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Otcenasek M[1], Halaska M[1], Krcmar M[1], Blovsky J[1]
1. FN Na Bulovce

ADVANCED 3D MODELLING – SIMULATION OF SQUEEZING AND VALSALVA MANOEUVRES IN HEALTHY NULLIPAROUS WOMEN.

Aims of Study

MRI based 3D modelling is an established diagnostic tool that significantly improves our understanding of the pelvic floor anatomy. To help us with the precise understanding of the pelvic floor function, not only static, but also dynamic models need to be created. We attempted to make a precise 3D model of all important organs of the female pelvis and to simulate their movements and changes of their shape during voluntary squeezing and during Valsalva manoeuvre.

Because all MRI scanners work with universal system of coordinates, different scans can be combined and their position reconstructed in a computer model. The acquisition of data for static reconstruction takes long time (minutes). On the contrary, the women can not hold Valsalva or squeeze for more than a few seconds. To overcome this problem, we examined six defined planes dynamically (with short time of acquisition of each image) and combined the data with the static model later in the computer.

Methods

Four healthy nulliparous women were involved in our study. Mean age was 23.4 years (SD 1.9), mean BMI 24 (SD 2.6). They did not complain of any of the lower urinary tract symptoms. A routine gynecological examination did not reveal any abnormal finding.

Because we planned to perform the dynamic examination of different planes consecutively (not during one exercise – the woman had to repeat the manoeuvre for each plane separately), it was necessary to ensure good reproducibility of the manoeuvres. This was performed during the initial visit, when the proper squeezing and Valsavla manoeuvre was explained and taught under control of ultrasound. The bladder was filled with 250 ml of sterile saline and a small rectal balloon catheter (7 mm diameter of the balloon) was inserted into rectum to monitor intrarectal pressure. A very good reproducibility of both manoeuvres was achieved (monitored by the position of the uretrovesical junction a by the intrarectal pressure curves).

The MRI examination was performed with the Siemens Impact scanner (1.5 T, pelvic phased-array coil). The bladder filling and rectal catheter was the same as during the training (see above). For the purposes of the static 3D modelling, we scanned three sets of images (T2-weighted, slice thickness 3 mm, gap 0.9 mm). First, axial images from the uterine fundus to the most distal muscle fibres of sphincter ani muscle. Second, frontal images from the sacral bone to the upper pole of the symphysis. Third, a special set perpendicular to the axis of the anal canal. We used the three sets to eliminate the partial volume artefact, which can produce major inaccuracies when the model is created from one dataset only. A standard method of 3D modelling was used (1).

For the dynamic examination, we used six planes - three semi-frontal (P, Q, R), one sagittal (B) and two parasagittal (A, C) - figures 1, 2. The planes were chosen to cover the different parts of the bladder base and of the levator ani muscle as most distinct structures seen on the dynamic scans. For each plane, the woman performed following sequence of pelvic floor exercise - rest (5 seconds), squeezing - (6 seconds), relaxation (5 seconds), Valsava (8 seconds). The whole sequence of manoeuvres was scanned (time of acquisition 0.81 s, gap 0). For rest, squeezing and Valsalva one image from each plane was chosen, that showed stable value of maximal intrarectal pressure during its acquisition (+-3 cm H_2O). The outlines of the visible organs representing different states of the pelvic floor in each plane was imported into the 3D models and the original static model was morphed to fit these outlines.

Results

Four computer models of continent nulliparous women were created. These models precisely demonstrate the anatomy of female pelvis at rest, and fairly precisely simulate the position of involved organs during Valsalva manoeuvre and squeezing. The changes of position and shape of each modelled organ (urinary bladder, urethra, uterus, rectum, vagina, levator muscle, internal obturator muscle, sphincter ani muscle, urogenital diaphragm) is described and analyzed. Specific spatial relationships of neighbouring structures are visualised and their function is discussed from the point of view of different theories of continence (hammock theory, integral theory, pressure transmission theory). Although not directly visualised, the shape and mechanical properties of the endopelvic fascia is estimated and modelled. All structures are presented individually and in groups, both at rest and during movements.

Conclusions

The small tissue contrast, great variability, significant post mortal changes and muscle relaxation during surgery are factors, which hindered the proper scientific evaluation of the female pelvic floor. Both the structure and function of individual parts of the region were only estimated with the help of different diagnostic tools, none of which had the capacity provide comprehensive information. The use of the magnetic resonance imaging constitutes a new era in urogynecology. Now it is possible to gain clear images of all major pelvic floor structures, construct 3D models of individual patients both at rest and during dynamic manoeuvres. This will help to make a precise diagnosis for each patient and to tailor surgical procedures individually in the near future.

Figure 1 - location of dynamic planes axial view

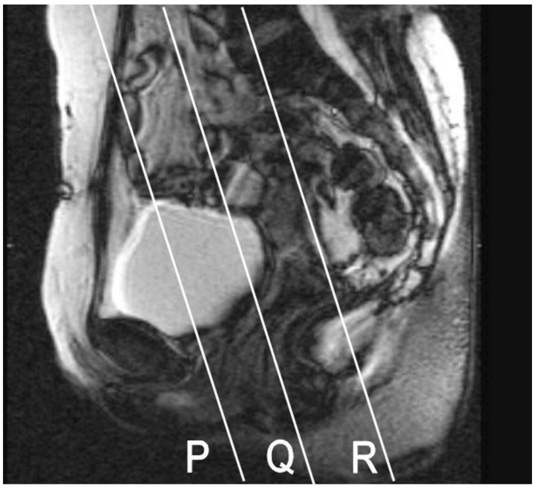
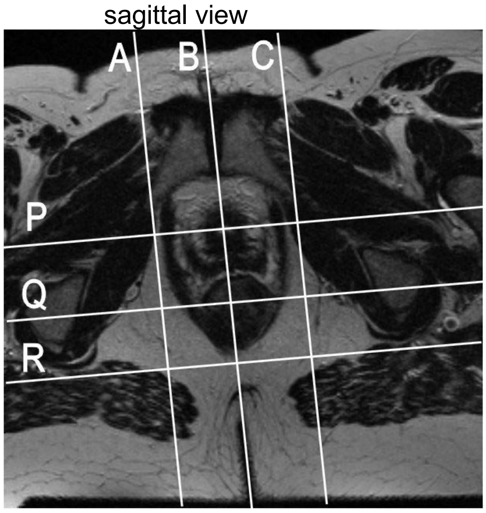


Figure 2 - location of dynamic planes sagittal view



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