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

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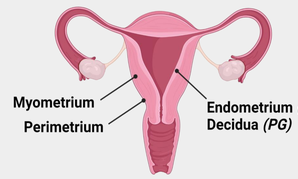
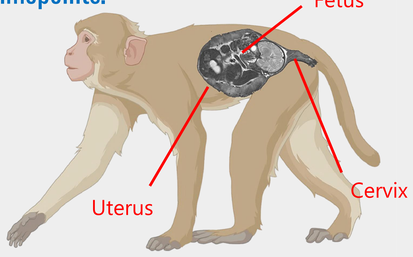
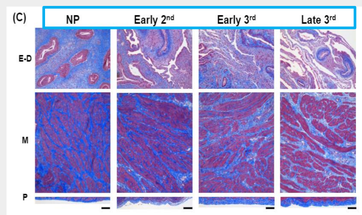
Introduction

- According to the CDC, there were 3,664,292 births registered in the US in 2021, and 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
- Humans and Rhesus Macaques have very comparable reproductive anatomies [2]
- **Purpose: Assess the shape, structure, and composition of the NHP uterus and cervix through four gestational timepoints.**







Methods

Gestational timepoints: nonpregnant (NP, n=3), early 2nd trimester (E2, n=3), early 3rd (E3, n=3), and late 3rd (L3, n=7).

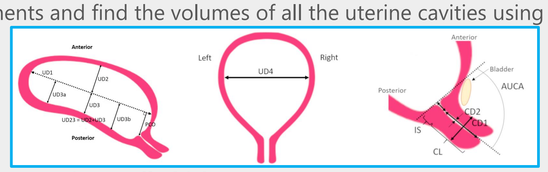
1. Composition - Hydration

Hydration levels were found by dehydrated samples for each monkey by lyophilization (freeze-dry) and was calculated using the following equation:

$$Hydration\ (\%) = \frac{Wet\ weight - Dry\ weight}{Wet\ weight}$$

2. Size - Uterine Volume

A parametric model of the human uterus was used to implement macaque measurements and find the volumes of all the uterine cavities using Solidworks.



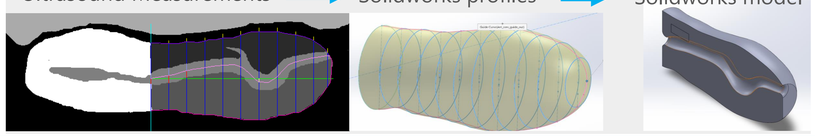
[3]

3. Size - Uterine Wall Thickness

Uterine wall measurements were taken from imaging with a dissecting microscope and a spatial calibration Matlab code and compared to measurements from ultrasound images.

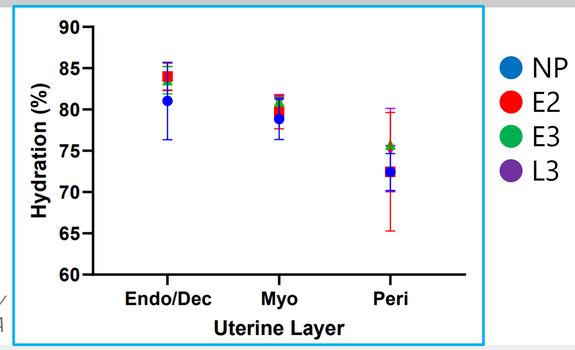
4. Shape - Cervix Model

Ultrasound Measurements → Solidworks profiles → Solidworks model



Results

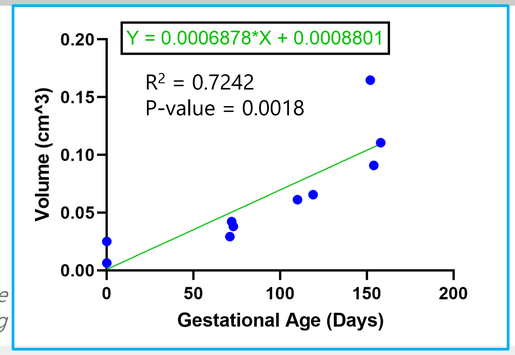
Figure 1: Hydration for each uterine layer throughout gestation



2-way ANOVA

- Significant decrease in hydration from endometrium-decidua to perimetrium
- On a tissue layer basis, no change in hydration occurs as a result of pregnancy at all gestational timepoints

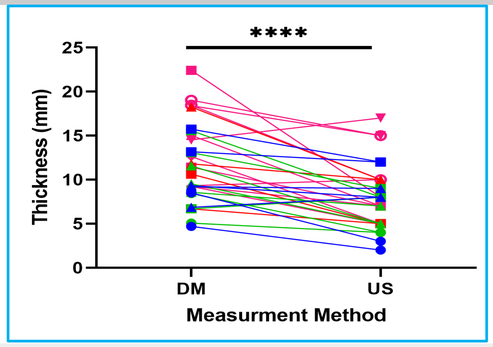
Figure 2: Supine uterine volumes throughout gestation



Simple linear reg

- Uterine cavity volumes in the supine position demonstrated a positive linear correlation with respect to gestational age

Figure 3: Uterine wall thicknesses measured from dissecting microscope (DM) and ultrasound (US) images

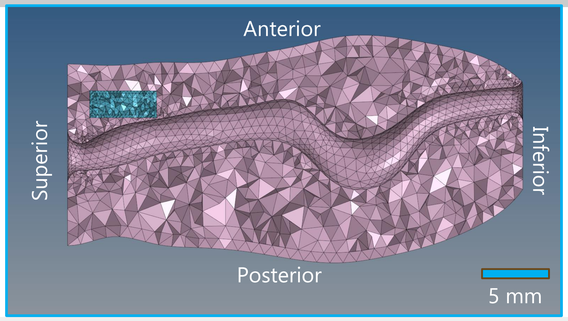


**** = p<0.0001

2-sample t-test

- Uterine wall thicknesses vary depending on the method of measurement
- Wall thickness does not change in pregnancy

Figure 4: Meshed model of NP monkey cervix



- First ever high-fidelity 3D NHP cervix model
- Uses include computational modeling of ultrasound wave propagation and cervical stresses throughout pregnancy

Conclusion

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.

Acknowledgments

I would like to thank PhD candidate Daniella Fodera as well as everyone at the Myers Soft Tissue Lab for this summer. I would also like to thank Amazon Science and the National Institute of Health Grant R01 HD072077 for funding. Finally, I'd like to thank Tim Hall, PhD, Helen Feltovich, MD, Ivan Rosado Mendez, PhD, and Lindsey Carlson from the Wisconsin Medical Center for their assistance in tissue collection and ultrasound measurements.

References

[1] M.J.K. Osterman et al. NVSS. 2023; 72 (1).
[2] C. Casteleyn & J. Bakker. IntechOpen. 2021.
[3] E.M. Louwagie et al. PLoS ONE. 2021; 16(1).