Injury prevention during childbirth: A model of pelvic floor

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Abstract: During vaginal delivery women suffer with several kinds of injuries which may negatively influence their quality of life. Different techniques are used for perineal protection during the second stage of the delivery. A method called manual perineal protection (MPP) is used to decrease the risk of severe perineal trauma. In order to quantify this method a special measuring glove was designed and forces generated by the obstetricians during real deliveries were measured. Measured forces were then used in computer simulation of the MPP method. The forces were applied on a previously developed FEM model of the pelvic floor during simulation of the vaginal delivery. The stress distribution in the perineal area was monitored. Reactions of perineal tissues were evaluated. The simulations of childbirth with and without MPP were compared.

Keywords: VAGINAL DELIVERY, FINITE ELEMENT MODEL, PELVIC FLOOR, MANUAL PERINEAL PROTECTION

1. Introduction

Female pelvic floor dysfunctions are very often associated with injuries of pelvic floor structures during vaginal delivery. It is reported that only 9.6% and 31.2% of women deliver with an intact perineum at their first and second births respectively [Smith]. Therefore, it is imperative that strategies that decrease the extent of perineal trauma are developed, assessed and promoted.

In the certain cases the method called manual perineal protection (MPP) can be used to successfully protect the integrity of the perineum during vaginal delivery [7]. Proper execution of the MPP is a complex problem with a high variation of obstetrical variables described by the accoucheurs [5]. Due to the nature of vaginal delivery, it is not possible to precisely repeat a modification of MPP in order to study its efficacy. Virtual modeling linked with measuring techniques seems to be a promising way how to improve the maneuvers and helps in better understanding of this topic.

The correct virtual modeling should always stay on relevant experimental data. (Several studies were published.) As the pilot research the stereophotogrammetry was presented [11]. Large deformations of the perinal skin were quantified, however, no information concerning acting forces was known. For this reason, a special measuring glove was designed and used by obstetricians during real deliveries. This unique measurement was published [10].

So far, the MPP has been simulated based on stereophotogrammetry data only [3,4]. The simplified model represented by a homogenous material were modelled. The forces applied by obstetricians were supplied by boundary conditions.

The main objective of this study is to improve the existing female pelvic floor FE model [6] and to simulate a delivery of a fetal head. The second aim is to simulate the MPP at the time of the head expulsion using hand forces measured during the real delivery.

2. FE Pelvic Model

Previously published finite element female model was used as a basis [6, 2]. Originally, the model consisted of the female pelvis, the levator ani muscle (LAM) with the fetal head modelled as a rigid body. Other surrounding structures were substituted by boundary conditions. For the refined FE model muscles forming the pelvic floor such as ischiocavernousos, bulbospongiosus and transversus perinei including anal sphincters and the anococcygeal ligament and the perineal membrane were added. The geometry of all structures was based on a live-subject’s MRI data and anatomical cadaveric measurements. Complete model geometry is shown in the Fig. 1.

The fetal head model and its trajectory through the pelvic floor structures was reconstructed based on the dynamic magnetic resonance of a vaginal delivery [1]. However, the fetal head was scaled up to ensure that its main dimensions corresponded to those of an average size term fetus.

Bones were modelled as rigid bodies, soft tissues as hyperelastic Ogden material to allow for large deformation. The muscle material constants were fitted using the stress-strain characteristic measured during a uniaxial tensile test and utilizing information from porcine samples or characteristics published previously in [2]. The perineal membrane was modeled as a layered membrane with perpendicular layers of fibers and a surrounding matrix. The skin was modelled by elastic shells. Material characteristics such as skin and ligaments were based on literature search.

3. Delivery Simulation

Using the new FE model, the vaginal delivery was simulated for the optimal fetal head size, position and orientation – i.e. left occipito-anterior position.

Fig. 1 Setup of the pelvic model.

Fig. 2 Phases of the delivery in side view displayed in chosen stations marked as d.
The simulation was prepared and results were analysed by VPS. The stress and strain distribution of the pelvic floor structures during birth was analysed by the Virtual Performance Solution (VPS 9.0; ESI Group, Paris, France) commercial software. The head station was defined as the distance between the interspinous diameter and the head vertex. The interspinous diameter is the distance between the tips of the ischial spines. The vertex denotes the top of the head in the upright position. The delivery simulation starts with the head placed in the upper part of the pelvis then rotates and descends according to prescribed trajectories. The head in chosen positions – stations - is shown in Fig. 2.

4. Measuring of forces during MPP

Several variations of the MPP maneuver exits. The used Finnish technique of MPP (FMPP) involves application of the thumb, the index finger and the middle finger of the dominant hand on the perineal skin. The thumb and the middle finger press anterolaterally to the fourchette to reduce midline perineal strain. The flexed middle finger is used to apply pressure against the perineal body to facilitate the process of the fetal head extension. The non-dominant hand controls the speed of the fetal head expulsion and facilitates the fetal head extension [10].

Since it is difficult to evaluate the actual contribution of the individual components of FMPP in a clinical setting a special measuring glove was designed, see Fig. 3. Using this glove forces applied by the obstetrician during FMPP were measured. This right-handed glove was designed in order to gather forces generated by the obstetrician during the head expulsion. The wireless sensors are placed on the thumb, the index finger and the middle finger. The glove is a part of system, which collects, transfers and stores data onto a PC. All detailed information including pilot measurements are published in [10].

During the delivery the glove was put on the accoucheur’s right hand and covered by the sterile medical glove. At the moment of the head expulsion the forces were measured.

5. Simulation of MPP

The proper time-force dependencies of fingers of the one chosen delivery are implemented to the pilot simulation of the FMPP. As the first step the preliminary simulation of the “hands on” technique was prepared and only the pressure loading of fingers without head delivery were implemented to control perineal structures reaction. Further the complete delivery with “hands on” was simulated. The obstetrician fingers working during the maneuver are supplied by prescribed pressure loading as is shown in Fig. 5. Measured forces are converted to pressures since the sensor surfaces are known. According to [3] the fingers during delivery are applied when the vaginal introitus is dilated to 8 cm anteroposteriorly and 4 cm transversely which corresponds to the head station equal to 11.4 cm in the presented model. At this moment, which corresponds to the beginning of the head expulsion, pressure loadings increase and continues till the end of the simulation.

6. Results and discussion

Our study confirmed the hypothesis that pelvic floor structures undergo large stress and deformation during the second stage of the labor, see Fig. 2. The caudal displacement of the LAM was 2.4 cm and 4.1 cm for the head station equal to 8.9 cm and 14.2 cm respectively. It corresponds to a 166% elongation of the LAM in the caudal direction. The perineal caudal displacement was 4.9 cm for the head station equal to 14.7 cm.

The stress values at the LAM were the highest at the anterior attachments to the tendinous arches when the head station was equal to 8.9 cm and reached 30.8 MPa. This was followed by a decrease in the LAM stress level as the stress in the perineal structures starts to increase with further head descent. The stress in the perineal body reached its maximum when the suboccipito-frontal diameter of the head was passing through the introitus. It was later than the priori expectation that this would happen when this area is stretched by the suboccipito-bregmatic diameter of the head. The suboccipito-bregmatic diameter passed through the introitus at the head station.
equal to 14.7 cm. Described head diameters are demonstrated in the Fig. 6. All monitored first principal stress values are summarized in Table 1 and displayed in the Fig. 7.

### Table 1

<table>
<thead>
<tr>
<th>Muscle / region</th>
<th>Head station [cm]</th>
<th>Max first principal stress [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAM / insertion to tendinous arches</td>
<td>8.9</td>
<td>30.8</td>
</tr>
<tr>
<td>Transversus perinei / perineal body</td>
<td>13.7</td>
<td>33.6</td>
</tr>
<tr>
<td>Transversus perinei / perineal body</td>
<td>14.7</td>
<td>91.47</td>
</tr>
</tbody>
</table>

**Fig. 7** The first principal stress distribution in the LAM and perineal muscles, d denotes the head station. Red circles mark the LAM attachments to the tendinous arches (left) and the area of perineal body (middle and right).

Concerning the simulation of the FMPP the stress and strain distribution is influenced by the missing subcutaneous structures. These structures are not crucial for the own delivery simulation. Currently they are substituted by appropriate linking elements. Skin deformations shows Fig. 8. Although the acting finger forces are similar, deformations caused by thumb and index finger are much higher than by the middle finger.

**Fig. 8** Strains of the loaded skin. Simulation without delivery. Differences in the stress distribution of the perineal skin during delivery are shown in Fig. 9. In case of “hands on” the stress moves from the posterior fourchette to the perineal body. The posterior fourchette is a critical place for tearing. The FMPP influences the stress distribution in this critical region.

**Fig. 9** Comparison of stress distribution in the model with “hands off” (left) and “hand on” (right) technique during delivery.

### 7. Conclusion

We were able to develop a complex model of the pelvic floor, to simulate the delivery of the fetal had and to simulate the MPP method. The main advantage of this model is that it allows detailed evaluation of individual pelvic floor structures hence increasing the internal validity of our findings and enables extending future applications of the model. Current state of the model enables further applications as the simulation of the manual perineal protection (MPP).

The pilot simulation of MPP shows a weakness of the model, which is the missing connective tissue between the skin and the perineal structure. Although the connective tissue is substituted by linking elements, it should be improved since it would influence the force transmission between perineal structures. Despite that the study confirmed the influence of the fingers pressure on the perineal skin during the vaginal delivery.

### 8. References


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