Title of thesis subject: Contribution of computational simulation to reducing risks during instrumented vacuum delivery

Keywords : computational simulation ; biomechanics ; obstetrical medicine, tissue damage

Laboratory : LEM3, Université de Lorraine

Doctoral school : C2MP (Chimie, Mécanique, Matériaux, Physique)

Host team : Department 1 MMSV (Mechanics of Materials, Structures and Living Tissues), team BIO2MS (Bimechanics and bioengineering of musculoskeletal system)

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State of art and clinical context

During vaginal delivery, the expulsion phase is a particularly high-risk period: in the event of anomalies, the obstetrician may have to perform an instrumental extraction, which accounts for between 15 and 20% of births, regardless of gestational age. Among the instrumental extraction techniques used in France, the obstetric suction cup is clearly predominant, and its use is constantly increasing. Like all extraction instruments, however, its use is not without risk in the event of inappropriate practice (Riethmuller et al., 2009), in terms of damage to the foetal scalp and tearing of maternal tissues, which are still frequent and constitute a major socio-economic problem. In both these situations, the aim is to understand and minimise damage to maternal and foetal tissues during this medical procedure.

Many questions remain unanswered concerning the ideal use of the suction cup. The shape and design of the suction cup could be improved (Goordyal et al., 2021) to minimise the risks associated with its use. Experimental studies on this subject are obviously limited by the difficulty of collecting clinical data during the labour phase. To overcome this difficulty, computational models (Chen et al., 2021; Oliveira et al., 2016) combined with physical simulators (O'Brien et al., 2017) can be used to model the behaviour of the different tissues involved during parturition and the effect of clinical practices on the risk of complications.

As part of a previous PhD thesis in the team, initial modelling, simulation and validation tools were proposed (Vallet et al., 2023b, 2023a, 2022, 2021). The present PhD thesis is a continuation of this previous work, which led to the development of a now solid collaboration between the maternity unit of the Nancy CHRU and the LEM3 biomechanics team. This previous work mainly concerned the development of experimental and methodological tools in the field of biomechanics, validated on the basis of a training dummy only, with well-controlled geometries and materials, but far removed from clinical reality. The aim now is to extend the scope of this previous work by bringing it closer to clinical reality.

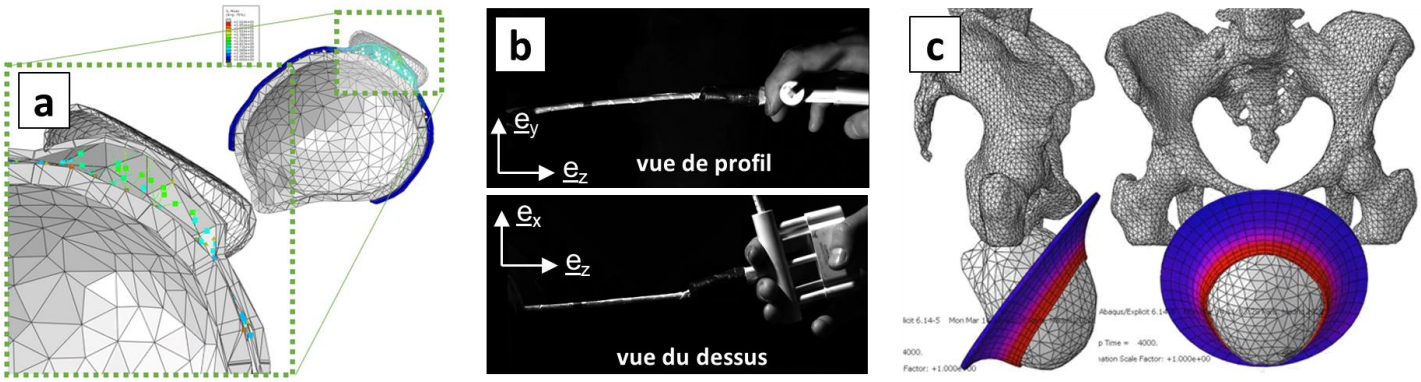

Figure 1 : developments carried out as part of the team's preliminary work. (a) Modelling of the suction cup-scalp-bone interface (b) acquisition of the instrumented suction cup extraction procedure (c) example of computational simulation of foetal head extraction.

Objectives and methodology

The aim of this PhD thesis is to define the conditions of use of the obstetric suction cup that minimise the risk of damage to maternal and foetal tissues. The methodological tools developed previously will be used and extended to increase the realism of the simulations proposed, and their ability to reflect the lesions observed in clinical practice. This objective is associated by various fundamental or applied tasks that will form the core of the thesis work :

- The implementation of realistic geometries based on the use of MRI medical imaging databases created in the IADI laboratory and their use to create a database that is statistically representative of a target population;
- Integration of realistic anisotropic hyperelastic constitutive laws based on the literature (Bauer et al., 2009; Gachon et al., 2020; Mazza et al., 2006; Parente et al., 2009) ;
- Integration of laws to account for soft tissue injuries based on damage mechanics (Chittajallu et al., 2022) ;
- The comparison between continuous damage models and other types of methods for soft tissue rupture modelling (Muth-Seng et al., 2018; Muth-seng et al., 2017; Roux et al., 2021) in their ability to account for the lesions observed during vacuum-assisted delivery ;
- Validation of the results obtained on the basis of a dialogue between experiments and computational methods, using both ad hoc mechanical tests and results from the literature (Bircher et al., 2019).

Partnerships

The PhD thesis will take place mainly in the LEM3 branch located at Vandoeuvre-lès-Nancy within the ENSEM engineering school, due in particular to the proximity of the clinician collaborators of the Nancy CHU maternity unit, the IADI laboratory and the CUESIM simulation centre. The experimental tests will be carried out in the biomechanics experimental room on the LEM3 located at the ENIM engineering school in Metz. The PhD thesis will be combined with another PhD thesis of an emergency doctor working on the relevance of low-fidelity physical simulators for obstetrics training.

Profile of PhD candidate

The candidate should have a background in solid and structural mechanics, such as engineering school, with solid skills in material behaviour and computational simulation. Specialisation in biomechanics (medical imaging, constitutive laws for biological tissues, clinical applications) would be welcome. He or she will need to demonstrate curiosity and creativity, be able to work in a highly multidisciplinary environment, and show strong motivation for the applications targeted.

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