Numerical Aspects of Subdural Haematoma Modeling and Prediction

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I. INTRODUCTION

One of the most frequent and deadly injuries resulting from head trauma is the acute subdural haematoma (ASDH), which roughly consists of rupturing a bridging vein (BV). Given the importance of this type of injury, two main aspects are necessary to consider: (i) to set accurate thresholds and damage criteria, generally deriving from experimental tests performed on human cadavers, animals or crash-test dummies [1]; and (ii) to develop numerical tools to avoid ethical concerns and to provide a reliable, cost-effective alternative. Once properly validated, a finite element head model (FEHM), including ASDH prediction, can be a valuable tool in developing head protective gear and reconstructing head traumas.

II. METHODS

The YEAHM FEHM [2] is the working substrate to integrate with a numerical model of the bridging veins. Starting from medical images, and after simplifying the complex set of vessels observed, a CAD model was created, including the superior sagittal sinus (SSS), transverse sinuses, straight sinus and 12 pairs of bridging veins (Fig. 1), with dimensions and orientations adapted from [3].

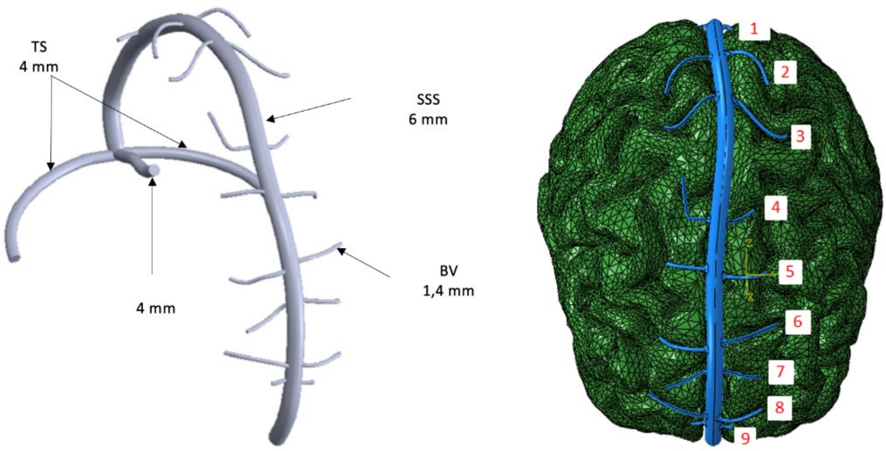

Fig. 1. Set of bridging veins and sinuses and integration into YEAHM model.

Besides a reasonable approximation of the geometry, proper modelling of constitutive behaviour and imposition of boundary conditions are essential for the accuracy of the model. In the present study, the mechanical (tensile) data were based on the work of Monea *et al*. [4]. Using the explicit version of the Abaqus FE package and fully integrated shell elements, tensile tests were replicated using solo veins as in the original test, but also within the complete vessel set (Fig. 2, left), both with success. A ductile damage model coupled with an elastic-plastic material law was used following the work of Migueis *et al.* [5]. Figure 2 (middle) depicts some numerical trials where the fillet radius between the BV and SSS was varied in order to avoid stress concentrations and to allow the correct prediction of rupture onset.

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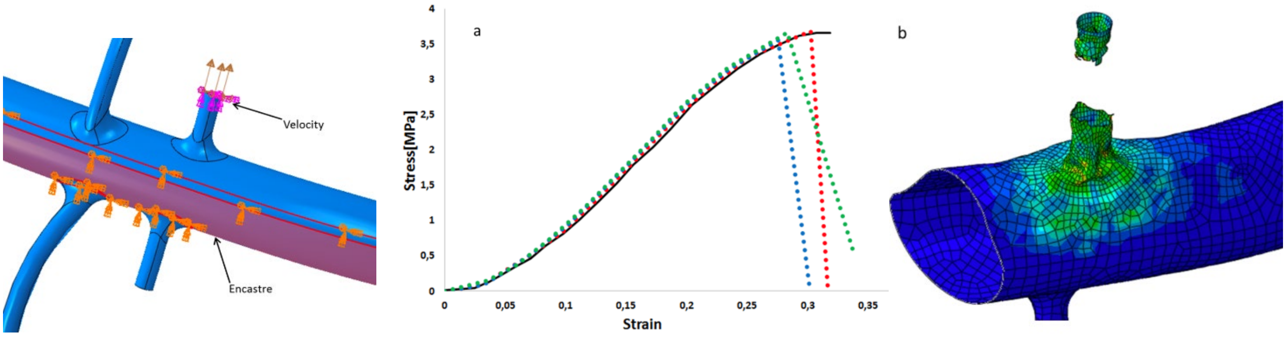

Fig. 2. Single vessel validation.

The imposition of boundary conditions (BC) was revealed as the most critical optimization stage. Roughly, the BVs are tied to the SSS (tied to the dura matter and indirectly to the skull) at one end and to the brain (and its meninges) on the other, crossing the subdural space where they are usually torn if there is a significant relative movement between skull and brain upon impact. To properly impose and fine-tune the set of BC to the SSS+BV vessels set, the experimental tests of Depreitiere *et al.* [6] were used as validation. The resulting set of BCs is shown in Fig. 3. Additionally, a fluid cavity interaction was defined using three parameters (fluid density, bulk modulus and the pressure-arterial [7]).

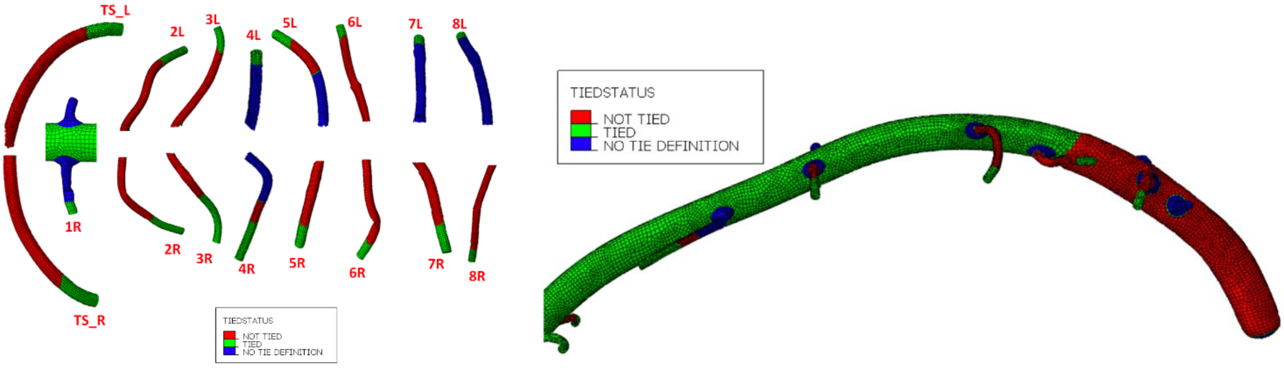

Fig. 3. Boundary conditions definition for BV+SSS set.

III. FINDINGS AND DISCUSSION

Depending on the number of cases considered, the success rate lay within a range of 83.3–90%, presenting encouraging results for ASDH prediction. The results were compared with others reported in the literature [8-9], estimating higher success rates and/or a high numer of cases. The methodology adopted resulted in the validation of 83.3% of the 12 reported cases in cadavers [6] regarding BV rupture, which attests to the success of the employed methodology. This shall now be extended in order to cover more variability in terms of age and gender variance.

IV. REFERENCES

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