"Purse String" Morphology of External Anal Sphincter in Nullipara Women with Ultrasound, High Resolution MRI, DTI and Fiber Tracking.

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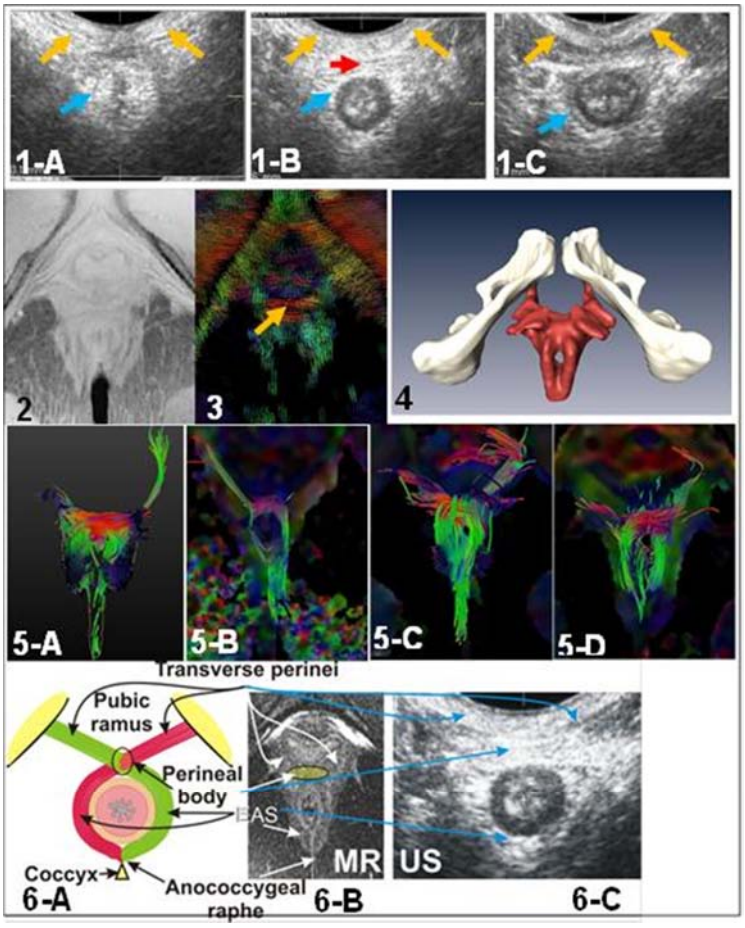
Purpose: The External Anal Sphincter (EAS), amongst the pelvic floor muscles, is the most commonly affected muscle in patients with fecal incontinence. Current belief is that the EAS is circular or "donut shaped" muscle in which: (1) The anterior ends of the EAS muscle fibers insert into the midline structure of perineal body. (2) Posteriorly the EAS attaches to the coccyx by a fibro-aponeurotic structure, i.e. "anococcygeal raphe". (3) A separate set of superficial muscles of the perineum, i.e. transverse perinei (TP), originate from the right and left pubic ramus (laterally) and insert into the perineal body in the midline[1]. We hypothesize that the EAS instead has an unique "purse-string" morphology with transverse perinei being extensions of the EAS muscles. Such structure contracts in a circumferential manner to generate higher anal canal pressure than the circular shape and has significant relevance for the effects of lateral episiotomy on EAS function and surgical reconstruction of EAS to treat anal incontinence.

Aim: To elucidate the structure of EAS and transverse perinei muscles in vivo in humans. Morphology of EAS and transverse perinei muscles was assessed using 3D trans-perineal ultrasound (US), high resolution magnetic resonance (MR) imaging & MR diffusion tensor imaging (DTI).

Methods: 14 nullipara women (all ages below 40 years), were recruited after obtaining IRB approved consent. 3D Transperineal Ultrasound volume images were obtained using a Philips HD11 machine, 3~9 MHz trans-vaginal transducer. Anal canal anatomy could be viewed in 3 orthogonal planes. High Resolution (HR) MRI were acquired in a 3T GE Excite MR scanner with phased-array torso coil, a 15 cm Field-of-view, a 256x192 matrix, 5 averages, prescribed off mid-section sagittal image, in both trans-axial as well perpendicular to the anal canal planes. Diffusion Tensor Imaging (DTI) were acquired at rest, in axial plane, with spin-echo echo-planar sequences with b-values of 0 and 500 s/m2 in 32 non-collinear gradient directions. They covered from the cranial end of pubic symphysis (anteriorly) and sacral S1 level (posteriorly) to the inferior most aspect of anal canal. Slices were acquired with 1.6 mm x 1.6 mm inplane resolution, 4 mm thick, 24 cm FOV, a total of 29~30 slices, in ~11 min. Subsequent image-processing to obtain principal eigenvalues and tensor map was performed using DTIStudio [https://www.dtistudio.org] and MedInria [www-sop.inria.fr/asclepios/software/MedINRIA]. Muscle fibers were tracked by placing seed points appropriately in the EAS and transverse perinei muscles[2].



Results & Discussion: Fig.1 shows serial tomographic sections of the anal canal, obtained using 3D-US volume technique, 2 mm apart, starting from the anal verge (top left) to the top of the anal canal (bottom right). Blue arrows depict EAS, yellow arrows depict transverse perinei and red arrows represent the perineal body. Fig.2 shows HR MRI & Fig.3 the corresponding color diffusion tensor images. Colors indicate the direction of principal component of the fiber tensor with blue S/I, green A/P, and red L/R, with perineal body indicated by arrow. DTI images in reveal that, for the perineal body and the lateral, medial and posterior aspects of EAS: The angle of fibers with the S/I axis of subject was 79.5^o, 65.7^o, 78^o and 85^o respectively, i.e., closely aligned towards the transverse plane. The angle of fibers with the A/P axis of the subjects, were 77.3^o, 10.9^o, 21.4^o and 75.0^o respectively. Fractional anisotropy (FA) was significantly lower (0.22$\pm$0.01) for the perineal body compared to the lateral (0.4$\pm$0.04), medial (0.38$\pm$0.03), and posterior (0.38$\pm$0.03) aspects of EAS muscles, strongly suggesting crossing over of the EAS muscle fibers from the right side of EAS into the left transverse perinei and vice versa. Fig.6 shows 3D reconstruction of the pelvic floor muscles and bone structure from HR MR images. The anal canal is observed as the opening in the external anal sphincter muscle (red) where the internal anal sphincter is located (not shown). The two wings stretching laterally to the bones (shown in white) are the transverse pernei. Region where the transverse perinei and external anal sphincter meet is the perineal body. Fig. 5 shows muscle fiber tracking in this anatomy. The fibers are calculated from the DTI images and then registered on to the corresponding HR MR images. A section from a 3D view is rotated to give the most inclusive view of the entire fiber length. The colors of the fibers are the same as the eigenvectors. It shows that the EAS muscle fibers cross over in the perineal body to continue as transverse perinei muscle to be inserted in to the pubic ramus of the opposite side. **Conclusion**: The above findings support our concept of the EAS anatomy in the proposed schematic in Fig. 7 depicting EAS anatomy wrt the pubic ramus, perineal body, IAS similarly in MRI and US image. Such combination of multiple imaging techniques strongly suggest that EAS is configured as a "purse-string" rather than a "dough-nut". **References**: [1] Larson KA et al. Am J Obstet Gynecol (2010)203:494. [2]F.M.Zijta et al. Eur Radiol (2011) 21;1243;