ANATOMICAL RISK FACTORS INCREASING PATHOLOGICAL GROWTH IN CRANIOSYNOSTOSIS

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Introduction

Craniosynostosis (CS) are rare diseases caused by the premature fusion of cranial sutures and lead to cranial deformations. The surgical treatment avoids neurological and aesthetical problems. The main types are based on the 4 main sutures affected: sagittal, metopic, coronal or lambdoid. However, clinical sub-groups were described depending on the timing of the suture fusion and the fusion of secondary sutures (fronto-parietal, squamous, lambdoid, parieto-mastoid and anterior base) [1-2]. The impact on the severity of the deformation is not known although it could have an impact on diagnosis and the surgical method applied [1]. Statistical methods are impossible due to the low number of patients and the hard radiological readings.

Many Finite Element Models (FEM) of pathological growth due to CS were developed [3-5]. However, input parameters in the models were very different as there is no consensus on pediatric material properties, bone thickness and growth mechanisms. The models are hard to compare. Furthermore, none try to analyze the sub-populations.

The aim of this study is thus to develop a parametric FEM capable of simulating multiple types of craniosynostosis and its sub-groups.

Methods

A parametric model was developed on MATLAB by simplifying the cranial vault geometry as a cut ellipsoid. 45 geometrical parameters were used to dimension the ellipsoid and model the bones, main and secondary sutures and fontanelles at each suture intersection. 18 mechanical parameters described the Young modulus of each part (fixed Poisson ratio of 0.28) and the applied pressure was calculated to obtain a logarithmic normal volume growth between 3 and 15 months. Two temporal parameters establish when the suture limits transform into bone (normal suture growth) and when an affected suture transforms into bone (craniosynostosis). The base of the skull was fixed at the center while the rest of the nodes could translate on the cut plane. The simulations were run on Radioss implicit solver. A convergence study was conducted on the mesh size and a sensitivity study analyzed the impact of parameter choices on growth results.

The normal growth model was evaluated using the final volume and shape comparison with a previously developed statistical growth model. The different cases were compared to the validated normal growth model in terms of deformation and strains at the sutures.

Results and Discussion

The geometrical parameters were chosen to fit a mean vault at 3 months. A model with 982 elements was chosen thanks to the convergence study. The sensitivity analysis lead to the choice of parameter values including a suture width of 0.5 mm, Young modulus of 200 and 3000 MPa for sutures and bones. The pressure P was applied such as P=1.28*log(time_step) + 5092, to obtain the clinically observed volume change during growth.

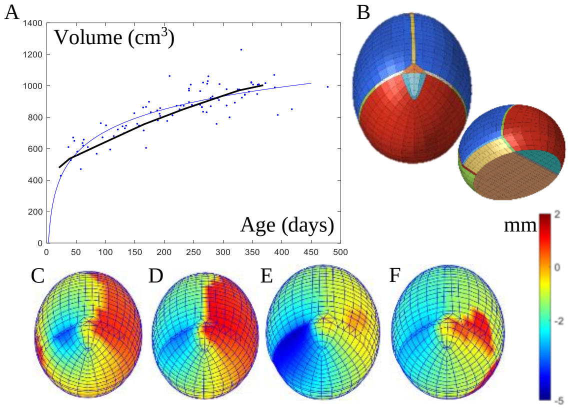

Figure 1: Normal volume comparison from clinical data (blue) and FEM results (black)(A). Initial FEM geometry (B). Deformation for partial (C), complete (D) fusions of the right coronal sutures with the right fronto-sphenoidal (E) and the right base sutures (F)–compared to normal growth, antero-superior view.

The deformations for all CS cases were comparable to clinical observations, except for metopic synostosis. Compensatory growth were under-evaluated. The study showed that fusion of the secondary sutures had a significant difference on the deformations observed, with little differences on contralateral suture strains.

Conclusion

The present study shows how FEM can help clinical classification and the surgical procedure applied [1], especially when statistical methods are not applicable. The under-evaluations were similar to the ones found in previous FEM [3-5] and are in regions not affected by surgery. Yet they show that growth mechanisms are still misunderstood.

References

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