PRIZE AWARD: Best Basic Science Abstract (Joint)

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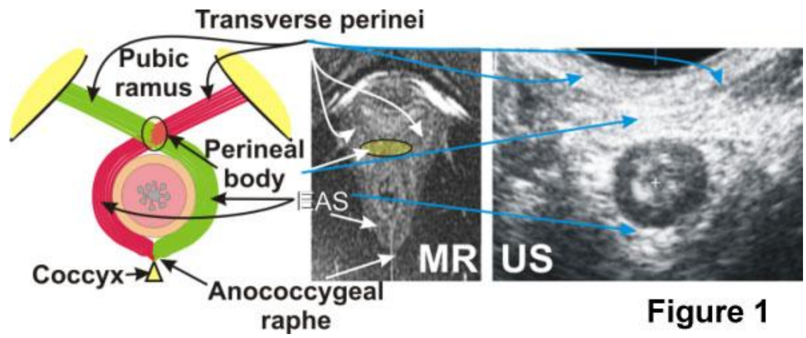
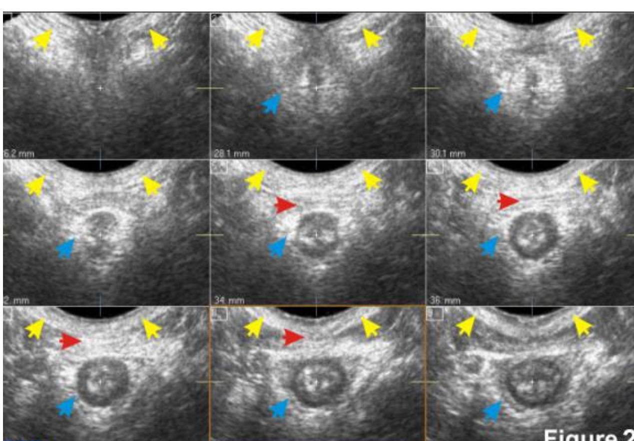
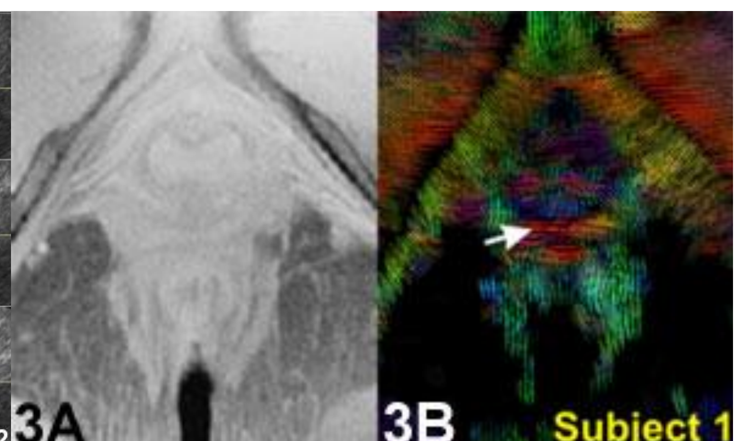
ELUCIDATION OF CIRCULAR VERSUS "PURSE STRING" MORPHOLOGY OF EXTERNAL ANAL SPHINCTER MUSCLE USING ULTRASOUND, HIGH RESOLUTION AND DIFFUSION TENSOR MAGNETIC RESONANCE IMAGING.

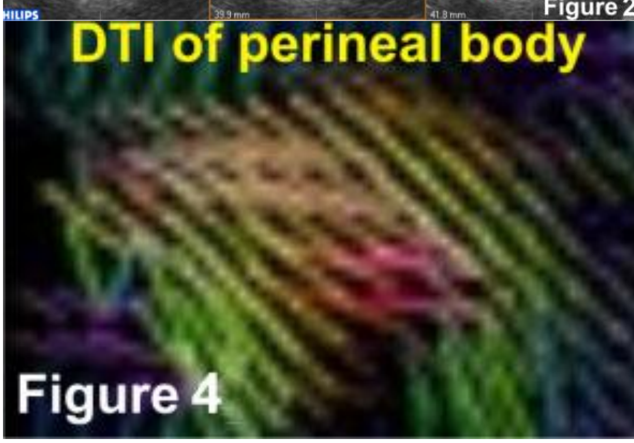
Hypothesis

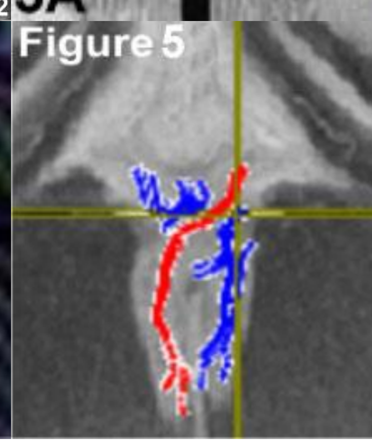
Amongst the muscles of the pelvic floor, the external anal sphincter (EAS) is the most commonly affected in patients with fecal incontinence, because up to 35% of women sustain injury of the EAS muscle during the first vaginal child birth. Current understanding is that the external anal sphincter (EAS) is a circular ring or "donut shaped" muscle and it contracts in a circumferential manner to increase the anal canal pressure (Fig.1, Left). It is suggested that at the anterior end the EAS muscle fibers are inserted into the midline structure of perineal body and posteriorly the EAS is thought to be attached to the coccyx by a fibro-aponeurotic structure, i.e., "anococcygeal raphe". A separate set of muscles, i.e., transverse perinea (TP), the superficial muscles of perineum originate from the right and left pubic rami (laterally) and are inserted into the perineal body in the midline. **We hypothesize that** the EAS instead of being a circular muscle, has actually an unique "purse-string" type of morphology and the constricting function of the EAS is due to the "tying-of-knot" like action of what is currently known as the EAS and TP muscles, with the TP muscles hypothesized as extensions of the EAS muscles.











Study Design

Towards elucidating the structure of EAS and TP muscles in vivo in humans, we assessed the morphology of EAS and TP muscles using 3D transperineal ultrasound (US), high resolution magnetic resonance (MR) imaging & MR diffusion tensor imaging (DTI). DTI probes the anisotropic nature of cellular water diffusion in the tissue structure that allows one to infer the direction of muscle fibers & micro-structural organization in vivo.

Material and Methods

Studies were conducted in 16 nullipara women after obtaining Institutional Review Board approved consent. 3D-US imaging was conducted using a Philips HD11 system. Anal canal anatomy could be displayed and viewed in 3 orthogonal planes. MR imaging was carried out on a 3T GE Excite MR scanner with a phased-array torso coil. High-resolution morphologic images, prescribed off a mid-section sagittal image, were acquired in both transaxial and perpendicular to the anal canal planes. Diffusion tensor images, 4 mm thick, were acquired with spin-echo echo-planar sequences with b-values of 0 and 500 s/m^2 in 13 non-collinear gradient directions. Subsequent image-processing to obtain principal eigen-values and tensor map was performed using DTIStudio[1]and MedInria[2] software.

Results

Fig. 1 shows the similarity of anatomy seen by MRI (mid) and US (right) images. Pubic ramus, perineal body, IAS and EAS are depicted and correspond to the schematic shown on the left, which reflects our concept of the EAS anatomy. Fig. 2 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 TP and red arrows represent the perineal body. Note the relationship of the 3 structures. Fig. 3.A shows high resolution MR images and Fig.3.B the corresponding color diffusion tensor map. Different colors in 2.B indicate the direction of principal component of the fibre tensor, blue indicating superior/Inferior orientation, red left/right and green anterior/posterior. The arrow indicates the anterior midline location of the EAS or the region of perineal body. Fig. 4 is magnified region of the perineal body, showing left-to-right criss-cross arrangement of muscle fibers. Fig. 5 shows one of the first muscle fibre tracking in this anatomy. The fibres are calculated from the DTI images, then registered on to the corresponding proton-density images. A section from a 3D view is rotated to give the most-inclusive view of the entire fibre length. The colors in Fig. 5 do not have any significance. It shows that the EAS muscle fibers cross over in the perineal body to continue as TP muscle to be inserted in to the pubic ramus of the opposite side.

Interpretation of Results

Analysis of MR and US images (Fig. 1, middle and right respectively) revealed that the cranio-caudal extent of transverse perinei and EAS are identical. As one follows the EAS muscle from the right and lateral directions they merge into the TP muscles. DTI images such as Fig. 3.B, in the 16 different subjects revealed that, for the perineal body and the lateral, medial and posterior aspects of EAS: (1) angle of fibres with the S/I axis of subject was 79.5^o, 65.7^o, 78^o and 85^o respectively, i.e. they were all closely aligned towards the transverse plane. (2) angle of fibres with the S/I axis of subject was 79.5^o, 65.7^o, 78^o and 85^o respectively, i.e. they were all closely the A/P axis of the subjects, were 77.3^o, 10.9^o, 21.4^o and 75.0^o respectively, suggesting a novel configuration shown in the schematic in Fig.1 (left). (3) Fractional anisotropy (FA), a robust intra-voxel measure equal to 0 for perfectly isotropic and 1 for perfectly anisotropic diffusion (e.g. in a long thin tube), was significantly lower (0.22+0.01) for the perineal body compared to the lateral (0.4+0.04), medial (0.38+0.03), and posterior (0.38+0.03) aspects of EAS muscles. Based on studies of the fibre tracts in the brain, the lower value of FA in the perineal body strongly suggests crossing over of the EAS muscle fibres from the right side of EAS into the left TP and vice versa, compared to unidirectional fibres in the other 3 regions. In Fig. 4, the right–to-left direction of the muscle fibres in the perineal body suggests that the muscle fibres in the anterior midline region of EAS cross to the opposite side. Note in Fig. 5 that the fibres of EAS muscle continue into the TP muscles on both sides.

Concluding Message

We suggest that the transverse perinei are actually the part of EAS muscles. Instead of the circular shape, we propose novel “purse string” morphology of the EAS muscle. Improved understanding of the EAS morphology as provided by this comprehensive set of imaging modalities has implications for EAS reconstructive surgery in the treatment of fecal incontinence.

References

1. https://www.dtistudio.org/
2. http://www-sop.inria.fr/asclepios/software/MedINRIA/

Specify source of funding or grant	**Departmental Discretionary Research Funds**
Is this a clinical trial?	**No**
What were the subjects in the study?	**HUMAN**
Was this study approved by an ethics committee?	**Yes**
Specify Name of Ethics Committee	**UCSD Human Research Protection Program**
Was the Declaration of Helsinki followed?	**Yes**
Was informed consent obtained from the patients?	**Yes**