut model in any plane and at any level. Figure 2 shows 4 views of the 3D model.

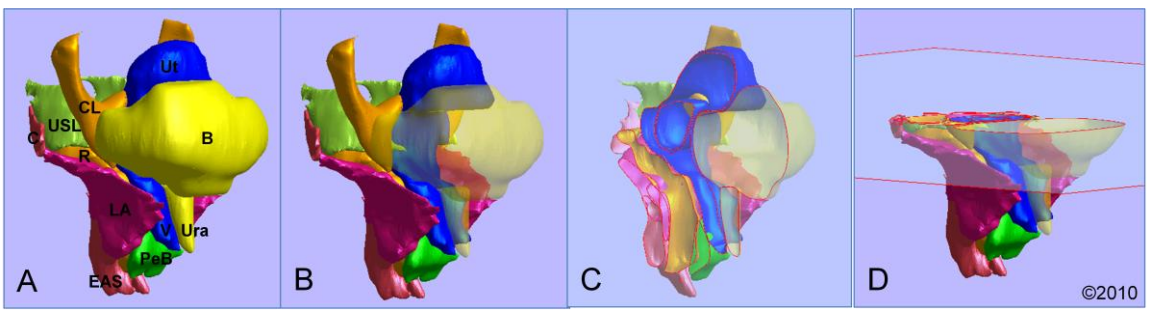

Figure 2. A. 3D model is shown without bone to illustrate selected features. **B.** Transparency of bladder and urethra to show the underlying structures. **C.** Middle sagittal cross section. **D.** Axial cross section. The bladder (B) and urethra (Ura) are *yellow*, the uterus (Ut) and vagina (V) are *blue*, the rectum (R) is *dark brown*, the cardinal ligament (CL) is *light brown*, the uterosacral ligament (USL) is *light green*, the perineal body (PeB) is *green*, the Levator Ani (LA) is *purple*, the external anal sphincter (EAS) and coccygeus (C) are *red*.

Interpretation of results

This study presents the interactive 3D models of pelvic supports based on real anatomy seen in MR scans of living women. These models were made using published descriptions of anatomical features as seen in MR images, to create the key structures involved pelvic organ disorders. It can be used as accurate examples to teach structural relationships in pelvic anatomy from 3D visualization. The ability to interact with the different structures facilitates learning complex anatomical relationships. Having models that are anatomically accurate is critical to avoiding errors in understanding that can arise from models conceptually based anatomy. Embedding the 3D models into PDF has advantages over the limited views of 2D images in printed publication [3]. After activating the 3D model by clicking the image, readers can manipulate the 3D model to look into the details within the models, which is especially useful for the anatomy study of spatial relationships of complicated structures. These files can be read with the standard Adobe Reader from 7.0 and higher available as a free download (get.adobe.com/reader/) that is on most computers making it readily available to all learners. We believe this will become the new publication standard for information of this type.

Concluding message

Our study demonstrated that 3D PDF can present the interactive 3D detailed models of pelvic supports which can be viewed and manipulated by readers without any specialized visualization software.

References

1. http://www.slicer.org/
2. http://www.adobe.com/
3. Ruthensteiner, B. and M. Hess (2008). "Embedding 3D models of biological specimens in PDF publications." Microsc Res Tech 71(11): 778-786.

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Was informed consent obtained from the patients?	**Yes**