Structural and Compositional Properties of Non-human Primate Uterus and Cervix Throughout Gestation

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Introduction: In 2021, 3,664,292 women in the US gave birth, however, 10.49% of these births were pre-term [1]. Pregnancy is a protected environment and changes in maternal anatomy at mid-gestational timepoints are poorly understood. To overcome this knowledge gap, a non-human primate (NHP) model was used to assess the shape and structure of the uterus and cervix through gestation.

Methods: Uterine tissue samples were dissected from Rhesus Macaque at the following gestational timepoints: nonpregnant (NP, n=3), early 2nd trimester (E2, n=3), early 3rd (E3, n=3), and late 3rd (L3, n=7). First, hydration levels of all uterine layers throughout gestation were found for samples from each layer by lyophilization. A 2-way ANOVA analysis was performed using the Prism GraphPad software. Next, a previously constructed parametric model of the human uterus was used to implement volumetric measurements of the NHP uteri across all gestational timepoints using Solidworks. A simple linear regression analysis was performed against gestational age. Uterine wall measurements were performed on dissecting microscope images of uterine tissue cross-sections and scaled using Matlab. These measurements were then compared to data previously taken from ultrasound images with a 2-sample t-test. Finally, a high-fidelity 3D model of the NHP cervix was built with detailed measurements from ultrasound images. These were used in Solidworks to loft the external cervical shape and a lofted cut to create the serpentine-shaped cervical canal. The model was then meshed using HyperWorks for future studies.

Results: The results of the hydration experiment demonstrated a significant decrease in hydration across the width of the uterine wall, from the endometrium-decidua to the perimetrium. On a tissue layer basis, no changes to hydration were observed (Fig. 1A). The uterine cavity volumes demonstrated a positive linear correlation with respect to gestational age (Fig. 1B). Uterine wall analysis showed a significant difference between the two measurement types. No difference in wall thickness was found with respect to pregnancy status (Fig. 1C). The first-ever high-fidelity 3D NHP cervix model was built, capturing the unique serpentine structure of the cervical canal. Future work will implement this model for analysis of ultrasound wave propagation and cervical stresses throughout pregnancy (Fig. 1D).

Conclusions: The results of this study demonstrate that, although the uterus exhibits dramatic structural changes throughout gestation, uterine wall thickness and hydration do not seem to be impacted by pregnancy. Further, modeling the distinctive and interesting shape of the NHP cervix allows for the enables many computational simulations to assess biomechanical changes to the cervix in pregnancy.

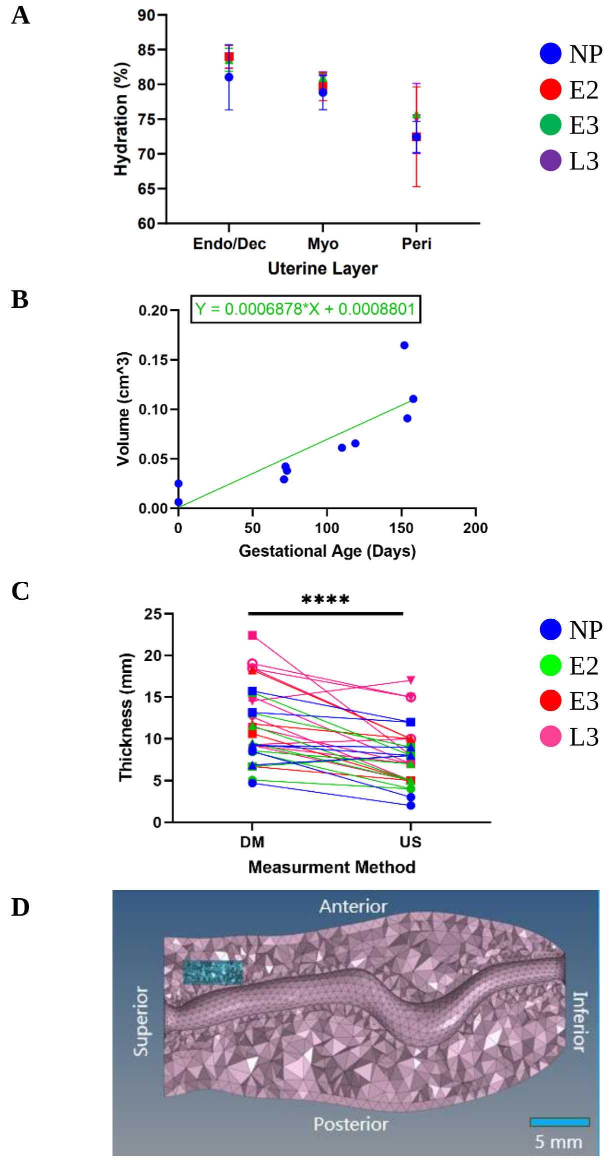

***Fig 1**. (A) Hydration levels for each uterine layer throughout gestation. (B) Supine uterine volumes throughout gestation. (C) Uterine wall thicknesses for dissecting microscope (DM) and ultrasound (US). Fig (D) Meshed model of NHP cervix.*

References:

[1] M.J.K. Osterman et al. NVSS. 2023; 72(1).

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