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APICAL SUPPORT: STRUCTURAL RELATIONSHIPS BETWEEN THE CARDINAL AND UTEROSACRAL LIGAMENTS SEEN IN MRI AND THREE-DIMENSIONAL RECONSTRUCTION

Hypothesis / aims of study:
The cardinal/uterosacral complex that comprises level I (apical) suspension is critical to pelvic organ support. An understanding of the structural interaction between the cardinal ligament (CL) and uterosacral ligament (USL) in living women is currently not available. The CL is considered a mesentery-like structure which is defined anatomically as the perivascular sheath of the internal iliac vessels extending from the iliac fossa to the pelvic organs [1]. The USL is composed of connective tissue and smooth muscle containing vessels and autonomic nerves connecting the genital tract to posterior pelvic structures [2]. The advent of modern MR imaging allows detailed in vivo, in situ analysis of pelvic floor structure. The purpose of this research was to study the characteristic features, anatomical distinctions and structural relationships between the CL and USL using MR cross-sectional anatomy and three-dimensional modeling.

Study design, materials and methods:
Twenty pelvic 3Tesla proton-density high resolution MR scans of women with normal pelvic organ support who volunteered as controls for an IRB approved study of pelvic floor disorders were analyzed. Detailed slice-by-slice examination of axial, sagittal, and coronal images of the subjects was conducted. Characteristic features of the apical support components in each plane were cataloged. The visibility of the characteristic features was tallied and a plane-specific percentage visibility was obtained. Next, one exemplar MR data set was selected for 3D reconstruction using Slicer 3.4 ® software (Brigham and Women's Hospital, Boston, MA). Tracings and 3-D models were made of the CL and USL in the plane in which each structure was best visualized so as to have a visual 3D appreciation of the orientation and relationships of the apical support elements.

Results: The study population had a mean age of 56.3 ± 7.2 years with a mean Body Mass Index of 27.9 ± 4.3 kg/m^2, and a mean parity of 2.1 ± 1.0. The CL was best seen in the coronal plane whereas the deep USL in the axial plane (note that the superficial USL was not consistently visible). The characteristic feature for identifying the CL was the web-like structure centered around the axis of the internal iliac vessels and its divisions going in a cranio-caudal direction to the uterus, cervix, bladder and the upper third of the vagina from its origin on the pelvic sidewall at the level of the greater sciatic foramen. From the 20 MR scans analyzed, the CL region was identified in 100% of cases. Its distal endpoint was 80% (16/20) to the cervix and 20% (4/20) to the vagina. The deep USL was seen as a thin well-defined band-like structure. We were able to identify 19 (95%) ventral and dorsal attachments of the USL from the 20 MRI scans analyzed. On the ventral end, the USL inserted to the cervix only in 2 (10.5%) cases, to the upper part of the vagina only in 8 (42%) cases, and to both the cervix and vagina in 9 (47%) cases. The dorsal USL attached to the coccygeus/sacrospinous complex in 14 (73%), to the sacrum in 4 (21%), and to the ischial spine in 1(5%).

Interpretation of results:
The deep USL and CL share a common region of insertion at the cervix or/and upper part of the vagina. These ligaments diverge as they pass to the pelvic walls. The difference in texture between the vascular sheath characteristic of the CL and the thin band-like structure of the USL allows their separate locations to be identified. The CL is oriented in a cranial-caudal direction and not in a transversal direction. The USL lies in a ventral-dorsal direction and consists of a deep and superficial part inserting into the genital tract. Although the deep (neuro-vascular) USL is easily visible in MR scans, identifying the superficial (fibrous) USL is not possible at present. Given the importance of the CL and USL to clinical practice, having a technique that allows them to be identified and studied in living women has great potential for identifying structural abnormalities in women with prolapse.

Concluding message:
We demonstrated that distinctive characteristics of the CL and USL can be evaluated in MRI and three-dimensional modeling. They have overlapping insertions onto the cervix and vagina but divergent courses to their peripheral attachments. This opens the door to their evaluation in living women with and without prolapse.

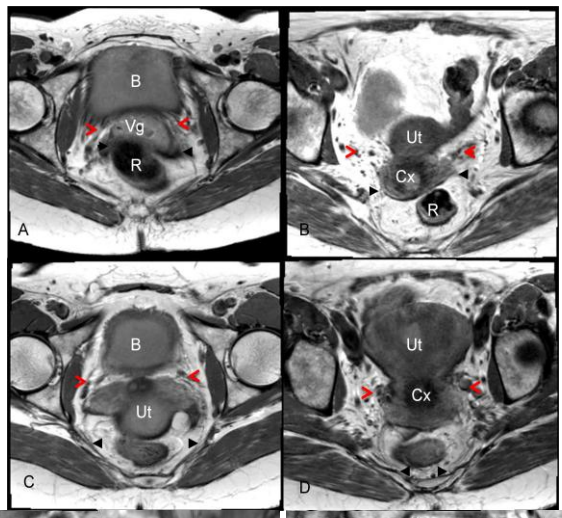

Figure 1A, B, C, D showing MR axial scans. B: bladder, Vg: vagina, R: rectum, Cx: cervix. Black arrow heads showing different ventral (A,B) and dorsal (C,D) attachments of the USL ; red arrow heads showing CL. 1A: vaginal insertion fibers of the USL, 1B: cervical insertion fibers of the USL, 1C: sacro-spinous ligament-coccygeus muscle insertion of the USL, 1D: sacral insertion of the USL
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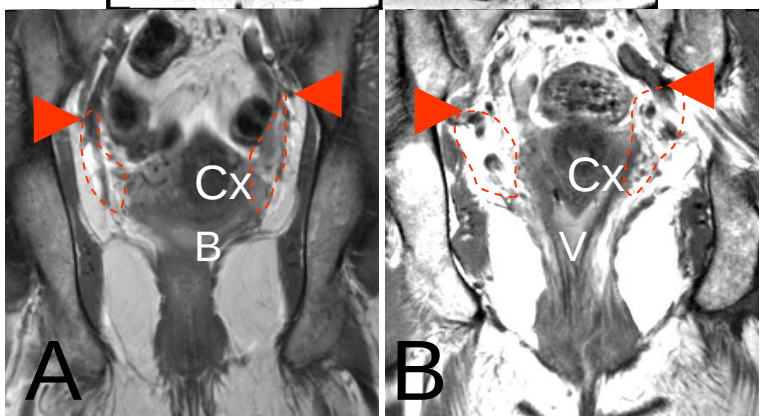

Figure 2:
Coronal scans showing origin of CL (red arrow head) at the level of the Great Sciatic Foramen for 2 different subjects. CL tracings for 3D Slicer modeling are in red dashed lines. 2A: CL insertion to the cervix (Cx) and bladder (B); 2B: CL insertion to the Cx and vagina (V). © 2010

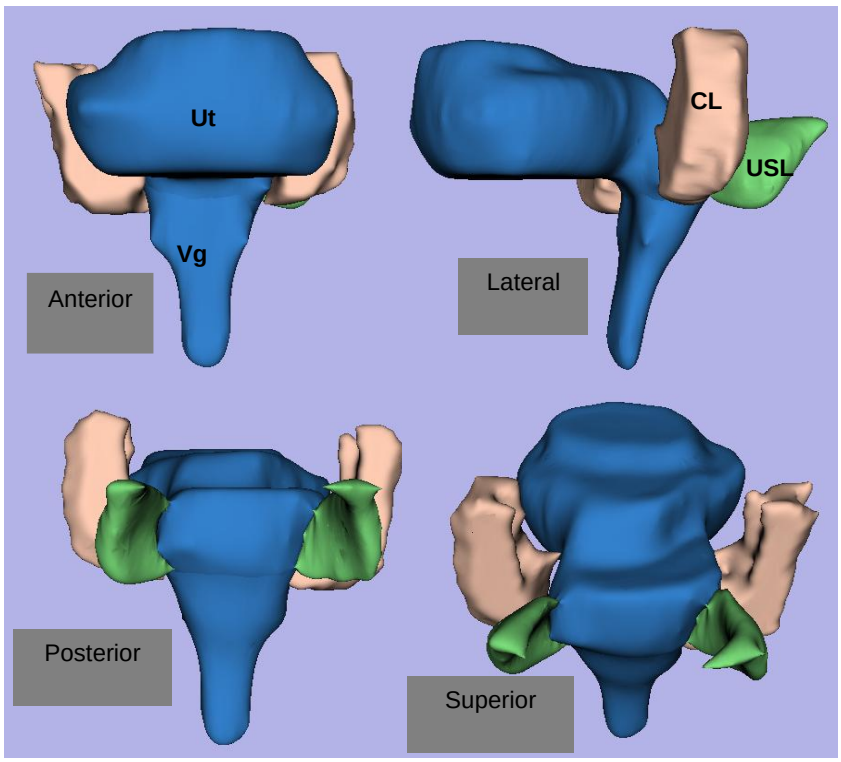

Figure 3:
3D Slicer model of the CL and USL constructed from MR scans. The geometry of the apical support is shown with the CL in a cranial to caudal direction and the USL in a ventral to dorsal direction. Fibers of both ligaments converge towards the cervical-vaginal junction. © 2010

References
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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	**University of Michigan Institutional Review Board 199-0395**
Was the Declaration of Helsinki followed?	**Yes**
Was informed consent obtained from the patients?	**Yes**