# BIOMECHANICS OF THE FETAL MEMBRANE UNDER DIFFERENT INTRAUTERINE PRESSURES

**Daniel Fidalgo (1), Michelle Oyen (2), Dulce Oliveira (1), Marco Parente (1), Renato Natal (1), Kristin Myers (3)**

*1. Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial (INEGI), Portugal; 2. Washington University, United States; 3. Columbia University in The City of New York, United States*

## Introduction

The fetal membrane is a complex biological structure that surrounds and protects the fetus during pregnancy [1]. It is a multilayered structure that comprises a mechanical dominant layer called the amnion, a compliant and extensible layer named the chorion, and part of the decidua [1]. It undergoes complex microstructural changes by the end of pregnancy [2], which will contribute to the weakening of the tissue in preparation for delivery [3]. Several factors associated with the mechanical response and the microstructure of the fetal membrane remain unknown and few studies were performed to define an accurate constitutive model able to characterize its mechanics and general behavior. Numerical methods might represent the key to access several information concerning the mechanical behavior of the fetal membrane. Therefore, this work aimed to analyze the biomechanics of the fetal membrane by resorting to the finite element method. The maximum principal stresses were analyzed for different intrauterine pressures. To do so, a finite element model of an inflation setup containing the multilayer fetal membrane was first calibrated using an experimental dataset.

## Methods

The calibration of the multilayer fetal membrane model Figure 1) was performed by adjusting the numerical apex displacement of our finite element numerical inflation setup to the experimental apex displacement reported by the *Skala Lab* – Morgridge Institute for Research. In terms of constitutive models, the amnion was characterized by the modified version of the Buerzle-Mazza constitutive model (Table 1):

| μo | q | m5 | m2 | m3 | m4 | N | v |
|---|---|---|---|---|---|---|---|
| 2.4 MPa | 2.96 | 0.463 | 0.00228 | 41.12 | 1.27 | 32 | 0 |

*Table 1: parameters of the modified version of the Buerzle-Mazza constitutive model to characterize the amnion.*

These parameters were retrieved from the literature, except for μo, which was obtained from inverse finite element analysis. The chorion (E=1MPa, υ=0.41) and the decidua (E=1MPa, υ=0.49) were characterized by elastic linear properties. The maximum principal stresses were analyzed in the amnion and the chorion layers for different intrauterine pressure.

## Results

The maximum principal stress in the amnion layer increased over the gestational weeks and for abnormally higher intrauterine pressure, while the chorion only experienced a slight increase (Figure 2).

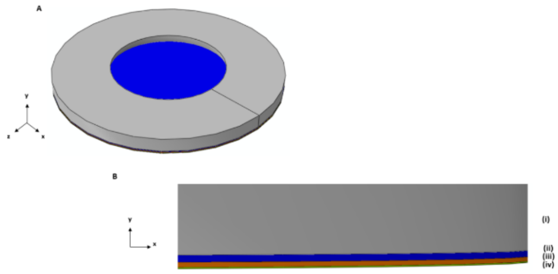

*Figure 1: Finite element setup of the inflation mechanical test using a multilayer fetal membrane model; A: three-dimensional view of the model; B: detailed view of the model (grey: clamping ring (i); blue: part of the decidua (ii); orange: chorion (iii); green: amnion (iv)).*

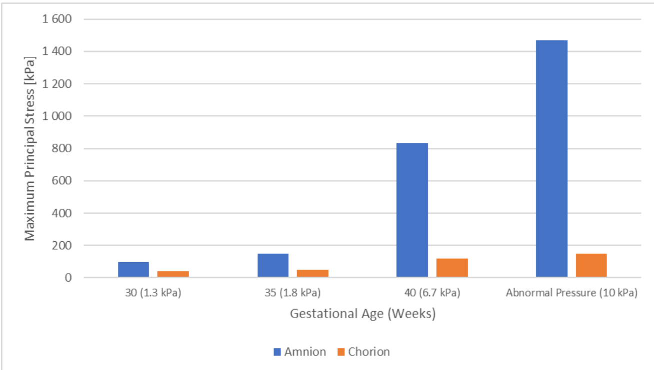


*Figure 2: Maximum principal stresses for different gestational weeks and abnormally high pressure measured at the apex region of the amnion and the chorion layers.*

## Discussion

These observations are aligned with the fact that the amnion is the dominant layer in the fetal membrane from a mechanical point of view, withstanding the majority of the forces associated with pregnancy and playing a more important role in the integrity of the fetal membrane as the intrauterine pressure increases [4].

## References

1. Jabareen et al, Eur. J. Obstet. Gynecol. Reprod. Biol. 144 Suppl, 134–141.
2. McLaren et al, Hum. Reprod. 14, 237–241.
3. Oyen et al, Am. J. Obstet. Gynecol. 195, 510–515.
4. Verbruggen et al, PLoS One 12, 1–14.