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An efficient method for automatic morphological abnormality detection from human sperm images

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ABSTRACT

Background and objective: Sperm morphology analysis (SMA) is an important factor in the diagnosis of human male infertility. This study presents an automatic algorithm for sperm morphology analysis (to detect malformation) using images of human sperm cells.
Methods: The SMA method was used to detect and analyze different parts of the human sperm. First of all, SMA removes the image noises and enhances the contrast of the image to a great extent. Then it recognizes the different parts of sperm (e.g., head, tail) and analyzes the size and shape of each part. Finally, the algorithm classifies each sperm as normal or abnormal. Malformations in the head, midpiece, and tail of a sperm, can be detected by the SMA method. In contrast to other similar methods, the SMA method can work with low resolution and non-stained images. Furthermore, an image collection created for the SMA, has also been described in this study. This benchmark consists of 1457 sperm images from 235 patients, and is known as human sperm morphology analysis dataset (HSMA-DS).
Results: The proposed algorithm was tested on HSMA-DS. The experimental results show the high ability of SMA to detect morphological deformities from sperm images. In this study, the SMA algorithm produced above 90% accuracy in sperm abnormality detection task. Another advantage of the proposed method is its low computation time (that is, less than 9 s), as such, the expert can quickly decide to choose the analyzed sperm or select another one.
Conclusions: Automatic and fast analysis of human sperm morphology can be useful during intracytoplasmic sperm injection for helping embryologists to select the best sperm in real time.

1. Introduction

Infertility is defined as the inability to conceive after 12 months of unprotected intercourse. Almost 15% of couples are infertile and at least 30–40% are attributed to male factor abnormalities [1,2]. Abnormalities in sperm morphology are often recognized as causes of fertility problems and may result to teratozoospermia.

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Sperm quality is an essential parameter which affects oocyte fertilization and embryo quality. There exists a correlation between abnormal sperm and embryo morphology at the later stage of cleavage [3]. Thoroughly, sperm development during spermatogenesis is reflected in the shape of the sperm. Consequently, a defect in sperm maturation causes problems and abnormalities in sperm morphology and its functionality in egg fertilization [4]. Male infertility can be determined by assessing some seminal plasma characteristics and sperm parameters, such as semen viscosity, volume, pH and sperm morphology, vitality, motility, and concentration [5].

In 1992, the first pregnancy and live birth of a child using intra-cytoplasmic sperm injection (ICSI) method occurred [6]. In recent times, ICSI has been used for various couples with normal, mildly, or severely abnormal semen parameters and by all means, in patients needing assisted reproductive technologies [7]. In several studies, the positive correlation between normal sperm morphology and high ICSI outcomes has been proven. In fact, low fertilization, implantation, and conception (pregnancy) rates are well associated with severe abnormalities of the sperm head [8].

Menkveld et al. [9] defined the normal sperm morphology as follows: the length and width of the sperm head are respectively between 3 and 5 μm and between 2 and 3 μm (between three-fifths and two-thirds of the head length) and with a well defined acrosome comprising 40–70% of the sperm head. The midpiece is axially presented as <1 μm in width and its size is one and a half times the head length. Also, the normal tail characteristics must be visible, such as uniformity, uncoiled, thinner than the midpiece, and with length of 45 μm. Cytoplasmic droplets (remnants) which comprised less than half of the sperm's head size can be also present.

In the intracytoplasmic morphologically selected sperm injection (IMSI) procedure, sperm selection is performed at high magnification (usually ×6000) [8]. Although, laboratories are commonly equipped with low magnification (∼×400 and ×600) microscopes, sperm selection by ICSI criteria and injection are routinely performed at these magnifications. The visual assessment of sperm is also usually performed manually. This method is subjective, inexact, non-repeatable, and unteachable. The CASA (computer aided sperm analysis) system is another way of assessing male fertility and it involves the use of different staining procedures [10]. These automatic techniques for analyzing human sperm morphology are essential to avoid human errors and variation in results. Therefore, researches still tend to the newly developed methodology and knowledge enrichment to analyze, classify, and select the best sperm morphology, before using ICSI [11]. As a result, computerized methods to select the best sperm morphology without staining and just before the use of ICSI, will be more suitable for embryologists.

Numerous studies have focused on the computerized selection method. In one of such studies, a fraction of boar spermatozoa heads was computed and an intracellular density distribution pattern was considered as normal by Sanchez et al. [11,12]. In this way, a deviation measure from this model was defined and the deviation from the model for the image of each sperm's head was computed. In the next stage, an optimal value for each cell classification was selected. Using morphological closing, the removal of sperm tails and the filling of holes in the contours of the heads were performed. Then, Otsu's method [13] was used to separate the sperm's heads from the background.

Bijar et al. [10] reported a fully automatic identification and discrimination of sperm parts (acrosome, nucleus, midpiece and tail) in microscopic images of stained human semen smear. In this study, sperm segmentation was performed based on a Bayesian classifier that uses the entropy based expectation-maximization (EM) algorithm and the Markov random field (MRF) model. Thus, sperms were stained and analyzed at a high magnification (×1000). Maree et al. [14] evaluated the influence of different staining methods on human sperm head dimensions and compared these with the fresh ones. Based on different staining methods, the morphometric dimension changes of human sperm head, has been reported [14].

In the aforementioned studies, sperms were fixed, stained, and photographed. Therefore, these stained sperms are not useful for the purpose of ICSI in real time. On the other hand, the proposed method in this study, detects fresh human sperm to injection in real time at low magnifications (×400 and ×600). It has an appropriate level of stability to detect sperm region in image. The key contribution of this research is the ability to work on noisy, low quality, and non-stained images. Furthermore, the proposed algorithm reduces noise without the loss of any information in the image. Another advantage of this study's proposed method is that sperm defects can be detected by low computation cost.

2. Methods

In this study, the sperms of infertile couples who visited infertility therapy center of Alzahra hospital were analyzed, after obtaining informed consent from the couples. This study was approved by the ethics committee of Guilan University of Medical Sciences.

2.1. *Proposed method*

The purpose of this study's algorithm is to enable the effective analysis of sperms in low resolution images. In the first step, the proposed method known as sperm morphology analysis (SMA), detects the region of sperm and then, sperm shape analysis was performed. Every sperm has three main parts: (1) head, (2) neck, and (3) tail. A sperm with abnormality in each of these parts would be considered abnormal sperm and generally have a lower fertilizing potential [5].

The steps in SMA are as shown in Fig. 1. Image noise reduction is the first step of this method. Then, the region of sperms is detected. Thereafter, the main parts of the sperm are analyzed. The details of each step are explained subsequently in this study.

2.2. *Noise reduction*

As a result of the low quality of the images, which were taken with a low magnification microscope, noise reduction is an important pre-processing step. Fig. 2 shows the details of this step.