Cervical Loading in Patients at Low-Risk for Preterm Birth for Tied and Sliding Fetal Membranes

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INTRODUCTION

- **Preterm birth (PTB)** globally affects 1 in 10 births [1]
  - PTB is delivery before 37 weeks gestation
- Current gold standard of PTB prediction is ultrasonic measurement of cervical length [2]
  - Cervical lengths of less than 25mm are considered at high-risk for PTB but has **only moderate ability to predict PTB** [3]
  - Cervical funneling (protrusion of fetal membrane into cervical canal) also thought to increase PTB [4]
- *In-silico* methods must be used to study biomechanics of human pregnancy
- **Normal loading** of reproductive soft tissues must be characterized
- **Loading patterns associated with PTB** must be identified
  - **Fetal fibronectin (fFN)** acts as adhesion between uterus and membrane and loss of fFN is linked to PTB

Hence, we are investigating cervical loading in low-risk patients for PTB to characterize normal cervical loading.

REFERENCES

1. https://www.who.int/news-room/fact-sheets/detail/ preterm-birth (updated: Feb 2018, accessed: April 2022)
2. "Prediction and Prevention of Spontaneous Preterm Birth: ACOG Practice Bulletin, Number 234", *Obstet Gynecol*, 138(2):e65-e90, 2021.
3. Berghella, *Contemporary Ob/Gyn*, 49:26-34, 2004.
4. Stolz et al., *Cureus*, 9(9):e1649, 2017.
5. Louwagie et al., *PLOS ONE*, 16(1): e0242118, 2021.
6. Maas, S, et al., *J Biomech Eng*, 134(1):011005, 2012.
7. Carlson et al., *Interface Focus*, 9(5):20190030, 2019.
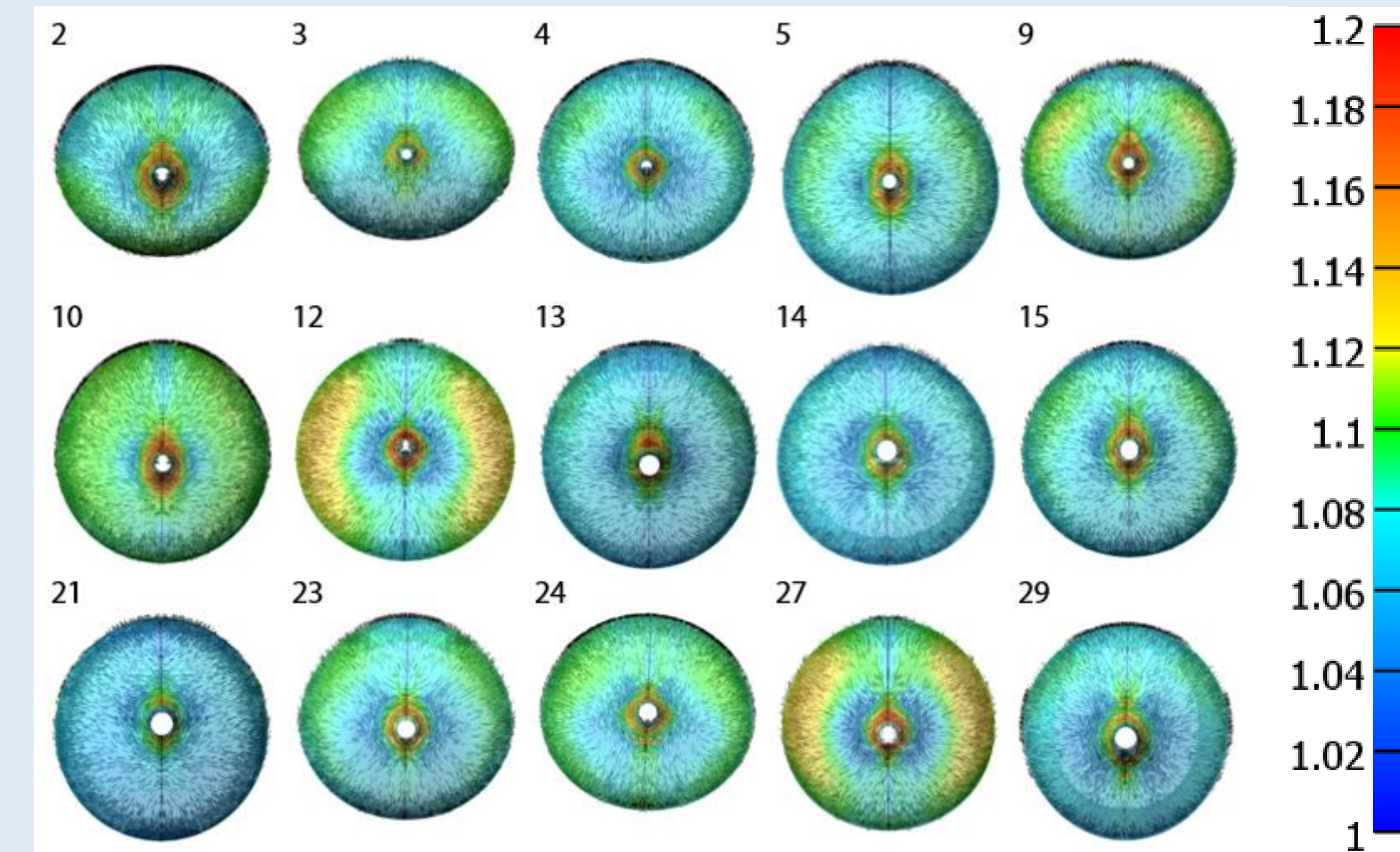8. Badir et al., *Prenatal Diagnosis*, 33(8):737-741, 2013.
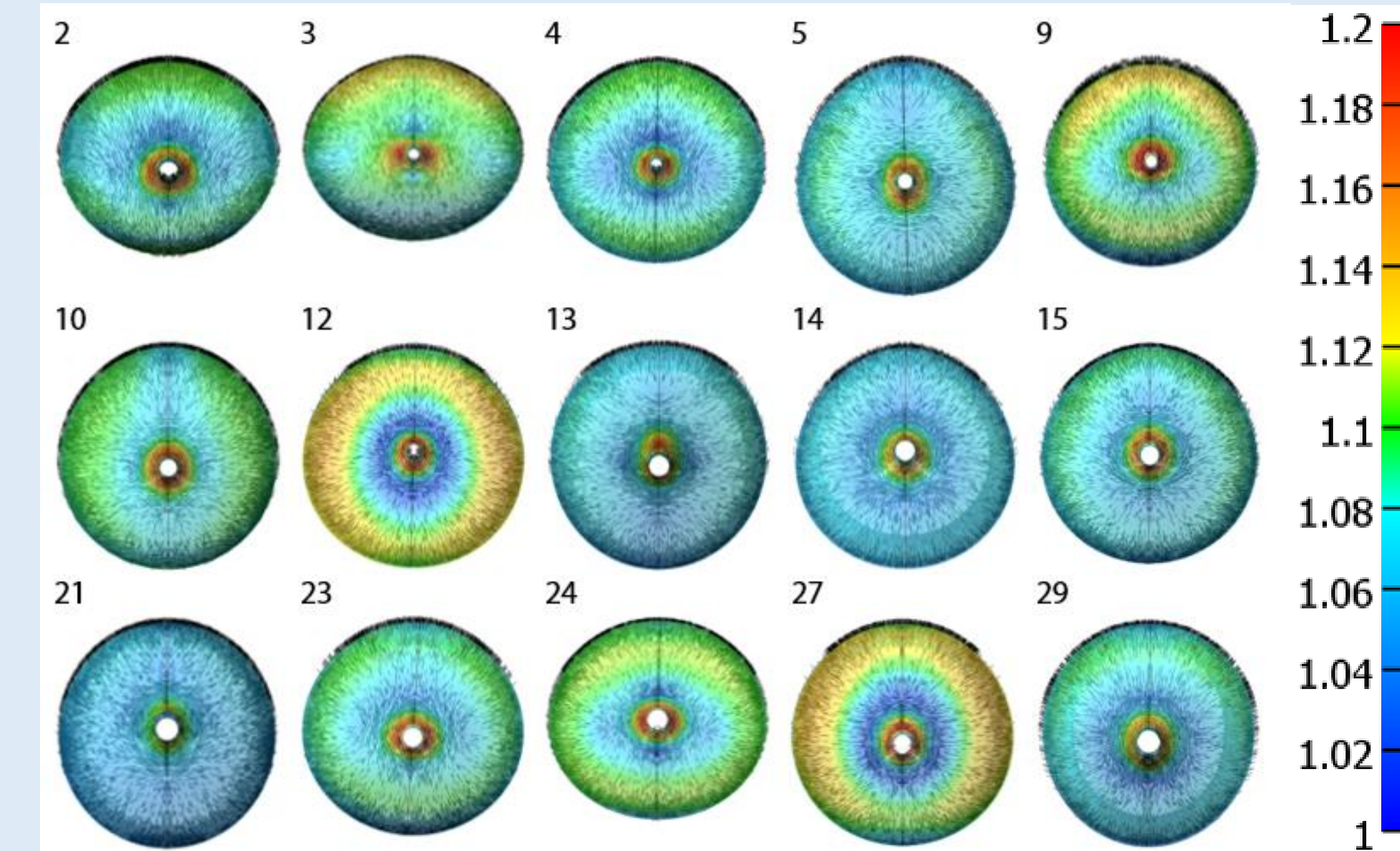
RESULTS & DISCUSSION

Sliding models experience higher levels of stretch
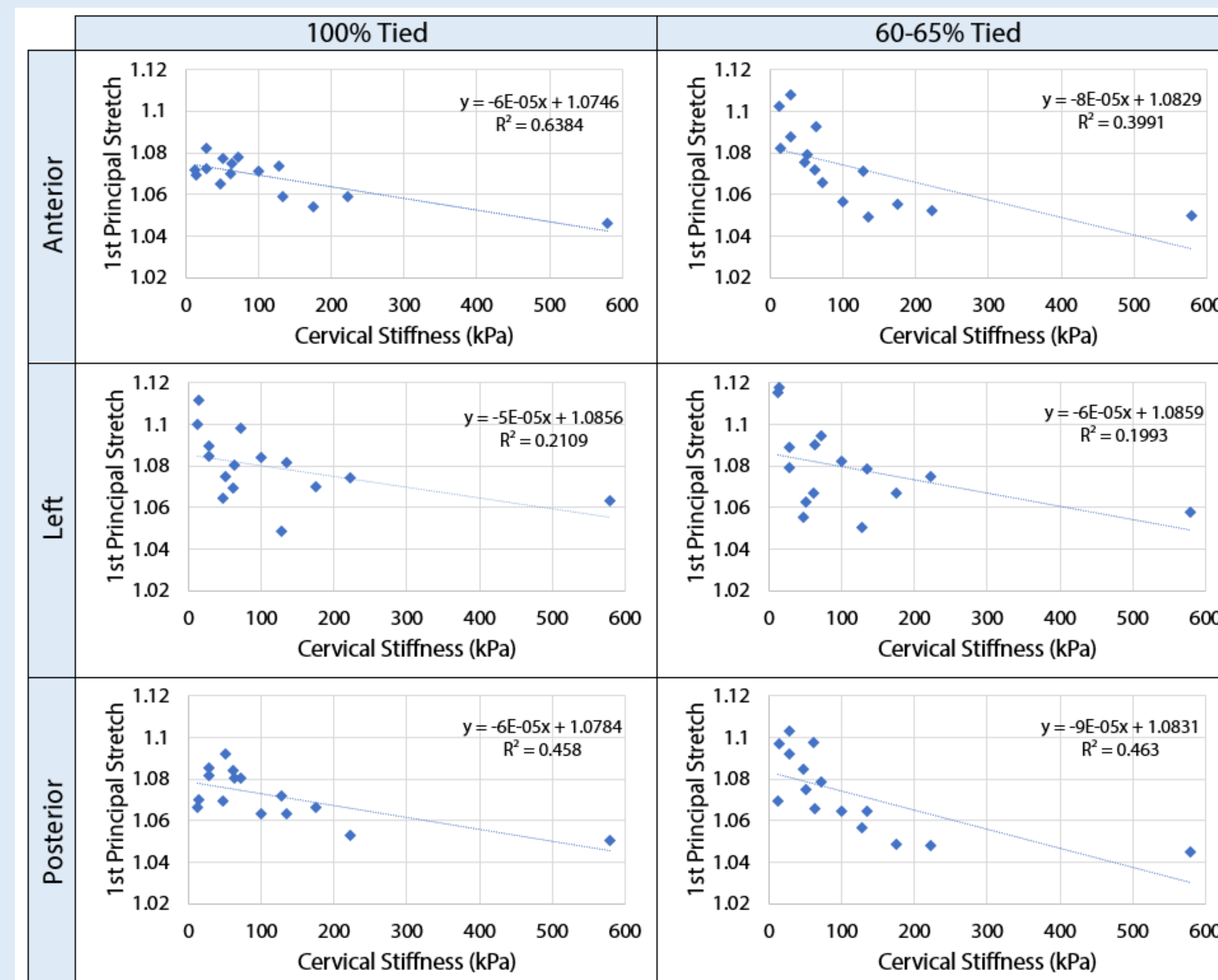### Not universal (5, 10, 13, 14, 21)

1st Principal Stretch Tied Models

1st Principal Stretch Sliding Models

As cervical stiffness increases, 1st principal stretch decreases
There appears to be no relationship between the ultrasonic parameters and principal stretch values.


METHODS

Patient Data and Cervical Stiffness Analysis

Patient Data
- Sonographer 1 visit 2 data set for:
  - Ultrasonic dimensions [5]
  - Cervical shear wave speed [7]

Cervical Stiffness Analysis
- Month 4 data [8]
- Assume linearity between shear wave speed and cervical stiffness

Used existing data sets of maternal ultrasonic dimensions and cervical stiffness
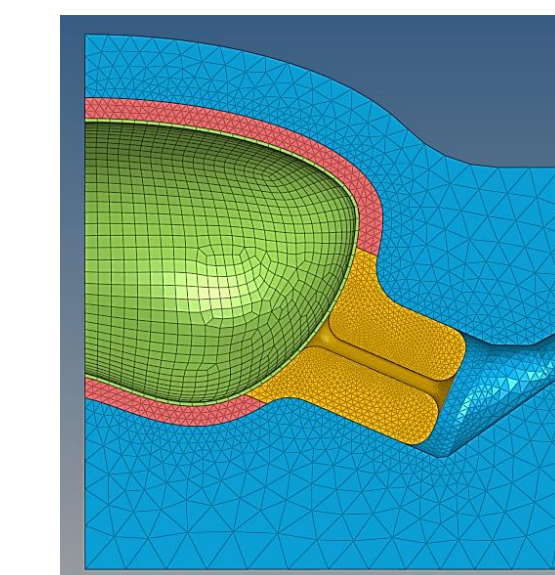

$y = 102.56x - 128.94$
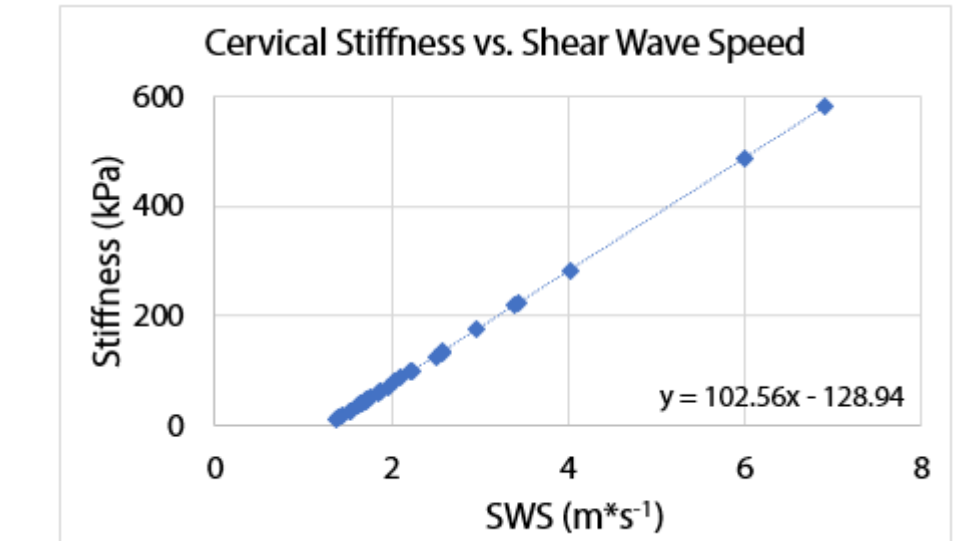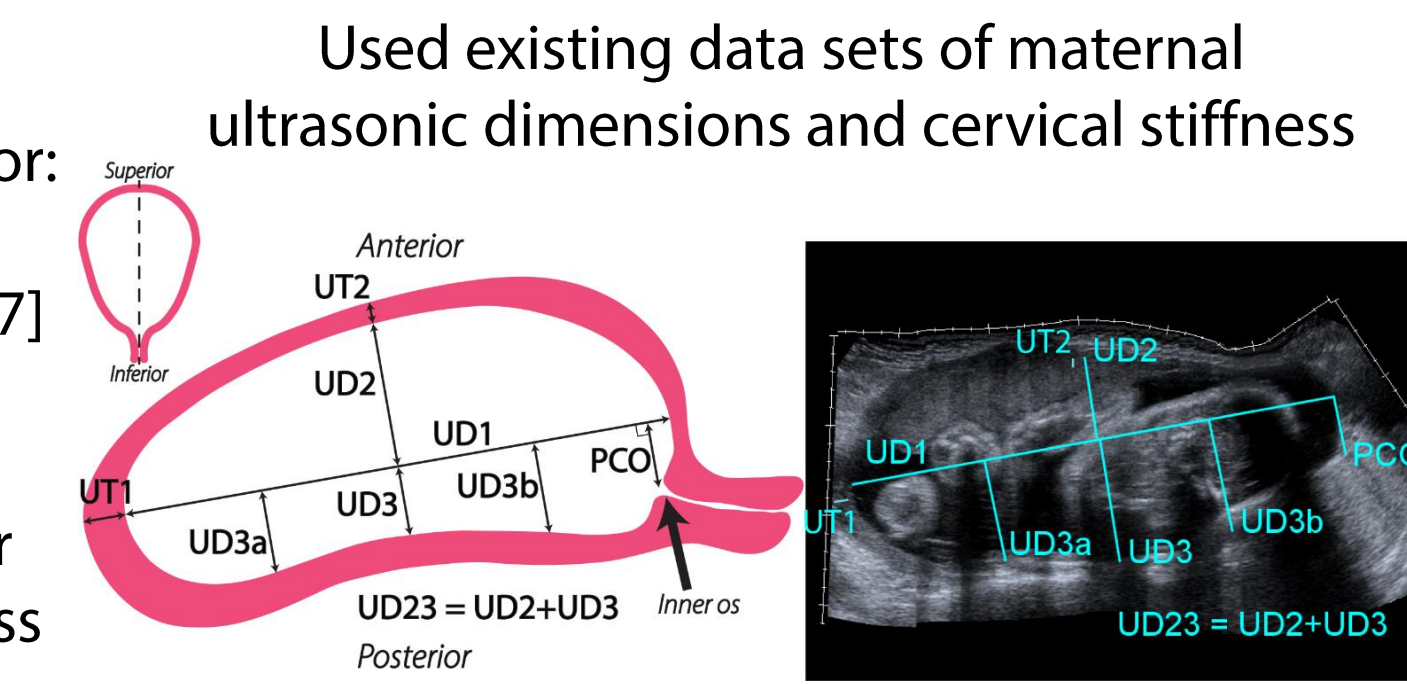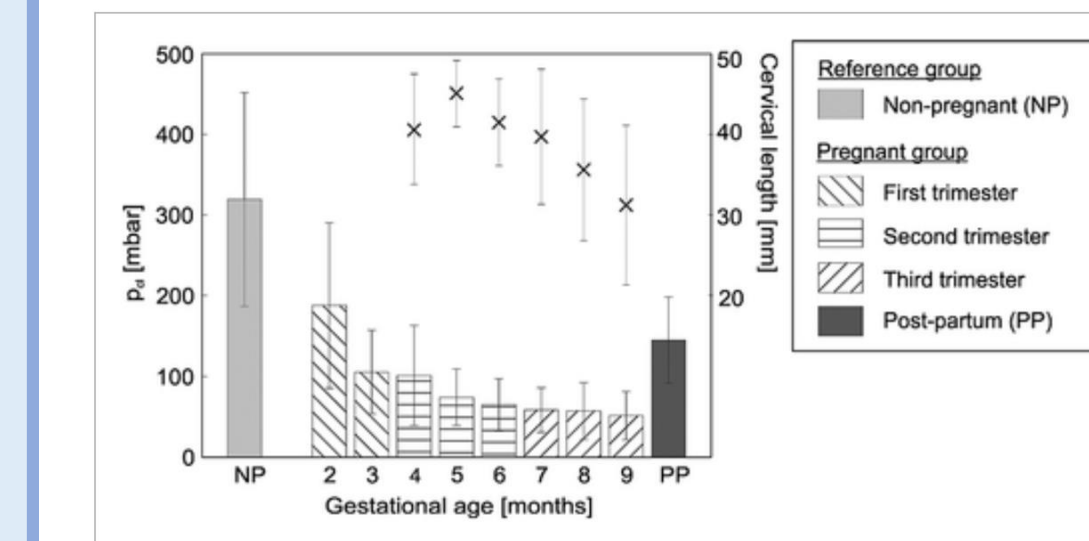
Parametric Patient-Specific Model and Finite Element Analysis

Parametric patient-specific geometry automatically generated in SolidWorks [5]

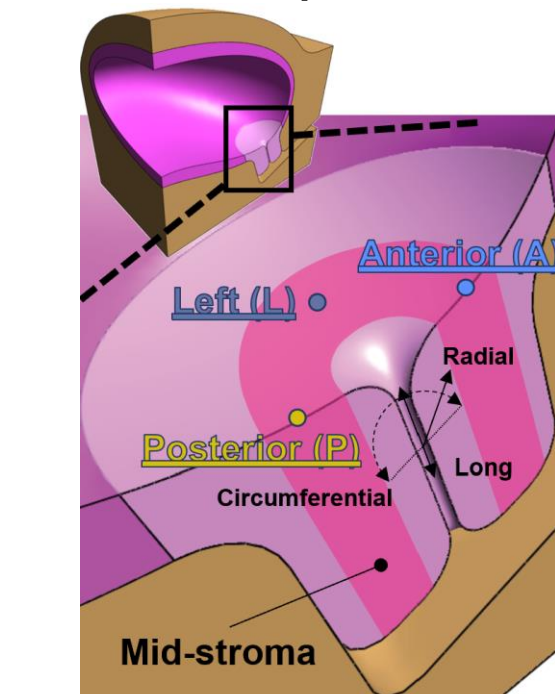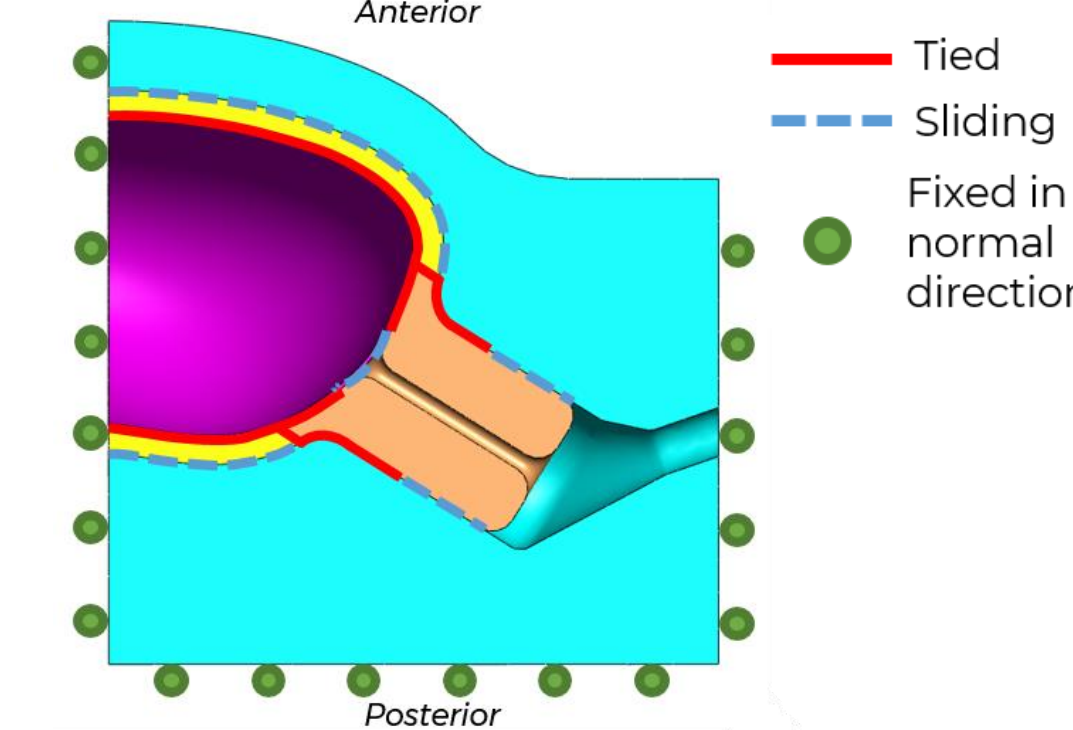Finite element simulation setup and run in FEBio v1.3.0 [6]
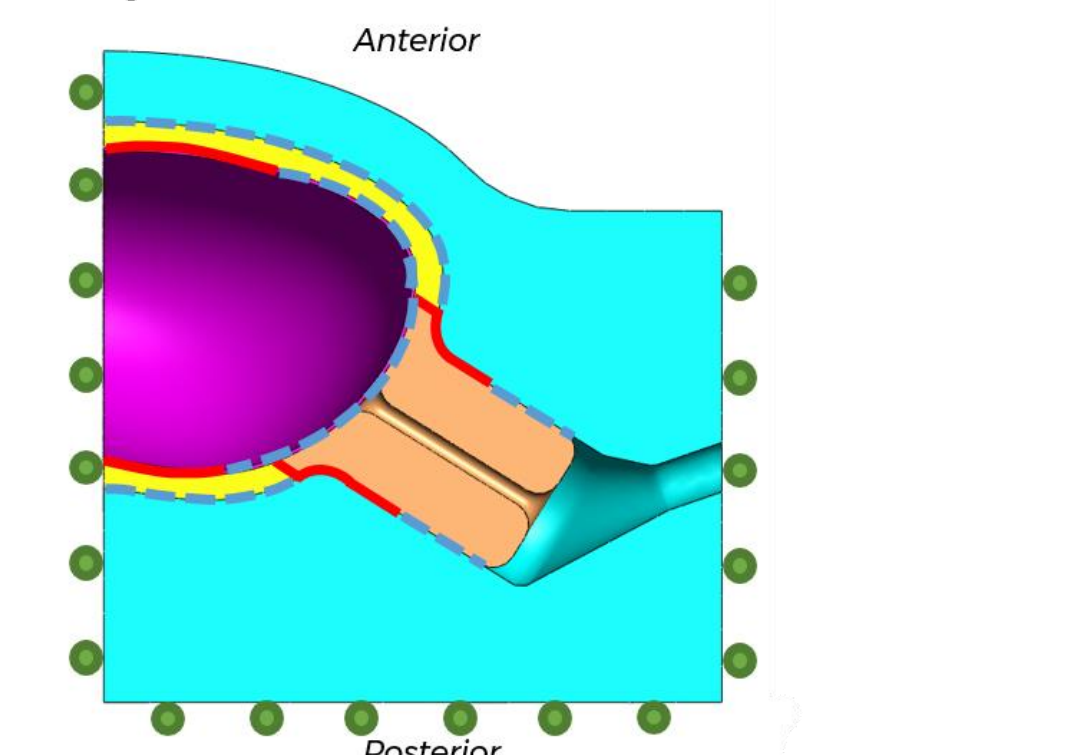
Discretized in Hypermesh

Tied Models: 100% tied FM area

Choose nodes to graph the stretch of the cervix under specific load pressure

Sliding Models: 60-65% tied FM area

LIMITATIONS

- Cannot compare to *in-vivo* loading results
- Assumed that shear wave speed to cervical stiffness was a linear relationship (data and models are limited to this assumption)
  - No direct way to go from one to another
  - No way to validate this assumption
- Idealized geometries (details not put into model)
- Simplified geometries outside of uterus and cervix (i.e. abdomen)
- Small data set (enough to start thinking but not enough for statistically significant solutions)

ACKNOWLEDGEMENTS