Determination of male reproductive function using microstructural waveguides

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Introduction

According to the World Health Organization (WHO) estimates, nearly 80 million couples are unable to conceive a child without medical assistance, among them 5 million in Russia, which make up 15% of the population of reproductive age .
Male factor infertility occurs in ~40% of couples experiencing infertility. Male infertility can be associated with various congenital and acquired conditions.
Today it is urgent to expand the capabilities of functional testing. Evaluation of male fertility should be a complex process, which includes assessment of lifestyle, psychological state, the general health of the reproductive system, semen parameters. The development of analytical systems based on machine learning algorithms is necessary to process such a quantity of clinical data of patients and identify patterns.

Optical analysis

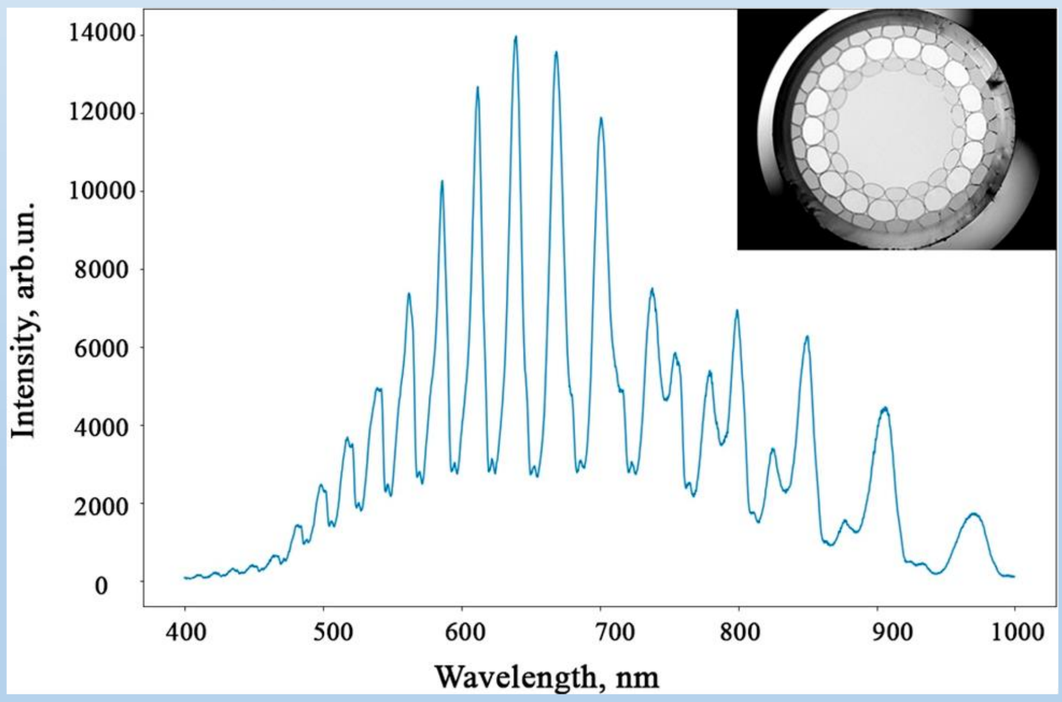

Figure 1. The transmission spectrum of MSWand its cross-section (wavelength, nm)

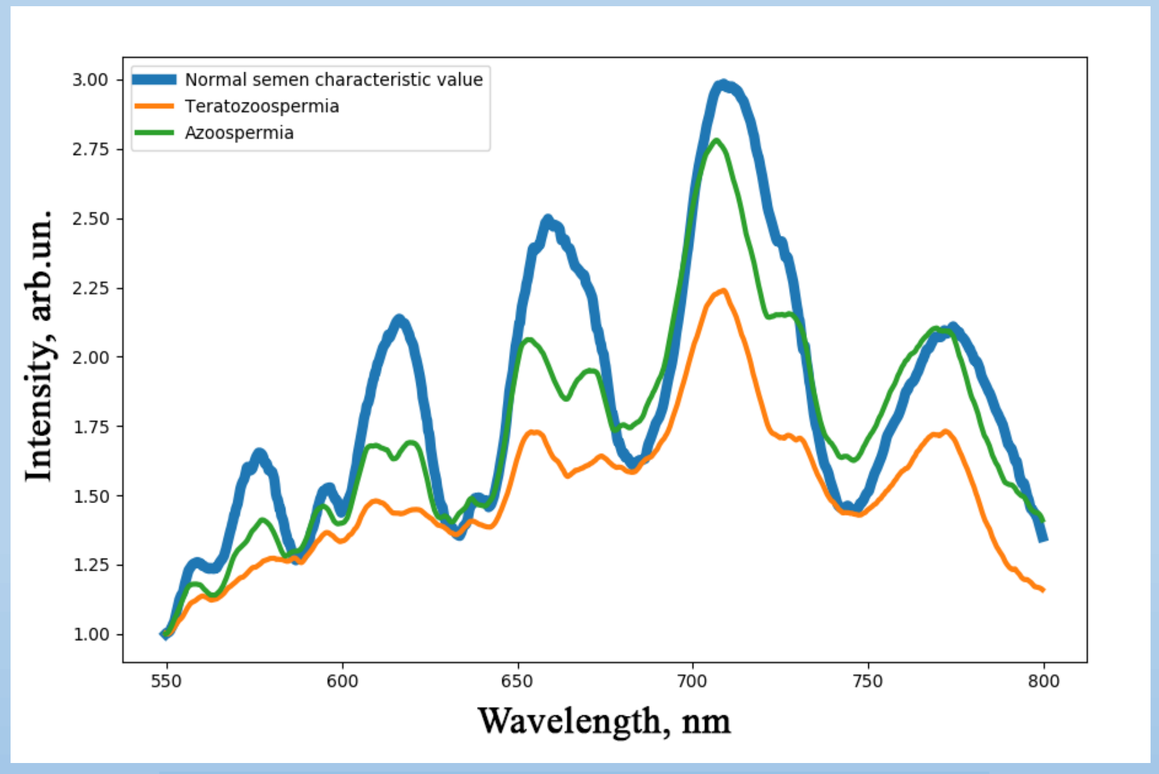

Figure 2. Spectral characteristics of the ejaculate with normal semen characteristic value, teratozoospermia and azoospermia.

Figure 2 shows the averaged spectral characteristics of the ejaculate, corresponding to normal spermogram values and the spectral characteristics of the ejaculate with some pathology.

Material and methods

The first stage of the study was devoted to verify whether ANN based on lifestyle questionnaire might be a valuable tool for preliminary evaluation and prediction of the semen profile. The inclusion criteria were a man aged 18–50 years from an infertile couple and attending infertility clinic for a fertility evaluation. Results of semen examination presented as a semen evaluation category were obtained from 135 men undergoing routine infertility evaluation. All participants were aged between 18 and 61 years and fulfilling inclusion criteria. Each of the participants filled up a questionnaire to assess the following data : age at the time of analysis, coffee consumption, alcohol consumption, smoking habit, occupational exposure to agents that are known to affect spermatogenesis (hot bath, potent drugs, radiation, work in hazardous production), lifestyle assessment (sedentary/active lifestyle, physical exercise), diseases and surgical interventions.
After receiving sperm from patients, it was left to liquefy for 15-60 minutes. Then part of the material was transferred to Eppendorf tubes without any processing (300 µl). The other part was transferred to centrifugation tubes. A table-top centrifuge (ELMI CM-6M) was set at 1900g (3300 rpm) and the semen was centrifuged for 7 minutes. After centrifugation, the upper layer of seminal plasma was carefully discarded and transferred to Eppendorf (300 µl). Then samples were frozen and stored at -20 ° C until spectral characteristics were analyzed using photonic crystal waveguides. In parallel with sample preparation, sperm was analyzed according of WHO recommendations. The concentration and motility of spermatozoa were determined in the Makler chamber. Sperm morphology was analyzed on hematoxylin-eosin stained smears. Patients with azoospermia were excluded from the study.
The second stage of the study is devoted to the analysis of ejaculate and seminal plasma using one of the most promising types of sensors - optical.

Neural network and its processing results

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                multiple                  74496
_________________________________________________________________
dense_1 (Dense)              multiple                  2580
_________________________________________________________________
dense_2 (Dense)              multiple                  210
_________________________________________________________________
dropout (Dropout)            multiple                  0
_________________________________________________________________
dense_3 (Dense)              multiple                  22
=================================================================
Total params: 77,308
Trainable params: 77,308
Non-trainable params: 0
_________________________________________________________________
```

Figure 3. Architecture of the

```
258/258 - 0s - loss: 0.1899 - acc: 1.0000
87/87 - 0s - loss: 0.2299 - acc: 1.0000

acc: 100.00%
```

Figure 4. The result of the work of the NN with training and control data. The spectral characteristics of ejaculate samples are used as input data.

The number of samples corresponding to the normozoospermia and any pathology (oligozoospermia (sperm concentration < 13×10^6/ml of semen), asthenozoospermia (motility<32% spermatozoa with progressive motility) and teratozoospermia).

	Normozoospermia	Pathology
Seminal plasma	35	174
Ejaculate	69	276

As a result of training the neural network on the set of spectral characteristics of ejaculate samples both on the training set (258 samples) and on the test set (87 samples), the neural network showed 100% accuracy (Fig. 4).

```
209/209 - 0s - loss: 0.1675 - acc: 1.0000
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Figure 5. The result of the work of the NN. The spectral characteristics of the samples of seminal plasma are used as input data.

Results and Conclusion

The network developed to evaluate the characteristic of sperm based on the basic questionnaire data about lifestyle proved to be the less efficient. The rate of correct answers was 88% for the training set, and 84% for the control set. Nevertheless, this artificial neural network could be used for preliminary evaluation and prediction of the semen profile.
Diagnosis and therapy of male infertility remain ineffective and are mainly empirical: the incomplete knowledge of the pathophysiology of male infertility, the lack of standard tests for assessing fertility, qualified specialists in the field of andrology and necessary technical resources. It is rather difficult to identify at which spermogram indicators the use of the ART program does not bring the expected result, to compare the results of the ART failures with the indicators of pathozoospermia and to reveal the patterns. For further studies in evaluating male fertility, it is proposed to use a comprehensive system that includes an analysis of the patient's lifestyle, medical history, spermogram and analysis of the spectral characteristics of the ejaculate / seminal plasma. Preliminary results obtained in this work (350 men) show its high promise.

References

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