

Xiani Yan, Jennifer A. Kruger, Poul M.F. Nielsen, Martyn P. Nash

Motivation

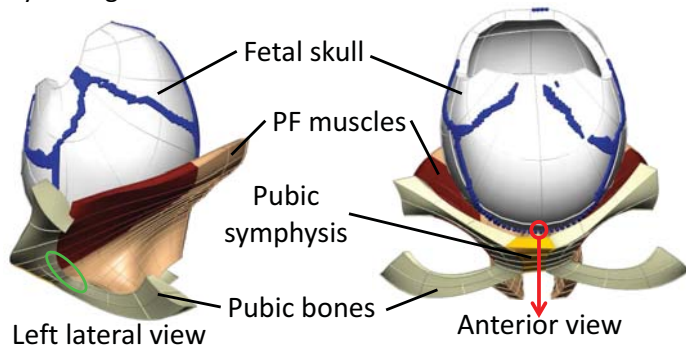
- Vaginal birth (second stage of labour) is strongly correlated with pelvic floor (PF) muscle injuries which may lead to PF dysfunction.
- The shape and size of the fetal head plays an important role in childbirth-induced injuries.

Objectives

- Build anatomically accurate finite element (FE) models of the fetal skull
- Simulate second stage of labour using fetal skulls of different sizes and shapes
- Construct a predictive model that quantifies intra-partum (during delivery) obstetric risks using the shape and size of the fetal head

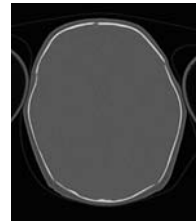
Modelling vaginal delivery

Fetal head was able to translate and rotate, negotiating its way through the birth canal.



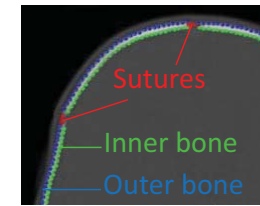
Most injuries occur at the muscle-bone (M-B) interface (green circle). The red arrow indicates the direction of fetal head descent.

Model construction of fetal skulls



Segmentation

Relevant structures identified on CT images of 26 newborn infants



Mesh fitting

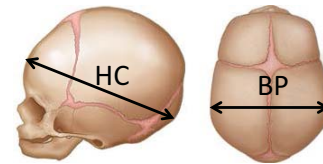
Data from slices of images combined to build G¹ (tangent) continuous FE models



Left lateral view

Predictive model- Partial Least Squares Regression

Input:



Left lateral view superior view

Routinely measured biometrical parameters for quantified on CT

- biparietal diameters (BP)
- head circumference (HC)

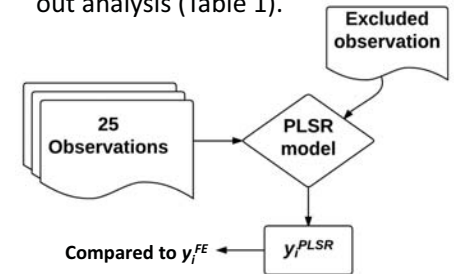
Response:

5 mechanical indices quantified from FE simulations of childbirth using each of the 26 fetal skulls

- Force required for delivery
- Maximum principal stress
 - At left M-B interface
 - At right M-B interface
- Maximum principal stretch ratio
 - At left M-B interface
 - At right M-B interface

Predictability:

Quantified for each of the 5 mechanical indices using leave-one-out analysis (Table 1).



$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N \left(\frac{y_i^{FE} - y_i^{PLSR}}{y_i^{FE}} \right)^2}$$

y_i^{FE} : FE prediction,
 y_i^{PLSR} : statistical model prediction
N: no. of subjects (26)

- For each mechanical index:
- Repeat for all subjects (N=26)
 - Compute normalised root-mean-squared error (RMSE, above)

Table 1: The normalised RMSE between the FE and PLSR predictions

Force (N)	Max. principal stretch ratio		Max. principal stress (kPa)	
	Left	Right	Left	Right
0.1520	0.0134	0.0114	0.1901	0.1673

Conclusion

- FE simulations of birth were conducted using 26 fetal skull models.
- A PLSR predictive model was generated to rapidly predict the mechanical indices, using routinely measured biometrical parameters for the fetal head.
- The PLSR model could be implemented in a clinical setting as a predictive and educational tool for birth planning.