SOME CONSIDERATIONS ABOUT AN EXPERIMENTAL MODELLING OF THE VAS DEFERENS PHYSIOLOGY

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ABSTRACT
The paper deals with an experimental model, which describes the physiological environment within the vas deferens. For this purpose, special testing equipment is built and includes the following components: a positioning controlling system, a constriction device and a flexible tubing.

The model is applied for a non-invasive reversible vasectomy procedure based on a new medical device, but it may be used to test and to develop other occluding devices implanted on the vessels of the human body with similar properties. By taking into consideration the migration potential of the implant in contact with the sperm propelled by the vas deferens muscles, the device effectiveness is investigated. In order to achieve the device improvement different shapes for the implant head are designed and experimentally tested.

KEY WORDS
Experimental testing, model, vas deferens, constriction device and positioning controlling system

1. Introduction
Currently, the medical device testing has been rapidly developed due to the increased interest for human health. In order to help and to improve the functionality of some organs the devices implanted into the human body are becoming widely used. The experimental testing is an important step and it is necessary to determine the efficiency of implanted devices and to study the interaction relations between the human body and the device.

The paper presents an experimental model capable to replicate the process of sperm propelling within the vas deferens. The proposed model is used for testing and developing of a non-invasive reversible vasectomy device, but it may be also applied for other vessels of the human body with similar properties. The structure of the paper is the following: some characteristics of the vas deferens and sperm are presented in the Section 2. The Section 3 describes the functioning mechanisms of the testing equipment used for experimentally modelling. The experimental results are illustrated in the Section 4. In the Section 5 some conclusions and the future work are presented.

2. The vas deferens physiology
The vas deferens is a 45 cm long muscular tube, which passes upwards from the testis through the inguinal canal behind the bladder where it is joined by the duct from the seminal vesicle to form the ejaculatory duct [1]. There are two and they are surrounded by smooth muscles. The external diameter varies between 2.5-3mm, while the central lumen is very small, its diameter being about one tenth of the total diameter [2].

Figure 1. The mechanism of sperm propelling within the vas deferens

The function of the vas is to transport sperm from the epididymis to the ejaculatory duct during sexual activity. Its lumen is stretchable and it is surrounded by a thick wall of three layers of smooth muscles. The inner and outer layers are arranged longitudinally, whereas the middle layer encircles the ductus deferens [3]. The vas also contains numerous nerves [4]. The smooth muscles...
are non-striated and have a major role because they influence the movement of the sperm within the vessel. The alternate contraction of circular and longitudinal smooth muscle layers produces peristaltic waves, which propel the sperm up along the lumen [5, 6]. The mechanism can be seen in Figure 1. The muscles contract behind the mass of sperm, which is pushed forward into a receiving segment, where the muscles are relaxed. Then, the receiving segment contracts by continuing the forward movement.

3. Materials and Methods

In order to simulate the process of sperm propelled by the action of the vas deferens muscles, special testing equipment is built, which involves a positioning controlling system (PCS), a constriction device (CD) and a flexible tube, as it is shown in the Figure 2. The water is used as the testing liquid.

The general functioning mechanism is the following: when a quantity of liquid is dropped within the tube, the constriction device attached to the PCS is set up so that to be behind the mass of liquid. By writing the desired speed parameters to the controller, the positioning is implemented and the actuator starts to move and together with it, the constriction device, which presses the tube and in the same time the liquid along the tube. Each component of the testing equipment is shortly described in the following sub-sections.

3.1. The Positioning Controlling System

The positioning controlling system is used, because, in accordance with the distance for different measurements, it provides a high accuracy and flexibility related to the control of speed. It has the following representative configuration, which includes the components: the PC-Positioning Controller, the SA-Servo Amplifier, the SMD-Servo Motor Driver, the Drive Mechanism and the VPCS-Visual Positioning Controller Software. By using the Visual Positioning Controller Software, the program in visual format is written to the position controller to implement and control the positioning. The positioning controller gives the positioning speed in command pulses to the servo amplifier, which controls the speed in accordance with the received signals.
The stepping motor driver has a stepper motor that rotates in proportion to the number of input pulses and transmits rotation to the actuator after receiving a signal from servo amplifier. Then, the positioning can be performed at high speed in proportion to the pulse frequency. The drive mechanism is equipped with sensors, actuator and auxiliary devices attached to the actuator, which are also controlled in accordance with the positioning. The drive mechanism converts the rotation motion of the stepping motor into a desired motion (horizontal and/or vertical motion) to move the machine.

### 3.2. The Constriction Device

The constriction device consists of a pair of rollers (Figure 5) attached to a coupling device (Figure 4), which is in direct connection with the moving part of the positioning controlling system. This assembling solution has been designed in order to make easier the contact between rollers and the testing platform. The figure 6 shows the assembly between these two devices.

**Figure 4. The coupling device**

**Figure 5. The constriction device**

**Figure 6. The assembling solution**

### 3.3. The Flexible Tubing

The flexible tubing used for the experimental testing is made of silicone. The figure 7 shows the way in which the constriction device actions on the silicone tube trial by simulating the process of vas deferens muscle contraction.

**Figure 7. The constriction device action on a silicone tubing trial**

### 4. Experimental results

The special equipment described in the Section 3 is applied for the testing of a medical device, which may be used for a possible non-invasive and reversible vasectomy procedure [7]. The testing step is necessary for the analyzing of the device behaviour under the action of the vas deferens and the sperm as well as for the establishing of the implanting site within the vessel. The device may be inserted within the vas deferens, as it can be seen in the Figure 8:

**Figure 8. The device-implanting site**

The main interest is to experimentally investigate the migration potential of the device in contact with the sperm propelled by the vas deferens muscles. For the purpose of the device effectiveness improvement, different shapes of the implant head (flat - Figure 9a, convex - Figure 9b and concave - Figure 9c) are designed.
The range of the velocities used for tests is between 30 mm/s and 150 mm/s. In order to obtain a better simulation of the normal conditions within the vas deferens, the maximum velocity of the liquid (150 mm/s) has been chosen so that to be closely related to the real medium ejaculation velocity of the sperm within the human body.

The experimental results show that at the maximum applied velocity of 150 mm/s the flat head has the best behaviour with a minimum displacement of 7.6 mm, while the concave head has the worst behaviour, with a displacement of 18.4 mm.

5. Conclusions and future work

The experimental model described in this paper simulates the sperm propelling process under the action of the vas deferens muscles. The achieved model has been applied for the testing of an occluding medical device, which may be used on a non-invasive reversible vasectomy procedure.

It is noted that the implant displacement within the vas deferens is influenced by the applied velocity level as well as by the shape of the implant head. Also, the testing results show that the flat head of the device has the best behaviour in comparison with the convex head and the concave head, respectively.

The experimental testing of different solutions designed for the implant head shows that the creating of the physiological environment is an essential step for the device effectiveness improvement. By taking into consideration the experimental results described in this paper the future work will incorporate the investigation, the development and the improvement of some alternative device constructions and further their medical application.

References