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Dynamic 3T Pelvic Floor Magnetic Resonance Imaging in Women Progressing from the Nulligravida to Primiparous State

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Abstract

Introduction and Hypothesis—To prospectively characterize dynamic pelvic 3Tesla magnetic resonance imaging (dp3T MRI) findings in nulligravida women and characterize changes 6 months after delivery in the same woman.

Methods—In this prospective study, nulligravida women seeking assisted reproductive technology for pregnancy were recruited. After physical examination by Pelvic Organ Prolapse Quantification (POP-Q), Brinks assessment and measures including the Pelvic Floor Distress Inventory-20 and Pelvic Floor Impact Questionnaire-7, pre-pregnancy dp3T MRI at rest, with strain, and evacuation were performed. Assessments were repeated 6 months postpartum. Analysis included Welch and paired t-tests for continuous variables, Fisher's Exact Test for differences in categorical outcomes, and paired t-tests for postpartum symptoms.

Results—Nineteen subjects (mean±SD age, 31±5 years) completed baseline clinical and dp3T MRI studies, 15 delivered and 10 (30.5±3 years) completed pre-pregnancy and post-delivery clinical and dp3T MRI assessments. There were no significant changes in scores of validated questionnaires (all $p>0.05$) or on POP-Q measures post-delivery. Two (20%) subjects without pre-

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pregnancy levator tears had tears on MRI post-delivery. MRI measures of pelvic organ descent were increased post-delivery. Seventeen pelvic soft tissue parameters increased by greater than 10% post-delivery including 5/70 (7.1%), 17/110 (15.5%), and 50/110 (45.5%) values exceeding thresholds at rest, strain, and evacuation, respectively.

Conclusions—Dynamic pelvic 3T Magnetic Resonance Imaging detected levator tears and increased pelvic organ descent, which can be directly attributed to pregnancy and delivery.

Keywords

dynamic pelvic 3T Magnetic Resonance Imaging; levator tear; nulligravida women; pelvic floor mobility; primiparous women

Introduction

Urinary incontinence (UI), pelvic organ prolapse (POP), and anal/fecal incontinence (AI/FI) symptoms commonly occur after pregnancy and delivery. [1–7] In a review of epidemiological evidence regarding the role of elective cesarean delivery, more than 50% of urinary and fecal incontinence symptoms in parous women could be attributed to parity. [1] There is a gap in the literature regarding pelvic floor changes that occur during pregnancy and delivery, and this study seeks to further understanding in this area by evaluating whether levator tears occur after childbirth and whether increased pelvic organ mobility occurs.

The literature suggests that levator muscle injury is associated with pregnancy/delivery and plays a key role in the development of pelvic floor disorders. Pelvic floor magnetic resonance imaging (MRI) of 160 women performed 9 to 12 months after first term vaginal delivery revealed increased odds for levator ani defects in women with forceps assisted delivery (OR 14.7, 95% CI, 4.9–44.3), anal sphincter rupture (OR 8.1, 95% CI, 3.3–19.5), and episiotomy (OR 3.1, 95% CI, 1.4–7.2). [8] In symptomatic women, levator tears were present in 55% of those with pelvic organ prolapse versus 16% of those without. [9] Levator muscle defects near the symphysis insertion in primiparous women are also associated with urinary incontinence, reported in 28% of 80 symptomatic versus 11% of 80 asymptomatic women. [10]

This study addresses a key gap in the existing literature regarding the development of anatomic pelvic floor changes in pregnancy and childbirth as there are currently no paired analyses of nulligravid and primiparous “within patient” pelvic floor MRI studies. The purpose of this study was to prospectively characterize dp3T MRI anatomic parameters including the anal sphincter, levator, apical, anterior and posterior vaginal compartments and bony pelvis and to evaluate changes at rest, strain and evacuation in healthy nulligravida women pre-pregnancy and 6 months post-delivery. Short-term postpartum pelvic floor symptoms and pelvic organ prolapse clinical examination findings were also evaluated.

Materials and Methods

Institutional Review Board approval and written informed consent were obtained. This prospective cohort study, sponsored by the *Eunice Kennedy Shriver* National Institute of

Child Health and Development, recruited nulligravid women seeking assisted reproductive technology for a pre/post pregnancy dp3T MRI characterization of the pelvis from 2009–2014. Prior to initiating an in vitro fertilization cycle, intrauterine insemination or other treatment, potential subjects were approached for participation. Subjects were nulligravid women with no reported symptoms of UI or FI by the Pelvic Floor Distress Inventory-20 (PFDI-20) [11] and met inclusion criteria including: ability to give informed consent, age 19 years, negative pregnancy test, ability to complete questionnaires and pelvic examination, digital rectal examination, and undergo a dp3T MRI pre-pregnancy and six months after delivery. Using the PFDI-20, absence of stress urinary incontinence (SUI) and FI symptoms was defined by an answer of “No” or if there is an answer of “Yes” with a bother component of “not at all” or “somewhat” to the question: “Do you usually experience urine leakage related to coughing, sneezing or laughing?” and an answer of “No” to the question, “Do you usually lose stool beyond your control if your stool is well formed or loose”, respectively. Exclusion criteria included: documented ulcerative colitis or Crohn’s disease, anorectal surgery, physical disability such as neuromuscular disease predisposing to functional incontinence, body mass index $>35 \text{ kg/m}^2$, previously documented uterine abnormality, smoking and contraindication to MRI.

Recruitment and Clinical Data Collection

Pre-pregnancy clinical history, evaluation of incontinence symptoms using the PFDI-20, demographic data, symptom-specific quality of life using the PFIQ-7, and data from standardized pelvic organ prolapse quantification (POP-Q) examination and a Brinks pelvic muscle assessment were collected. [12,13] These measures were performed by a pelvic reconstruction surgeon or nurse practitioner, both certified in the standardized collection of these measures. The patient then underwent dp3T MRI.

The subject was followed in the Reproductive Endocrinology and Infertility clinic. If she became pregnant and delivered, a dp3T MRI was scheduled for six months after delivery. We anticipated that approximately 64% of pregnant subjects would have a vaginal delivery and 36% would have cesarean section. [14] Date and mode of delivery (vaginal/cesarean, including operative vaginal delivery) were collected by chart review. Repeat evaluation of clinical data, review of systems, quality of life questionnaires, and pelvic examination were performed six months postpartum by research personnel masked to delivery mode. Questionnaires were administered in a standardized fashion by a research nurse trained in the standardized use of these instruments. Symptom specific distress and impact questionnaires included the PFDI-20 and PFIQ-7. [11]

Image Data Collection

MRI Protocol—After MRI safety questionnaire and pregnancy test were performed, the subject was placed upon the MRI table, rolled onto her side and approximately 120 ml of ultrasound gel was placed into the rectum by catheter-tipped syringe. The subject was turned supine, and a phased-array coil was centered over the low pelvis. The subject was instructed to lie still for 15–30 minutes while static images were initially obtained during quiet breathing. Breath-hold sagittal baseline images were centered on the urethra, vagina, rectum, and coccyx. After baseline images, each subject was instructed to “bear down” for strain

images using a standard script. They were instructed to strain even if there was some leakage of gel. Subsequently, the patient was instructed to evacuate the rectal gel during a sagittal dynamic cine MRI data acquisition. Specifics of the MRI study are noted in the footnote of Table 4.

MRI Parameters Pre-pregnancy and Post-delivery—MRI parameters were *a priori* defined based upon preliminary studies and review of the existing literature and were measured and recorded by a single radiologist (MEL) with greater than 15 years pelvic floor MRI experience. Threshold values of anatomic parameters utilized to differentiate normal versus abnormal for continuous variables were based, when available, on previous data (Table 1). These included osseous parameters such as obstetrical conjugate, transverse diameter, intertuberous distance, interspinous distance, pubococcygeal line, and angle of pubic arch. They also included soft tissue parameters such as M-line, H-line, hiatus length, and levator muscle thickness. Pubococcygeal line was measured as the distance from the posterior inferior symphysis pubis to the last vertical joint of the coccyx. M-line was defined as the distance from the posterior annular rectal fibers perpendicular to pubococcygeal line. H-line was the distance from the posterior annular rectal fibers to posterior inferior symphysis. Measures of pelvic organ descent at strain also included urethral angle and posterior levator plate angle. Urethral angle was the angle between the urethral and the long axis of the patient. Posterior levator plate angle was the angle between the pubococcygeal line and the posterior wall of the rectum. Pre-pregnancy and post-delivery patient data two standard deviations beyond these means were prospectively considered “abnormal” for the analysis.

Categorical variables including cystocele, rectocele, enterocele, levator insertion tear, levator muscle tear, anal sphincter tear, and vaginal shape were abnormal if beyond previously reported criteria. A cystocele was defined as bladder neck position > 1cm below the pubococcygeal line (PCL). A rectocele was defined as an anterior bulge > 2 cm and enterocele was defined as bowel loops protruding caudally between the bladder and rectum. Uterovaginal prolapse was defined as cervical position below the PCL. Levator tears were graded 0–3 on each side then summed using previously published criteria by Delancey et al, with the reader having previously undergone training in this technique for prior research. [9] Anal sphincter abnormalities were defined as focal defects in the normal anal muscle signal intensity. Vaginal shape was classified as abnormal if not H- or butterfly shaped. The MRI reader was blinded to delivery mode.

To evaluate within-patient change in MRI parameters related to delivery, a 10% difference between pre-pregnancy and post-delivery measurements was considered a positive change for continuous variables, based upon previous work by Rizk et al. [24] Many of the soft tissue parameters were evaluated for changes that may represent increased descent of pelvic structures or mobility of the structures (such as urethral rotation) during strain or evacuation, relative to rest. For the categorical variables, abnormal within-patient change was positive if the pre-pregnancy and post-delivery responses differed, (e.g. no rectocele pre-pregnancy versus rectocele post-delivery in same subject).

Sample Size and Data Analysis

Based upon previously reported rates of abnormalities detected on MRI in nulliparous and primiparous women, [10] a 20% rate of levator muscle tear in subjects was estimated. Sample size calculation was performed using numbers as close to 0 (pre-delivery tear rate) as permitted by nQuery Advisor. Initial sample size of 27 women was calculated to have 80% power to detect a difference in proportion of 0.20 when the proportion of discordant pairs was expected to be 0.21 with a 0.05 one-sided significance level.

Continuous data on all women taken pre- and post-pregnancy were summarized using means, medians, and standard deviations. Discrete data were summarized as percentages. Continuous measurements taken before and after childbirth such as obstetrical conjugate, PCL or transverse diameter were compared using Welch and paired t-tests. Differences in categorical outcomes such as presence or absence of rectocele were assessed using Fisher's Exact Test. For analysis based upon postpartum symptoms defined by questionnaire, women were classified as either having or not having new pelvic MRI abnormalities. PFDI-20 and PFIQ-7 total and subscale scores and Brinks pelvic muscle assessments baseline and postpartum were compared using paired t-tests. POP-Q values were compared by signed rank test.

Results

Population

A total of 21 of the attempted 27 subjects were recruited and consented, and 19 (ages 24–43 years) completed pre-delivery demographic data, clinical questionnaires, physical examination, and pre-pregnancy dp3T MRI (Figure 1). Of these 19 subjects, 15 achieved pregnancy and 10 completed post-delivery physical examination, questionnaires, and MRI imaging a mean $\pm$ SD, 228 $\pm$ 98 days post-delivery.

Demographics and Clinical Characteristics: Pre-pregnancy and Post-delivery

Pre-pregnancy clinical and demographic data for the nulligravid population who underwent dp3T MRI evaluation are described in Table 2. Subjects had a mean age of 31 $\pm$ 4.7 years and a median POP-Q stage 1. Values of baseline PFDI-20 and PFIQ-7 total and subscale scores were consistent with inclusion criteria. Of the 10 women undergoing post-delivery evaluations, 4 underwent vaginal delivery and 6 cesarean section. The demographics of the subset of patients who became pregnant were similar to the entire population (data not shown). The mean age of those who became pregnant was 30.5 $\pm$ 3.2 years; the mean age of those never pregnant was 32.8 $\pm$ 8.8 years. There were no significant changes in individual POP-Q measures pre-pregnancy and post-delivery (all $p > 0.09$). There were no significant differences in symptom specific distress or impact scores (PFDI-20 and PFIQ-7) pre-pregnancy to post-delivery (Table 3).

MRI Parameters

Pre-Pregnancy—MRI characteristics of patients who became pregnant were similar to those of the entire population (Table 4). Pre-pregnancy, no subjects had a levator muscle tear, sphincter tear, or levator insertion injury, and all subjects had normal levator muscle score

(0/6) by Delancey et al criteria described in the methods. At rest, the shape of the vagina demonstrated normal H- or butterfly shape in all but one subject with symmetric, flattened appearance of the vagina.

Compared to published “normal” threshold values collected from the literature (Table 1), soft tissue values in this asymptomatic nulligravid population typically fell within these parameters during rest and strain maneuvers. M-line and H-line values, exceeded published thresholds defined as 2 SD beyond the published mean in only 7/133 (5.3%) of soft tissue measurements at rest, in 8/209 (3.8%) during strain and in 79/209 (37.8%) of subjects with evacuation (Figure 2). There were no cases of MRI-diagnosed rectocele, cystocele, enterocele, uterovaginal prolapse or abnormal urethral angle in pre-pregnancy MRIs at rest or during strain. A single subject had posterior plate angle 10.5 degrees with strain. Abnormal evacuation parameters included posterior compartment, 22/209, 10.5 % (posterior plate descent, rectocele), apical compartment 36/209, 17.2 % (M-line, H-line, cervical descent), and anterior compartment 21/209, 10.0 % (cystocele, bladder neck descent, and urethral hypermobility).

Post-delivery—For the 10 subjects with follow-up MRI, interval development of a unilateral grade 2 levator tear in one subject post vaginal delivery and a unilateral grade 3 tear in one subject who underwent elective cesarean delivery without labor were noted. The subject with the grade 3 tear had a mildly bulged right vaginal contour (Figure 3). No anal sphincter tears were identified post-delivery.

Values were beyond previously published thresholds in 4/70 (5.7%) pre-pregnancy soft tissue parameters at rest versus 5/70 (7.1%) post-delivery at rest, including H-line and M-line. During strain, soft tissue values were beyond threshold for 6/110 (5.5%) parameters pre-pregnancy versus 17/110 (15.5%) strain post-delivery, including posterior plate descent (N=5), M-line (N=5), cervical descent (N=4), urethral hypermobility (N=2), and cystocele (N=1). During evacuation, the proportion of soft tissue values beyond threshold measures on pre-pregnancy images, 42/110 (38.2%), increased to 50/110 (45.5%) post-delivery (Table 4 and Figure 4).

Increased mean dynamic movement of pelvic structures on continuous variables greater than 10% from pre-pregnancy to post-delivery strain involved all three compartments, such as increased posterior plate descent (from 2 degrees below PCL at baseline to 14 degrees below PCL post-partum), M-line enlargement (37% larger), cervical descent (222% further descent), urethral hypermobility (144% additional rotation), and bladder neck descent (137% further descent).

Despite the relative change, other than a single cystocele in the subject with grade 3 levator tear, diagnosis of POP using MRI criteria (cystocele, rectocele, enterocele, uterovaginal prolapse) did not change from pre-pregnancy to post-delivery with strain (all $p>0.05$). On pre-pregnancy and post-delivery evacuation images, prevalence of rectocele (31.6% vs 50.0%, $p=0.43$), cystocele (15.8% vs 50%, $p=0.08$), and uterovaginal prolapse (15.8% vs 40%, $p=0.02$) were noted, respectively. No enteroceles were identified on any strain or evacuation images. Osseous parameters were unchanged, 5/60 (8.3%) pre-pregnancy versus

4/60 (6.7%) post-delivery. Except for worsened posterior plate descent in the vaginal subset ($p<0.01$), there were no significant differences between the mean values for all parameters between subjects with vaginal and cesarean deliveries (all $p>0.05$).

Discussion

The results of this prospective cohort study definitively showed that levator muscle tears were noted on MRI post-delivery that were not seen prior to pregnancy. Further, there was increased descent and mobility of pelvic floor structures, with increased mobility determined using predetermined threshold values as provided in Table 1, during strain or evacuation MRI after a first pregnancy, regardless of whether the subject had a vaginal or cesarean delivery.

Several studies have previously described detection of anatomic abnormalities by magnetic resonance imaging (MRI) of the pelvic floor, but all have been limited to either nulliparous or postpartum populations without direct comparison of the same patient pre-pregnancy and post-delivery. [26–29] Therefore, the current study's detection of two new levator defects after documentation of no defect pre-pregnancy is novel, and the presence of a defect after cesarean section without labor could be considered controversial. Previous studies of nulliparous women, have visualized 8% levator defects on MRI in one series, [18] and none have been reported in another series. [10] Despite the underpowered nature of the current study for subset analysis of vaginal versus cesarean delivery, it confirms that pelvic floor abnormalities after either vaginal delivery and cesarean section, as defined by MRI measures, may develop in the absence of significant patient symptoms at 6 months postpartum. The difference in the current study relative to the previous literature is the documentation that no defects were identified pre-pregnancy in these subjects. It should be noted that in the subject with a new levator tear after elective cesarean section, there were numerous other changes of worsened multi-compartmental pelvic organ descent including a new cystocele, posterior plate descent during strain from 0 degrees pre-pregnancy to 39 degrees, M-line enlargement during strain from 21.1 mm pre-pregnancy to 34.6 mm post-delivery, and urethral hypermobility during strain from 1 degree pre-pregnancy to 61 degrees post-delivery. This subject's cervix had no descent during strain at pre-pregnancy, but there was 30 mm cervical descent post-delivery. These findings raise the possibility that tears and pelvic mobility occur at least in part due to pregnancy itself, rather than only vaginal delivery.

Only fairly recently have dynamic MRI studies included evacuation of inserted rectal gel as part of the protocol, and evacuation criteria are not as well documented in the literature. This current study confirmed that few of the straining thresholds that diagnose POP are present in asymptomatic nulligravida women. However, a greater percentage would meet MRI criteria for prolapse after first childbirth, and these changes did not differ between patients with vaginal delivery versus cesarean delivery, although numbers were small. Importantly, normal criteria have not been developed for evacuation MRI, and these current data show that published criteria frequently suggest prolapse in all three compartments in asymptomatic nulligravid or primiparous women. The high prevalence of prolapse parameters as noted in

this study should raise questions about the application of published strain thresholds in evacuatory MRI imaging.

Although MRI may improve detection of anterior and posterior defects beyond clinical examination, increased detection may not be of clinical significance if the findings are not symptomatic. This study found many examples of asymptomatic posterior compartment abnormalities such as rectocele and posterior plate laxity during evacuation imaging, suggesting that current parameters in the literature for strain imaging may not accurately translate to evacuation phase MRI. There were no specific MRI parameters that correlated with POPQ and physical examination due to the lack of abnormal clinical findings.

There are several limitations of this study. The post-delivery population proved difficult to re-image, highlighting challenges in MRI re-imaging with the use of rectal gel, reducing the study power; however, 20% of subjects did have levator tears as was estimated *a priori*. Despite the prospective design, there may be biases in the population since they were recruited from a tertiary care reproductive endocrinology and infertility clinic. The paucity of post-delivery pelvic floor symptoms limits the characterization of symptomatic versus asymptomatic patients. Due to the small number of subjects, inter-reader variability was not assessed in this trial, but has been reported previously using similar parameters in a large number of postpartum women. [30] Lastly, the overall study population included both c-section and vaginal delivery subjects, which represent a heterogeneous population. Strengths include intra-patient comparison, utilizing a masked MRI evaluator, use of a standardized evacuation protocol, validated outcomes measures, and certified pelvic floor examiners.

In conclusion, pregnancy and delivery resulted in increased pelvic mobility in both vaginal delivery and elective cesarean delivery patients. Dynamic pelvic 3T MRI detected new levator defects that were not present prior to pregnancy. Furthermore, current pelvic soft tissue parameters during strain are frequently exceeded even in asymptomatic nulligravid women when applied to dynamic evacuation imaging. Longer-term follow-up is needed to determine whether these findings are predictive of the development of clinically relevant pelvic floor signs and symptoms.

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Summary Statement

Pregnancy and delivery resulted in increased pelvic mobility and new levator muscle defects in vaginal and elective cesarean delivery patients on dynamic pelvic 3T MRI.

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Figure 1.
Patient Flowchart
Dp3T MRI=dynamic pelvis 3 Tesla Magnetic Resonance Imaging

Figure 2.

Sagittal dynamic T2-weighted MRI during evacuation phase (c) relative to baseline (a) and strain (b) imaging in a 30-year-old nulliparous female with worsened pelvic floor prolapse on despite absence of clinical symptoms or signs of pelvic floor dysfunction. A rectocele (arrow) and cystocele with urethral hypermobility (open arrow) are only present on evacuation series. S, symphysis pubis. UB, urinary bladder. Straight line, pubococcygeal line. R, rectum.

Figure 3.

Axial T2-weighted MRI in a 36-year-old female after childbirth shows new onset tear of right levator muscle with flattened appearance of the vagina developed after delivery. Although the subject had increased pelvic organ descent after delivery, she remained asymptomatic. There is discontinuity of the right levator with bulging of the hiatal fat (arrows). Levator muscles are noted with open arrows. Asterisk, urethra. R, rectum.

Figure 4.

Sagittal dynamic T2-weighted MRI in a 27-year-old female with worsened pelvic organ prolapse after delivery. There is increased pelvic organ descent from baseline evacuator (a) to postpartum evacuator (b) sagittal MRI. Rectocele (arrow) is present on both studies but larger after delivery. A new anterior compartment cystocele (open arrow) is seen only after delivery. Patient was asymptomatic at the time of baseline and postpartum evaluations. S, symphysis pubis. UB, urinary bladder. Straight line, pubococcygeal line. R, rectum.

Table 1

Normal Anatomic MRI Parameter Measures

Anatomic Characteristic	Measure Mean±SD	Reference
At Rest		
Obstetrical conjugate, mm	124±9	15
Pubococcygeal line (PCL), mm	115±13	15
Transverse diameter, mm	129±7	15
Intertuberous distance, mm	124±11	15
Interspinous distance, mm	110±7	15
Angle of pubic arch, degrees	>90	16
Axial levator hiatus length, mm	41.0±6.8	17
Levator muscle thickness, mm	5.5±0.65	18
M-line (annular rectal fibers to PCL), mm	19±12	19
H-line (annular rectal fibers to posterior inferior symphysis), mm	47.9±5.4	20
Strain		
Posterior levator plate angle below PCL, degrees	<10	21
Urethral angle, degrees	<30	19
Bladder distance below PCL, mm	<10	22
Bladder neck descent relative to at rest, mm	<32	23
Cervical descent relative to at rest, mm	7.0±0.6	24
Cervix position below PCL, mm	<0	25
M-line during Valsalva, mm	<20	20
H-line during Valsalva, mm	56.9±13.5	20

Table 2

Subject Demographics and Baseline Questionnaire Results

Variable (N=19)	Mean±SD or median (range)
Age, years	31.00±4.7
Weight, pounds	149.26±25.4
BMI, kg/m ²	24.60±4.1
POP-Q Stage	1 (0–1)
Brinks Score	9.75±1.65
PFDI-20, total	14.48±22.5
PFIQ-7, total	0.53±1.6
POPDI	3.16±5.8
CRADI	4.44±8.4
UDI	6.89±12.5

BMI, Body Mass Index

POP-Q, Pelvic Organ Prolapse Quantification System

PFDI-20, Pelvic Floor Distress Inventory, range total score, 0–300

PFIQ-7, Pelvic Floor Impact Questionnaire-7, range total score, 0–300

POPDI, Pelvic Organ Prolapse Distress Inventory, subscale score range, 0–100

CRADI, Colorectal Anal Distress Inventory, subscale score range, 0–100

UDI, Urogenital Distress Inventory, subscale score range, 0–100

Brinks Score, range, 3–12

Table 3

Symptom-specific Questionnaire Scores Baseline and 6 Months Post-Delivery

	Baseline Total (N=19)	Post Total (N=10)	Percent Change	Post C-Section (N=6)	Post Vaginal (N=4)	Overall Change p- value*	Difference in Change p- value [†]
PFDI-20 (Total) Mean, (SD)	14.48 (22.51)	13.10 (22.72)	-9.53	20.44 (27.51)	2.08 (4.17)	0.35	0.37
PFQ-7 (Total) Mean, (SD)	0.53 (1.61)	0.40 (1.26)	-24.53	0.67 (1.63)	0 (0)	NC	NC
POPDI, mean, (SD)	3.16 (5.80)	2.50 (4.03)	-20.89	4.17 (4.56)	0 (0)	0.22	0.24
CRADI, mean, (SD)	4.44 (8.42)	3.93 (6.99)	-11.49	6.55 (8.22)	0 (0)	0.76	0.78
UDI, mean, (SD)	6.89 (12.53)	6.67 (15.61)	-3.19	9.72 (20.01)	2.08 (4.17)	0.34	0.36

NC=Not Calculable.

* p-value reflects comparison of baseline to all post-delivery;

[†] p-value reflects comparison of change from baseline for C-section versus vaginal delivery

PFDI-20, Pelvic Floor Distress Inventory, range total score, 0–300

PFQ-7, Pelvic Floor Impact Questionnaire-7, range total score, 0–300

POPDI, Pelvic Organ Prolapse Distress Inventory, subscale score range, 0–100

CRADI, Colorectal Anal Distress Inventory, subscale score range, 0–100

UDI, Urogenital Distress Inventory, subscale score range, 0–100

Table 4

MRI Vaginal Compartment, Levator and Osseous Measures Pre-pregnancy and 6-Month Post Delivery

Variable Mean (SD)	Baseline Total (N=19)	Post Total (N=10)	% Change	Overall Change p-value
Anterior Compartment				
Distance from Bladder neck to PCL at Rest, mm	21.45 (3.98)	21.20 (3.38)	-1.17	0.24
Distance from Bladder neck to PCL at Strain, mm	17.15 (4.72)	10.99 (13.48)	-35.92	0.11
Distance from Bladder neck to PCL at Evacuation, mm [#]	-2.18 (8.70)	-3.77 (15.79)	72.94	0.76
Bladder neck descent (strain - rest), mm	4.30 (4.05)	10.21 (11.91)	137.44	0.15
Bladder neck descent (evacuation - rest), mm	23.63 (7.91)	24.97 (14.16)	5.67	0.95
Urethral angle change (strain - rest), degrees	7.29 (13.92)	17.80 (19.56)	144.17	0.22
Urethral angle change (evacuation - rest), degrees	41.38 (25.61)	47.84 (31.58)	15.61	0.36
Apical Compartment				
H-Line at Rest, mm	52.35 (9.72)	52.64 (5.54)	0.55	0.69
H-Line at Strain, mm	49.77 (8.98)	52.50 (5.33)	5.49	0.42
H-Line at Evacuation, mm	59.54 (9.95)	60.07 (8.85)	0.89	0.20
M-Line at Rest, mm	15.21 (3.67)	17.82 (5.14)	17.16	0.42
M-Line at Strain, mm	16.06 (5.21)	21.95 (8.21)	36.67	0.22
M-Line at Evacuation, mm	28.09 (9.13)	28.36 (8.56)	0.96	0.75
Cervix distance to PCL at Rest, mm	52.52 (10.50)	54.75 (10.08)	4.25	0.41
Cervix distance to PCL at Strain, mm	48.96 (10.27)	43.31 (17.93)	-11.54	0.33
Cervix distance to PCL at Evacuation, mm	21.54 (19.45)	19.58 (29.90)	-9.10	0.77
Cervix descent (strain-rest), mm	3.55 (5.29)	11.44 (13.93)	222.25	0.13
Cervix descent (evacuation - rest), mm	30.97 (14.59)	36.51 (28.18)	17.89	0.42
Posterior Compartment				
Angle of Levator Plate with PCL at Rest, degrees	0 (0)	1.60 (5.06)	NC	0.34
Angle of Levator Plate with PCL at Strain, degrees	1.67 (2.98)	14.10 (15.97)	744.31	0.04
Angle of Levator Plate with PCL at Evacuation, degrees	21.38 (9.78)	25.30 (12.52)	18.33	0.38
Levator muscles				
Right Levator Muscle Thickness, mm	5.93 (1.83)	5.75 (1.28)	3.13	0.17
Left Levator Muscle Thickness, mm	5.56 (1.24)	5.24 (1.70)	6.11	0.26
Right Levator Tear Score	0	0.30 (0.95)		0.35
Left Levator Tear Score	0	0.20 (0.63)		0.35
Osseous structures				
Obstetric Conjugate, mm	123.85 (11.2)	121.09 (7.13)	-2.23	0.06
Pubococcygeal Line (PCL), mm	106.53 (7.92)	105.02 (7.49)	-1.42	0.45
Transverse Diameter, mm	119.60 (5.26)	117.40 (5.53)	1.87	0.47
Interspinous Distance, mm	104.84 (6.01)	102.23 (5.12)	2.55	0.73
Intertuberous Distance, mm	117.22 (6.79)	116.50 (7.70)	0.62	0.80

Variable Mean (SD)	Baseline Total (N=19)	Post Total (N=10)	% Change	Overall Change p-value
Pubic Angle, degrees	83.22 (5.90)	82.10 (5.11)	1.36	<.0001

The MRI exam included multiplanar localizer, axial T2 Fast Spin Echo (FSE) at rest (3mm/0mm gap; Field of View 25cm), coronal T2 FSE during strain (3mm/0mm) (Field of View 25cm), sagittal T2 FSE images (10mm/0mm), and angled transverse high resolution anal T2 FSE (1.5mm/0mm) (Field of View 15cm). Single ultrafast sagittal T2 Half-Fourier Acquisition Single-Short Turbo Spin Echo (10mm) image centered on the anal canal were obtained at rest and during maximum strain. Osseous and soft tissue data were measured from images at rest. Change in pelvic floor data were calculated by review of dynamic sagittal images during strain and evacuation. During rectal evacuation, dynamic sagittal cine T2 Half-Fourier Acquisition Single-Short Turbo Spin Echo (10mm thick) images centered on the anal canal were used to measure dynamic soft tissue parameters for comparison with strain technique. The image with maximum displacement during the evacuation was selected for measurements. PCL=Pubococcygeal line;

- Negative values are below the PCL