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ESTIMATES OF THE LEVATOR ANI SUBTENDED VOLUME BASED ON MAGNETIC RESONANCE LINEAR MEASUREMENTS

Hypothesis / aims of study:
The Levator Ani Subtended Volume (LASV) was already described. It is a new parameter based on three dimensional (3D) reconstructions from magnetic resonance imaging (MRI) of pelvis. This parameter is associated to laxity of levator ani muscles, and showed good correlation with Pelvic Organ Prolapse (POP) individual measurements and ordinal POP stages. However, the 3D reconstructions is a time consuming process that limitates the use of this parameter in clincial pratice. Our hypotesis, based on an geometrical interpretation of levator hiatus - Figure 1 - is that LASV can be estimate through a mathematical formula based on simple linear measurements. Aim: to estimate the LASV based on MRI linear measurements.

Study design, materials and methods:
This is a retrospective chart review of 35 women with POP, stages I-IV. The 3D Slicer software was used to obtain the LASV from 3D reconstructions and assumed as reference values. Several linear measuremnts were performed, as shown in Figure 1, and the best ones which fit our criteria were chosen. The criteria to chose the parameters were: (1) The predictors should present difference across POP ordinal stages based on analysis of variance; (2) The predictors should present significant and high correlation coefficients with LASV - assumed in this study as greater than or equal to 0.8; (3) The predictors should present positive and significant correlation with POP-Q measurements and POP ordinal stages. After that, the subjects were randomized in two groups, 1 and 2. The coefficients of the mathematical equation were obtained from a regression analysis using LASV from Group 1 as dependent variable and the predictors previously chosen. Two observers, blinded to POP ordinal stages, performed new linear measurements of pelvic MRI of subjects from Group 2. Using the mathematical equation, the estimated LASVs were reached. The estimated LASV from observer 1 and 2 were called respectively, eLASV-1 and eLASV-2. The LASV, eLASV-1 and eLASV-2 were compared between then and correlated with each other, and with POP-Q measurements and POP ordinal stages. Also, a residual analysis was performed to validate the mathematical equation. Finally, the reliability analysis was performed.

Results:
The predictors chosen were M-line, H-line and width of levator hiatus (WLH_1), Figure 1. The coefficients of the equation were determined to compound the equation to estimate LASV:

$$eLASV = -72.838 + 0.598.H\text{-}line + 1.217.M\text{-}line + 1.136.WLH_1$$

The eLASV-1 showed no difference with the LASV, but showed difference with eLASV-2. The LASV, eLASV-1 and eLASV-2 showed similar and good correlation with POP individual measurements and ordinal stages, Table 1. The residual analysis showed normal distribution of the estimate values and the errors, from both observers, when compared with reference values. The intra and interclass evaluation of the estimated values indicated a good the reliability of the eLASVs, the Cronbach's Alpha of H-line, WLH_1, M-line, and eLASV were respectively .90, .92, .93 and .96; the mean of inter-item correlation for the same parameters were respectively .82, .86, .86 and .92.

Interpretation of results:
We demonstrated a method that can be easily replicated and improved, allowing volume estimates based on linear measurements from MRI. We believe that our innovation was also the interpretation of the MRI linear measurements as components of a volumetric parameter to evaluate the pelvic floor, as shown in Figure 1. Despite this geometrical interpretation of the levator hiatus we tried not to assume only the mathematical findings to choose the predictors of the mathematical equation. We also used comparisons and correlations tests between predictors and clinical parameters to support the results obtained from the linear regression analysis. We assumed that the predictors should not only represent the dimensions of the 3D volume, but also should be reliable, easily obtained and be clinically correlated with POP. From the multiple linear measurements tested, the M-line, H-line and width of the levator hiatus at infrapubic level fitted our criteria. As demonstrated, we successfully determined an equation based on three linear parameters that were obtained from only two MRI views, one axial and one sagittal. The eLASV showed good correlation with the LSAV, obtained from the 3D reconstructions, and with POP-Q measurements and POP ordinal stages.

Concluding message:
The LASV can be estimated using 2D MRI measurements. It can represent an easy strategy for clinical application of this parameter against the time consuming manual or semi-automatic segmentation processes. The discrepancies between eLASV-1 and eLASV-2 were credited to the variability of the observers' measurements, but not to the mathematical equation. The clinical relevance of this parameter should be proved in further studies.

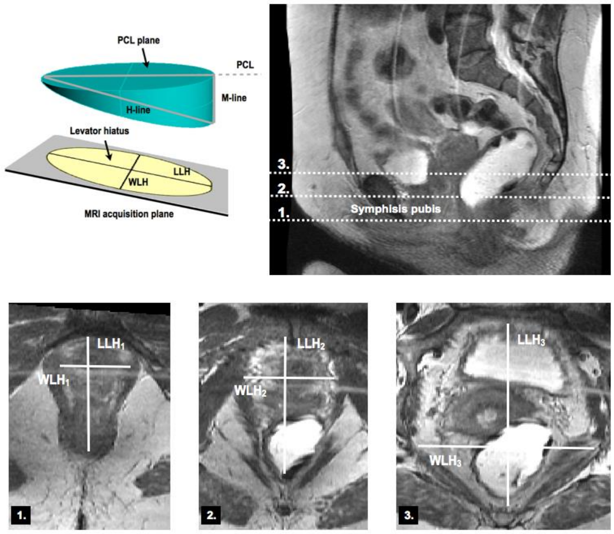

Figure 1. A schematic view of the axial planes chosen to obtained the width the levator hiatus (WLH) and the length of the levator hiatus (LLH). The subscripted numbers represent the planes described as follows: (1) immediately inferior to the symphisis pubis, (2) midpubic plane and (3) immediately above symphisis pubis. The geometrical representations of levator hiatus was included to illustrate that the Magnetic Resonance Image acquisition planes were not coincident with levator hiatus geometry.

Table 1

	Pearson's correlation coefficients					Spearman's correlation ranks
		POPQ measurements				
VARIABLES	$LASV_2$	Ba	Bp	C	TVL	POP ordinal stages
$LASV_2$	1.00	0.59*	0.53^{NS}	0.42^{NS}	0.12^{NS}	0.58*
eLASV-1	0.90 **	0.69**	0.60*	0.45^{NS}	0.36^{NS}	0.55*
eLASV-2	0.94 **	0.74**	0.66*	0.56*	0.27^{NS}	0.55*

NS - not significant; * statistically significant at the 0.05 level; ** statistically significant at the 0.01 level

Table 1. Pearson's correlation coefficients and Spearman's correlation ranks between: observed levator ani subtended volumes (LASV); estimated LASV based on measurements form observers 1 and 2, respectively eLASV-1 and eLASV-2. The POP-Q individual measurements were identified as follows: Ba - the most descended edge on the anterior vaginal wall; Bp - the most descended edge of posterior vaginal wall; C - the most distal edge of the cervix or the leading edge of the vaginal vault after total hysterectomy; TVL - the total vaginal length.

References
1. Rodrigues AA Jr, Bassaly R, McCullough M, et al. Levator ani subtended volume: a novel parameter to evaluate levator ani muscle laxity in pelvic organ prolapse. Am J Obstet Gynecol 2012 Mar; 206(3): 244.e1-9. Epub 2011 Oct 12.

Disclosures
Funding: São Paulo Research Foundation (FAPESP), Brazil for the post-doctoral fellowship financial support to Antonio Antunes Rodrigues Jr. **Clinical Trial:** No **Subjects:** HUMAN **Ethics Committee:** University of South Florida Division of Research Integrity and Compliance Institucional Review Boars, FWA n.00001669 12901 Bruce B. Downs Blvd. MDC035 Tampa, FL 336124799 813 9745638 FAX 813 9745618 **Helsinki:** Yes **Informed Consent:** No