Quantitative ultrasound imaging of uterine peristalsis and machine learning for prediction of successful fertilization

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Abstract

Introduction

About 20 % of women at reproductive age have difficulty to become pregnant, with *in-vitro* fertilization (IVF) representing the last-resort treatment. Besides the high cost, IVF success rates remain below 30 %. In IVF, after hormonal stimulation, the produced oocytes are picked up, fertilized *in vitro*, and the formed embryo(s) are transferred back into the uterine cavity. There is increasing evidence that uterine receptivity, supported by favorable uterine peristalsis (UP), plays an important role in successful fertilization (embryo implantation). Spatiotemporal strain analysis by transvaginal ultrasound is here proposed for quantitative UP characterization and prediction of IVF success by machine learning (ML).

Aims and Methods

Uterine strain analysis by ultrasound speckle tracking is adaptively adjusted to the uterine anatomy. We complement frequency and amplitude features with novel features based on UP velocity and coordination, which are extracted by dedicated spatiotemporal analysis through k-space representations (▶ **Fig. 1**). The extracted features were first evaluated in 11 healthy volunteers to differentiate between the different phases of a natural menstrual cycle and then evaluated in 73 IVF patients to predict successful fertilization before embryo transfer. The optimal feature combination was investigated by ML for improved prediction of embryo implantation.

Results

In healthy volunteers, the obtained quantitative feature values are in agreement with those reported in the literature based on qualitative visual inspection.

In IVF patients, significant differences in UP amplitude, frequency, velocity, and coordination are associated with successful fertilization (Table 1), possibly due to reduced microstreaming and shear stress imposed to the embryo.

79.4 % prediction accuracy is obtained by ML (5-fold cross-validation) with only three features (amplitude, velocity, coordination) for all the 73 IVF patients.

Conclusion

Advanced ultrasound UP quantification provides valuable features for prediction of IVF success, which can be further supported by ML predictive modelling. The proposed methods can contribute to improved understanding of UP dynamics and improved decision-making during IVF treatment, potentially leading to increased success rates.

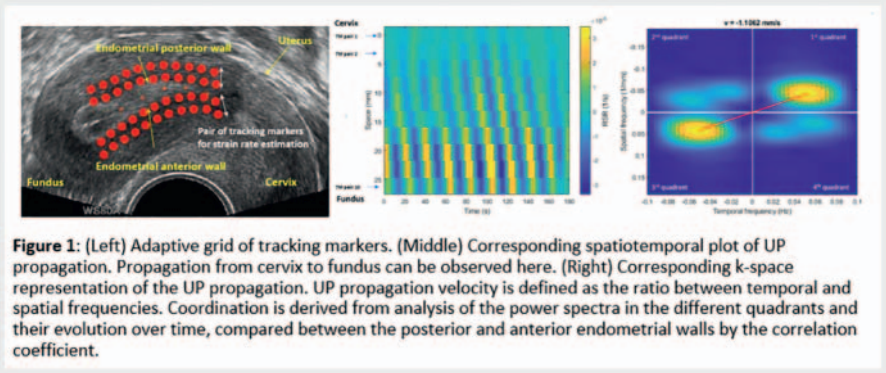

Figure 1: (Left) Adaptive grid of tracking markers. (Middle) Corresponding spatiotemporal plot of UP propagation. Propagation from cervix to fundus can be observed here. (Right) Corresponding k-space representation of the UP propagation. UP propagation velocity is defined as the ratio between temporal and spatial frequencies. Coordination is derived from analysis of the power spectra in the different quadrants and their evolution over time, compared between the posterior and anterior endometrial walls by the correlation coefficient.

Yizhou Huang received the M.Sc. degree in electrical engineering from the Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands, in 2017, and P.D. Eng. diploma in healthcare system design from TU/e in 2019. He is now a Ph.D candidate at TU/e, and his research mainly focuses on ultrasound image processing, especially on motion analysis of the uterus, coronary flow measurements with ultrafast ultrasound and machine learning techniques.