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Three dimensional model of the female perineum and pelvic floor muscles

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ABSTRACT

Objective: The anatomy of the perineum and the pelvic diaphragm of woman is complex. A numerical complete three-dimensional (3D) model of every muscle of the woman pelvis doesn't exist. The pathophysiology of genital prolapse is still debated. Knowledge of anatomy is essential to better understand its mechanisms. The aim of this research was to build a complete three-dimensional model of the female perineum and pelvic floor muscles.
Study Design: To model the pelvic muscles we reconstructed them in three dimensions from tracing a magnetic resonance imaging (MRI) of a female pelvis from a cadaver.
Results: We obtained a complete anatomical model of the muscles of the perineum and pelvic floor. Each muscle was built thanks to the MRI.
Conclusion: We obtained the first complete anatomical model of the perineal muscles and pelvic diaphragm. It could be a good educational and simulation tool for better understanding normal and pathological pelvic mobility.

Introduction

The anatomy of the female pelvis is still imperfectly known whereas anatomical descriptions vary. Muscles of the pelvic diaphragm and perineum as well as the pelvic ligaments and fascias provide the suspension and support of pelvic organs. Knowledge of this anatomy is essential to the understanding of the pathophysiology of genital prolapse. Our team already developed a simulation model from the tracing of dynamic magnetic resonance imaging (MRI) of the pelvis of a control patient [1]. It included the pelvic organs (vagina, uterus, rectum and bladder), which were modeled in three dimensions (3D). It was necessary to add the ligaments (round, uterosacral, broad and umbilical) as well as a pelvic diaphragm closing the pelvic excavation to make the model consistent and comparable to the dynamic MRI of the control patient. The topography given to these ligaments and to the pelvic diaphragm was determined according to our anatomical knowledge. They could not be modeled from MRI because these structures were hardly visible. The model, although functional and coherent, is therefore not anatomically correct since its geometry is approximate. Other existing simulation models include only the levator ani muscles (LAM), which were reconstructed from MRI [2–6]. Continuous improvement of imaging allows us to study anatomy but the results are still imperfect for the accurate distinction of the various muscles and ligaments of the pelvis. We know that results of MRI tracing alone have a large intra-and inter-individual variability [7]. That is why Janda and al. and Sora and al. compared the results of an MRI tracing with anatomical dissections [8,9]. The method used by each team was different and only focused on the LAM without the perineal muscles. Thus, we aimed at completing our anatomical model of the female pelvic floor muscles and perineum muscles with the greatest accuracy. For this, we used the tracing of the MRI of a female corpse.

Materials and methods

The objective was to obtain an accurate 3D reconstruction of the pelvic diaphragm and of the perineum to complement the existing simulation model. We used a female fresh corpse. So we do not need an institutuonal review board approval.

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3-tesla MRI and CT-scanner were performed. Slices were made in three planes, T1-weighted, as well as coronal slices, T2-weighted. The slice thickness was set to 3 mm (mm) not to have a big space between two slices. We traced muscles on MRI through Avizo® software 7.0. For each structure to be rebuilt, the contour was traced manually, and the software was then instructed to build an optimized surface in the form of a scatter plot and triangular facets. The resulting surfaces were treated using Catia® software.

We wanted to individualize the bulbospongiosus muscle, superficial and deep transverse perineus muscle, ischiocavernosus muscle, sphincter ani externus muscle, obturator internus muscle, LAM and coccygeus muscles.

Results

We traced every muscle on the pelvic MRI performed. We started by rebuilding the bony pelvis since all muscular and ligamentous structures are inserted into it. We used the CT scanner, and not the MRI because the bone structures are more contrasted on the scanner and therefore better individualized. A method for semi-automated contouring allowed us to obtain the bony pelvis in 3D. We also contoured organs on the MRI (bladder, uterus, vagina and rectum) to make the model consistent. The uterus was the only organ easy to contour. We were able to trace each muscle of the perineum and pelvic floor. The gluteus maximus muscles were also traced to have a complete anatomical model. A 3D reconstruction was carried out using Catia® software.

Perineal muscles (Fig. 1)

Superficial perineum muscles

MRI contouring of the ischiocavernosus muscles did not show any difficulty. Bulbospongiosus muscles were difficult to identify due to a low contrast difference between them and the adjacent structures (especially the pubovaginalis fascicle of the LAM). This muscle is located on either side of the vagina and urethra and is continuous with the pubovaginalis fascicle of the LAM. Downwards, it joins the perineal body that appears on MRI as non-individualized fibrous clusters. We contoured the sphincter ani externus muscle (EAS) but we could not identify the sphincter ani internus muscle. The boundaries between the EAS and the LAM were sometimes a little blurry, considering the interpenetration of LAM fibers between those of the EAS.

Deep muscles of the perineum

The insertion on the ischium of the deep transverse perineus muscle could not be perfectly displayed. It seems that this muscle inserts partly on the pubococcygeus muscle and on the ischiocavernosus muscle. It seemed to us that its fibers were crossing the perineal body.

The urethral lumen being virtual, we continued contouring the bladder wall by that of the urethral wall and thus its sphincter without perfectly individualizing it. We traced the endopelvic part of the obturator internus muscle (Fig. 1).

Pelvic floor muscles (Figs. 2 and 3)

Levator ani muscles

The iliococcygeus subdivision of the LAM was clearly visible on MRI. We found its insertion on the internal obturator muscle up to the ischial spine. The pubococcygeus and puborectalis subdivisions were more difficult to individualize, particularly in their retropubic bone insertion as the limits were hardly visible. We were not able to identify the three fascicles of the pubococcygeus muscle classically described but only one muscle in continuity determining the urogenital hiatus with a latero-vaginal portion, a latero-rectal portion and a retro-anal portion like a sling.

Coccygeus muscles

The coccygeus muscle was clearly visible on MRI with an insertion on the ischial spine and an ending on the coccyx and the first sacral pieces.

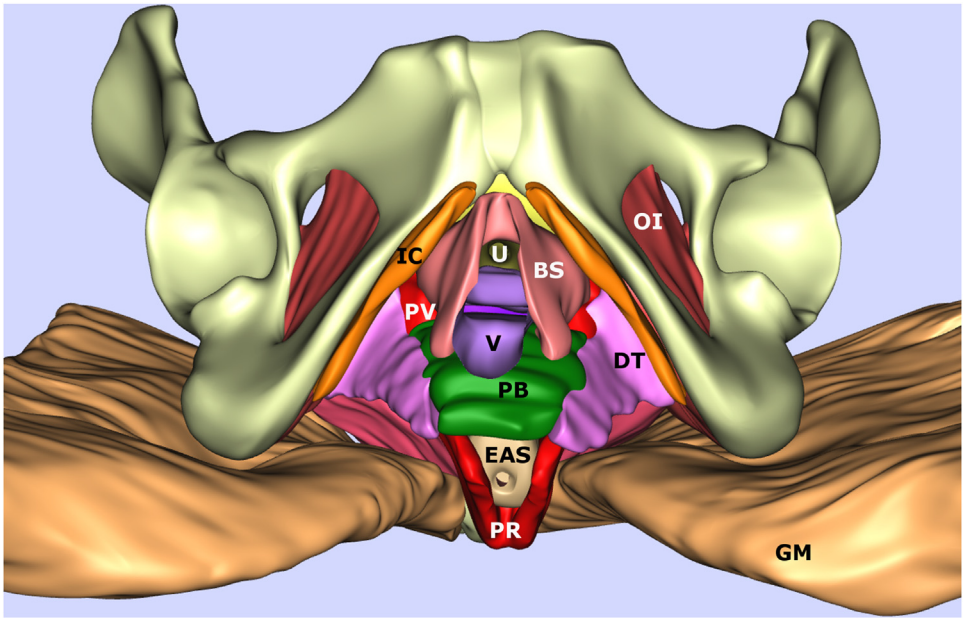

Fig. 1. xxx.
B: bladder; LAM: levator ani muscle; OI: obturator internus muscle; IIC: iliococcygeus muscle; C: coccygeal muscle; PV: pubovaginal muscle; PA: puboanal muscle; PR: puborectal muscle; EAS: external anal sphincter; IAS: internal anal sphincter; UES: external urethral sphincter; BS: bulbo spongiosus muscle; PB: perineal body; IC: ischio cavernosus muscle; DT: deep transverse perineal muscle; GM: gluteus maximus muscle.