SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA18211
STSM title: Computational modelling approach to study maternal-fetal heat exchange under different physiological and clinical conditions
STSM start and end date: 12/07/2021 to 13/08/2021
Grantee name:

PURPOSE OF THE STSM:

The up to date knowledge of maternal-fetal thermoregulation is limited in two studies performed in animals. The understanding of thermoregulation in pregnancy will answer many open questions, leading to improvement of maternal and fetal health and wellbeing, and reduction of negative outcomes.
While it is known:

a) That shorter or longer umbilical cord is related to several complications, including increased incidence of operative interference, intrapartum complications, more chances of birth asphyxia etc (Balkawade et al 2012), and
b) That hypocoiling and/or hypercoiling have negative maternal and neonatal outcomes (hypertensive disorder, caesarean section, congenital anomalies etc) (Chitra et al 2012);

it is still unknown how these parameters affect the maternal-fetal heat exchange, and therefore it remains unknown if several adverse outcomes can be predicted and prevented if the exact role of these factors will become known and therefore can be detected on time and/or being monitored.

Aim of the STSM:
Knowing the umbilical cord's key role in maternal-fetal heat exchange, the purpose of this project is to understand how umbilical cord's length and umbilical cord index (UCI) affect fetal thermoregulation.

Additional objectives:

1. To simulate several structural conditions and investigate their relationship with the heat flow and thermoregulation.
2. To better understand the structure-function relationship of the human umbilical cord.
3. To investigate the heat properties and understand this important human mechanism.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

From the second day of this project (13/07/2021) I had daily scheduled meetings with Dr Anastasia Topalidou (AT) (between 07:00am-09:00 BST), to discuss outputs, actions, and organise the daily activities. Due to the number of simulations (27 simulations) and the associated computational time

(from 6-10 hours for sparce grids to 20-24 hours for dense grids) we needed 26 calendar days (weekends included) to run the 27 simulations (sometimes in two computer devices simultaneously). The project lasted 33 calendar days with many parallel activities.

12/07/2021: 1st meeting with AT. Physiological factors, parameters and values needed for the model were discussed. Initial model was created and tested. Tables with final values and parameters were agreed. Model was approved by both DK and AT.
13/07/2021: Morning meeting. Run a preliminary simulation with a sparce, a medium and a dense grid. Test and validation. Accuracy assessed.
14/07/2021: Morning meeting. Run simulation 1 (length 40 cm, UCI 0.075) sparce grid. Run simulation 2 (length 40 cm, UCI 0.075) medium grid.
15/07/2021: Morning meeting. Run simulation 3 (length 40cm, UCI 0.075) dense grid.
16/07/2021: Morning meeting. Run simulation 4 (length 40cm, UCI 0.2) sparse grid. Run simulation 5 (length 40cm, UCI 0.2) medium grid.
17/07/2021: Morning meeting. Run simulation 6 (length 40cm, UCI 0.2) dense grid. Literature search for studies published after 2018.
18/07/2021: Morning meeting. Run simulation 7 (length 40cm, UCI 0.3) sparce grid.
19/07/2021: Morning meeting. Run simulation 8 (length 40cm, UCI 0.3) medium grid.
20/07/2021: Morning meeting. Run simulation 9 (length 40cm, UCI 0.3) dense grid.
21/07/2021: Morning meeting. Run simulation 10 (length 60cm, UCI 0.066) sparse grid. Discussion on thermal characteristics of the umbilical cord with Prof. Soo Downe.
22/07/2021: Morning meeting. Run simulation 11 (length 60cm, UCI 0.066) medium grid.
23/07/2021: Morning meeting. Run simulation 12 (length 60cm, UCI 0.066) dense grid.
24/07/2021: Morning meeting. Run simulation 13 (length 60cm, UCI 0.2) sparse grid. Meeting with Dr Eleni Asimakopoulou (Lecturer in Fire Engineering, expert in heat transfer and computational mechanics). Discussion on heat transfer/heat flux.
25/07/2021: Morning meeting. Run simulation 14 (length 60cm, UCI 0.2) medium grid.
26/07/2021: Morning meeting. Run simulation 15 (length 60cm, UCI 0.2) dense grid.
27/07/2021: Morning meeting. Run simulation 16 (length 60cm, UCI 0.3) sparse grid.
28/07/2021: Morning meeting. Run simulation 17 (length 60cm, UCI 0.3) medium grid.
29/07/2021: Morning meeting. Run simulation 18 (length 60cm, UCI 0.3) dense grid.
30/07/2021: Morning meeting. Run simulation 19 (length 80cm, UCI 0.075) sparce grid.
31/07/2021: Morning meeting. Run simulation 20 (length 80cm, UCI 0.075) medium grid.
01/08/2021: Morning meeting. Run simulation 21 (length 80cm, UCI 0.075) dense grid.
02/08/2021: Morning meeting. Run simulation 22 (length 80cm, UCI 0.2) sparce grid.
03/08/2021: Morning meeting. Run simulation 23 (length 80cm, UCI 0.2) medium grid.
04/08/2021: Morning meeting. Run simulation 24 (length 80cm, UCI 0.2) dense grid (laptop overheated and shut down. No saved outputs. Run 24 again). Set up of the International Research Network for the study of Biomechanics in Pregnancy and Childbirth.
05/08/2021: Morning meeting. Run simulation 24 again.
06/08/2021: Morning meeting. Run simulation 25 (length 80cm, UCI 0.3) sparce grid.
07/08/2021: Morning meeting. Run simulation 26 (length 80cm, UCI 0.3) medium grid. Meeting: Discussion on future projects and international collaborations via the International Research Network for the study of Biomechanics in Pregnancy and Childbirth.
08/08/2021: Morning meeting. Run simulation 27 (length 80cm, UCI 0.3) dense grid.
09/08/2021: Morning meeting. Outputs and results categorised. Outputs analysed. Tables with results created.
10/08/2021: Morning meeting. Preparation of outputs for depositing in Open Access repository. Metadata files created. Meeting and discussion of the results with two clinicians from Greece.
11/08/2021: Organise dissemination activities (papers/presentation/STMS report) and next steps (grant application).
12/08/2021: Creation of an algorithm (stepwise representation) of the engineering/research problem.

13/08/2021: Drafting the methodology for the first output (scientific publication). Creation of a table of the STSM activities. Project close-out. Lessons learned.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Project's aim and objectives were fully obtained. Based on the average length of the umbilical cord (UC) and the lower (short) and higher (long) 10th percentile, three different UC lengths were studied (40cm, 60cm and 80cm). For each of them an average UCI and two ubnoraml conditions (UCI <10th centile and UCI >90th centile) were investigated: 40cm UCI 0.075, 0.2, 0.3; 60cm UCI 0.066, 0.2, 0.3; 80cm 0.075, 0.2, 0.3. In order to achieve mesh independence for each model a sparce, a medium and a dense grid were used. The percendage difference of both velocity and temperature profiles were calculated less than 5%. Specifically, for the 27 simulations the percendage difference between the sparce and the medium grid ranged from 0.000%-4.119%, and was 0.000%-4.119% between the sparce and dense and medium and dense, and 0.000%-2.462% between the medium and the sparce grid. The results showed that there were significant differences in the temperature of the umbilical artery output depending on both the length of the UC and the UCI. Flow velocity and pressure exhibited a similar behaviour to the temperature. This shows that both UC length and UCI should be taken into consideration during the antenatal period, and there effects should be monitored. Also, the temperature of the umbilical vein ouput was related to the length of the UC.

This highly trans-disciplinary STSM project resulted in new knowledge in the field of the maternal-fetal heat exchange. This is the first study that investigated and calculated the effect of the UC length and UCI in the maternal-fetal heat exchange.
It was unknown how the UC length and UCI affect the maternal-fetal heat transfer and especially the heat that is transfer from the fetus to the mother. Apart from this, pressure was another important parameter revealed from this study. These variations can result to several complications and negative maternal and neonatal outcomes. Understanding the mechanics and the significance of these structural variations, while knowing exactly which parameters they affect, may lead to the prevention of several adverse outcomes.

(Tables with results and outputs cannot be submitted as part of this report, as this work is unpublished and the draft manuscript is currently under preparation. Full results can be submitted separately to the STSM Committee).

FUTURE COLLABORATIONS (if applicable)

Dr Anastasia Topalidou founded the "International Research Network for the study of Biomechanics in Pregnancy and Childbirth". During this STMS I had the chance to participate in the kick-off meeting (network's set-up) and meet researchers from several countries and disciplines. I became member of the Network's Committee representing Greece. This was a unique opportunity to join actively a network that focuses on the biomechanics of pregnancy and childbirth.

In addition, I had the chance to meet Dr Eleni Asimakopoulou and discuss future opportunities and collaborations.

During this STMS the following dissemination and future activities were agreed:

1. Publish the results of the STSM study in a scientific journal
2. Publish a paper describing the engineering problem and the research questions in the field
3. Present the outputs of this STSM in a Conference.
4. Submit a grant application.