Injury prevention during childbirth: The model of obstetrician

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Abstract: During childbirth, a technique called manual perineal protection (MPP) is often used to prevent injuries of relevant tissues. The obstetrician uses his (or her) hand to apply certain forces at the perineum in order to decrease its excessive loading during child delivery. Amount of applied forces as well as the correct posture of the obstetrician during the MPP technique are based so far on the experiences and approach of the obstetrician himself (or herself). In order to assess the role of obstetrician and in order to optimize the MPP technique, mathematical models may be of use. This work presents a combination of both experimental measurement and mathematical modeling. In the experimental part, a unique device is developed to measure forces applied by obstetrician during real child delivery. In the modeling part, the obstetrician is represented with an active musculoskeletal human body model in an AnyBody Modeling System software. Providing forces and muscle activities of the model may lead to the assessment and optimization of the MPP technique.

Keywords: VAGINAL DELIVERY, MANUAL PERINEAL PROTECTION, ANYBODY MODELING SYSTEM

1. Introduction

During a vaginal delivery, injuries of relevant tissues may occur such as ruptures of perineum, levator ani muscle and the obturator muscle [1]. In fact, only 9.6 % and 31.2 % of women deliver with an intact perineum at their first and second births respectively [2]. These injuries may have consequences in future in terms of female pelvic floor dysfunctions (perineal pain, anal incontinency, dyspareunia) [3].

In order to prevent injuries during childbirth, a technique called manual perineal protection (MPP) is often used [4]. The obstetrician uses his (or her) hand and fingers to apply certain forces at the perineum in order to decrease its excessive loading during child delivery. Amount of applied forces as well as the correct posture of the obstetrician during the MPP technique are based so far on the experiences and approach of the obstetrician himself (or herself). Still, proper execution of the MPP technique is a complex problem with lots of obstetrics variables [5].

In order to assess the role of obstetrician and in order to optimize the MPP technique, mathematical models may be of use. Here, we present a combination of both experimental measurement and mathematical modeling. At first, it is essential to determine forces applied by the obstetrician hand and fingers during the MPP technique. Although there are existing devices on the market (see e.g. [6]), these are not suitable for our application. Therefore, we develop our own experimental measurement system in a form of a glove for obstetrician. It records forces that are exerted by the obstetrician hand during a real delivery.

These data are used in the mathematical modeling of child delivery. The obstetrician is represented with a musculoskeletal model in the AnyBody Modeling System (AMS, Aalborg, Denmark, Version 7.2, AMMR 2.2.2) [7]. Here, human body is formed of rigid bones that are interconnected via joints based on real anatomy [8]. Muscles, tendons and ligaments are considered using models that enables active motion of the whole body model [9]. Kinematics of the AMS model is prescribed here using the data from the motion capture system during a delivery with physical model, see e.g. [10]. Finally, the results in terms of muscle activities of individual muscles are obtained.

2. Experimental measurement device

In the MPP technique used in this study, the obstetrician applies the force of his (or her) dominant hand at the perineum via thumb, index finger and the middle finger. 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 [11].

To record these forces during this particular technique, we develop our own measurement glove. It must be 100% safe for child and the mother, it needs to measure forces acting at three defined points, it must be very simple to use and finally it must be durable for repeated use. The proposed prototype is depicted in Fig. 1.

![Measurement glove with force sensors.](image)

As force sensors, three force sensitive resistors Tekscan FlexiForce A201 are used. The device is powered with 3V coin battery and its rate is 100 samples per second. To achieve maximum safety, the glove is wireless and its electronics is isolated from obstetrician and touched surface. For each use, that is, for each child delivery, the glove is covered with new sterile surgical glove.

Experimental measurement includes real deliveries of 20 volunteers, see [11]. The forces are measured at the moment of the head expulsion. The example of measured data are depicted in Fig. 2. Here, evolution of forces in time for all the fingers are displayed for one particular volunteer.

![Measured time-force dependencies of fingers during MPP. The curve no. 1 (blue) denotes thumb, no. 2 (dashed red) denotes index finger and no. 3 (green) the middle finger.](image)
3. Obstetrician model

To represent the obstetrician, the AnyBody Modeling System is used. Here, human body is represented with rigid bones interconnected via joints. Active motion of the model is enabled by considering muscles, ligaments and tendons as type of simple models within AMS. Particular focus is given to the model of hand. In order to simulate the MPP technique properly, it is necessary to prepare the hand model in a great detail. Special attention is paid to the muscle attachment sites. Their proper definition allows us to determine exactly the positions and trajectories of individual muscles and hence to capture realistic moment arms and muscle activity during the MPP within the musculoskeletal model.

We use the MRI scans of real hand to obtain locations of muscle attachments. In AnyBody Modeling System individual muscles are replaced with user defined number of action lines or virtual muscle elements. These elements need to be placed within muscle volume in a way that respects anatomy of the muscle. Therefore, two tasks are to be solved in the mathematical modeling: placing required number of endpoints onto attachment surfaces and then pairing these endpoints in order to specify individual elements.

For the first task we use modified k-means algorithm. Given a finite set of points \( \omega \subset \mathbb{R}^N \), \( N \in \mathbb{N} \) and number \( k \in \mathbb{N} \), original k-means method iteratively tries to approximate solution to k-partition problem. That is to partition set \( \omega \) into \( k \) classes \( \omega_1, \ldots, \omega_k \) each corresponding with point \( c_i \in \mathbb{R}^N \), \( i = 1 \ldots k \) called centroid, in such way that

\[
\sum_{i=0}^{k} \sum_{x \in \omega_i} \|x - c_i\|^2
\]

is minimal. In our setting, we use set of centres of gravity of the triangles in the mesh as a set \( \omega \). We modify the basic k-means method to ensure that the partition does not depend on density of points of the mesh [12].

The second task (pairing of the endpoints) is based on Euclidean matching problem in two dimensions. It can be proven that the minimality of total pairing distance ensures that no two line segments connecting paired points intersect. The minimal pairing is obtained by Hungarian algorithm which finds minimal matching in weighted bipartite graph [12]. The resulting minimal matching with pairs connected by lines can be seen in Fig. 3.

![Fig. 3 Opponens pollicis connectivity with five muscle elements.](image)

The results from the k-means method are used to represent muscle attachment sites and muscle lines in the AMS model of the obstetrician hand. Individual muscles and tendons are represented with a type of simple muscle model [9] that includes contractile elements as well, see Fig. 4. Hence, both elasticity and muscle activity are included in the model. The geometry of the completed detailed hand model is depicted in Fig. 4. Finally, the hand model is embedded in the musculoskeletal model of whole human body within the AMS software to obtain the model representation of an obstetrician.

4. Simulation of the MPP and results

The AMS model of the obstetrician is employed for the simulation of the MPP technique. Here, the inverse dynamics method is used. It means that the motion of the obstetrician is prescribed and muscle activities and forces that correspond to that particular motion are calculated. To do that, an optimization algorithm is embedded in default in the AMS software. Typically, an objective function of a form

\[
G = \sum \left( \frac{f_i}{N_i} \right)^p
\]

is defined, where \( f_i \) is a force in an individual muscle, \( N_i \) is a normalization factor and \( p \) is a number (\( p = 3 \) by default). The objective function thus represents a higher order sum of muscle activities. Minimization of this objective function for prescribed motion leads to the solution in terms of resulting muscle forces and activities.

In this particular application, the kinematics data of the obstetrician performing the MPP technique are obtained using the motion capture system XSens that uses the IMU sensors instead of markers. Employing this device, the obstetrician performs the MPP protection technique during the child delivery with the physical model, see Fig. 5. While the right hand is used for the MPP technique itself, the left hand is used to support the head of the child model.

![Fig. 5 Obstetrician performing MPP technique with physical model for kinematics data recording using XSens motion capture system.](image)

Finally, all the experimental data gathered include forces exerted by hand of the obstetrician during a real delivery and the kinematics of the obstetrician during the MPP technique with the physical model. These are used as input data for the simulation of...
MPP technique with musculoskeletal model of the obstetrician within the AMS software. The method of inverse dynamics is applied.

In fact, the MPP technique are simulated considering various postures of two obstetricians. The reason is to assess the MPP technique under varying conditions for its optimization. The example of the results is provided in Fig. 6. The musculoskeletal AMS model of the obstetrician performing the MPP technique in standing position is displayed. Colouring of individual muscles corresponds to the level of their activities calculated in the model. Namely, there is an increased muscle activity on the lower back due to the bent posture. This leads to increased joint reaction forces and hence it may cause increased problems within this body part.

![Simulation of the MPP technique in the AMS software with the musculoskeletal model of the obstetrician. Coloured muscles correspond to their muscle activity.](image)

**Fig. 6** Simulation of the MPP technique in the AMS software with the musculoskeletal model of the obstetrician. Coloured muscles correspond to their muscle activity.

5. Conclusion

The aim of this study is to present the abilities of mathematical modeling for improvements in medical field. Namely, the aim is to contribute to the knowledge regarding the manual perineal protection, i.e. the technique performed by obstetricians to prevent injuries of tissues during vaginal delivery.

The musculoskeletal model of hand is developed in great detail and embedded with the whole human body model in the AnyBody Modeling System software. To perform simulation of an obstetrician performing MPP technique, experimental data are necessary to gather as model input. Hence, unique measurement device is developed to record forces exerted by the hand of obstetrician during the delivery. Second, kinematics of the obstetrician is obtained during the delivery with physical model using the motion capture system.

The results of the mathematical modelling are obtained in terms of individual muscle activities and forces of the obstetrician. Hence, the MPP technique may be assessed and optimized from the perspective of the obstetrician and possible overloading of his or her body parts. In the example presented in this study, increased activity of the lower back muscles is obtained due to the bent postures. This indicates possible problems within this body part.

6. References

9. [https://anyscript.org/tutorials/Muscle_modeling/lesson5.html](https://anyscript.org/tutorials/Muscle_modeling/lesson5.html)

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