BIOMECHANICAL INTEGRITY OF THE CERVIX IN PATIENTS AT LOW- AND HIGH-RISK OF PRETERM BIRTH

Erin Louwagie (1), Jacqueline Hairston, MD (2), Mirella Mourad, MD (2), Ronald Wapner, MD (2), Kristin Myers, PhD (1)

1. Mechanical Engineering, Columbia University, New York, NY, USA; 2. Obstetrics and Gynecology, Columbia University, New York, NY, USA

Introduction

Preterm birth (PTB) is birth before 37 weeks. Globally it occurs in 10% of pregnancies [1]. Despite its prevalence, PTB is difficult to predict and prevent [1,2]. Clinically, a short cervical length measured via transvaginal ultrasound and a history of PTB are predictors of PTB. Yet, cervical length screening sensitivity is only around 50%, and it is particularly poor at predicting PTB in low-risk populations and first-time pregnancies [3]. In this study, cervical aspiration stiffness is reported for pregnant patients at high- and low-risk for PTB. Additionally, patient-specific computational models are constructed from ultrasonic maternal anatomy and cervical stiffness to calculate overall cervical structural integrity. The biomechanical integrity of the cervix is compared between patients who deliver preterm and those that deliver to term.

Methods

Ultrasonic dimensions of the maternal uterus and cervix and *in-vivo* cervical aspiration stiffness (Pregnolia AG, Switzerland) were measured between 16-24 weeks gestation using an Institutional Review Board approved protocol at Columbia University Irving Medical Center. Measurements were taken in three clinical patient cohorts: 1. high-risk (sonographic short cervix and no history of PTB, n=17), 2. high-risk (history of PTB, n=26), and 3. low-risk for PTB (normal cervical length, n=50). Using our established parametric modeling methods [4], we built models of each patient's uterus, cervix, fetal membrane, and supporting abdomen. We discretized models into elements (Hypermesh Altair, Troy, MI) and assigned all tissue material properties based on existing data, with a patient-specific cervical fiber stiffness determined through inverse finite element analysis (FEA) of the in-vivo aspiration procedure. Physiologically inspired loading, contact, and boundary conditions were applied, and FEA was run in FEBio Studio v1.3.0 for 16 patients from each cohort [5].

Results

The first principal stretch magnitude is generally larger in the high-risk group than the low-risk group (Fig. 1). The patients from the high-risk group who delivered extremely preterm (<28 weeks) have the largest 1st principal right stretches at the uterocervical junction and the lowest of all cervical stiffnesses by aspiration.

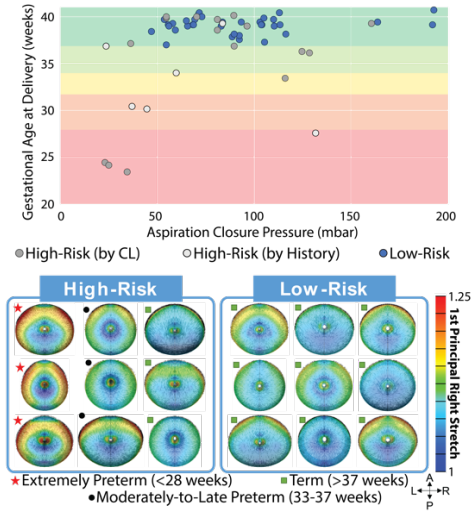

Figure 1: A) Cervical aspiration measurements and gestational outcomes. B) 1st principal stretch in the proximal cervix for a subset of subjects at high- and low-risk for PTB.

Discussion

The computational results show a distinct stretch pattern in patients at high-risk for PTB, with excessively high radial stretches at the utero-cervical junction. The increased stretch at this junction in patients who delivered extremely prematurely shows that uterine wall tension is a driving factor in causing cervical funneling. Additionally, patients who delivered extremely preterm had the softest of cervices. A powered clinical study is needed to prove cervical stiffness and overall structural integrity are better predictors of PTB.

References

1. WHO, "Preterm birth", 2018.
2. Medley et al., *Cochrane DB Syst Rev*, 11, 2018.
3. Berghella et al. *Contemporary OB/GYN.* 49, 4, 2004.
4. Louwagie et al., *Plos One*, 16(1):e0242118, 2021.
5. Maas et al., J Biomech Eng, 134(1):011005, 2012.

Acknowledgments

This work is supported by the Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health under award number 1R01HD091153 to KMM, 3UG1 HD040485-18S1 to MM, and The Iris Fund. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.