Identifying Immotile Live Sperm at One Glance: Sperm Viability Classifier Powered by Deep Learning

Aojun Jiang,[1] Jiaqi Wang,[1] Huan Zhao,[2] and Zhuoran Zhang[1]

[1] The Chinese University of Hong Kong (Shenzhen), Shenzhen, China
[2] Luohu People's Hospital, Shenzhen, China

Background

About 20 percent of couples worldwide suffer from infertility, and more than 50 percent of them are due to male reproductive dysfunction. One of the main causes of male infertility is azoospermia. This type of patient has no sperm in the semen and is unable to fertilize oocyte through normal sexual intercourse. The infertility problem can be effectively resolved through IVF, a clinical treatment that involves the collection of sperm through epididymal or testicular puncture. The selection of high quality sperm is crucial. **However, when a sperm is not swimming, it is challenging to judge whether the immotile sperm is viable or not.** We hypothesize that sperm viability information can be reflected by a sperm's morphology in microscopic image. This study aims to test the hypothesis and to develop an AI-based technique to non-invasively predict the viability of immotile sperm using a single image, without invasive sample processing.

Method & Result

Dead/live sperm dataset

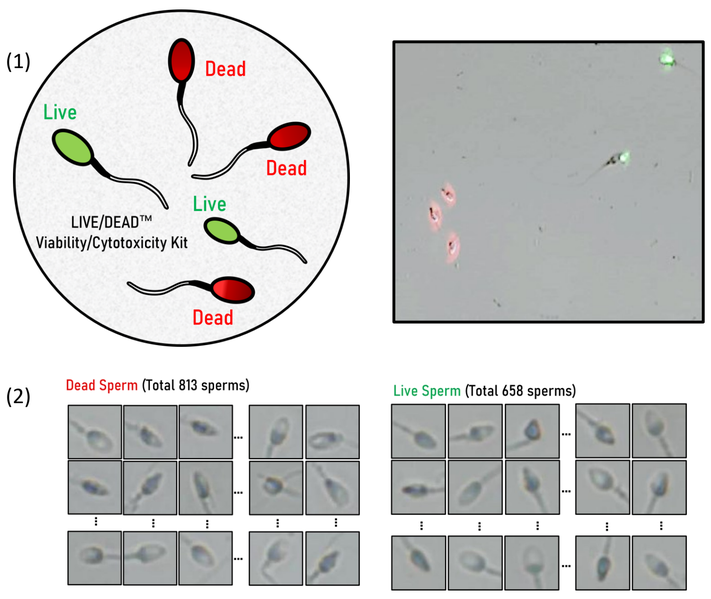


Figure 1 Collection of semen dataset from 10 patients. (1) Staining of dead and live cells using fluorescent dyes, with dead cells stained red and live cells stained green. (2) The collected sperm dataset (813 dead sperm + 658 live sperm).

Highly reproducible sperm detection algorithm

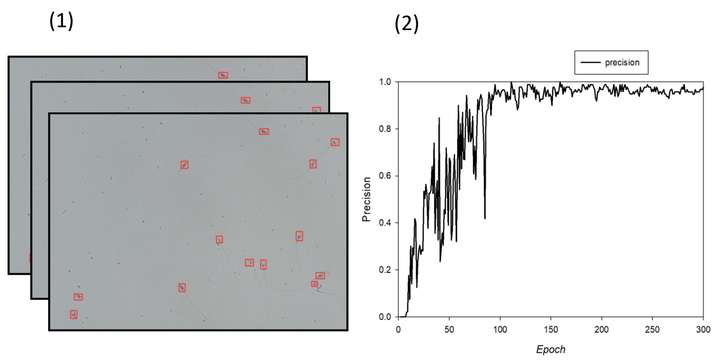


Figure 2 The YOLO v5 algorithm is used for sperm detection. (1) Detection results of the algorithm. (2) Dividing the sperm dataset into training: validation = 8:2, the training results achieved 94.8% detection accuracy. By optimizing the dataset, the algorithm is made reproducible in real medical scenarios with a consistent accuracy of over 90%.

ViT-based algorithm for sperm dead or live prediction

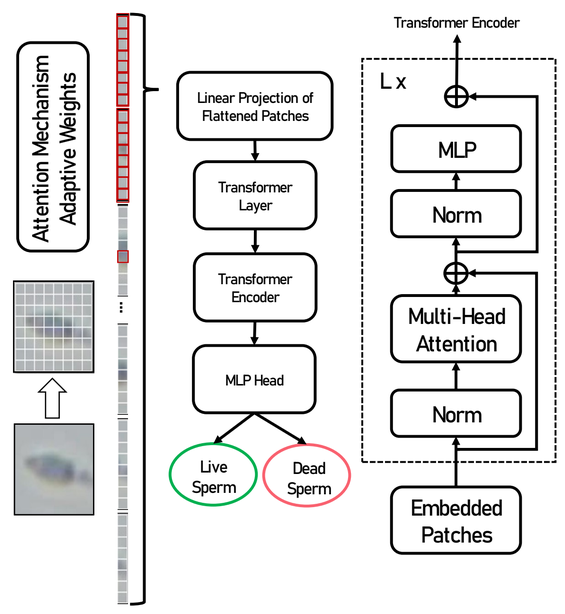
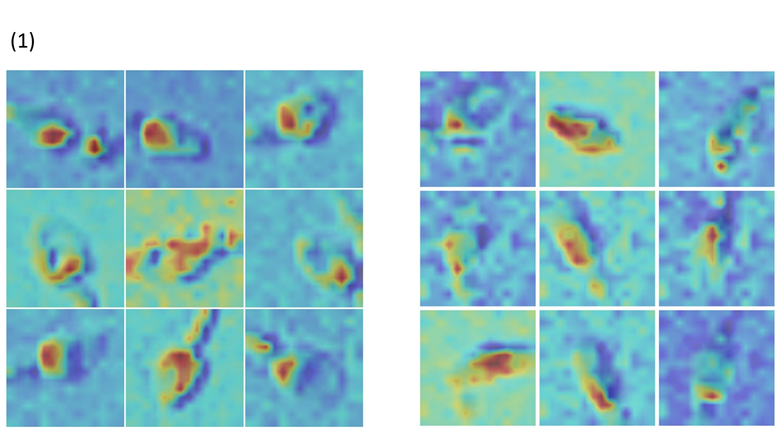


Figure 3 A Vision Transformer was trained to predict sperm viability information from images. The ground truth (live/dead) was obtained from fluorescent labeling.

Exploration of prediction results and attention mechanisms

Figure 4 On blind tests, the developed AI model achieved an accuracy of 94.9%, recall of 97.0%, and specificity of 93.3%. (1) Further by visualizing the model weights, model attention heatmap analysis revealed that the AI model paid more attention to the cell nucleus of sperm, further indicating that morphological changes between live and dead sperm mainly exist in cell nucleus. As a proof-of-concept, the results suggest that sperm morphology in microscopic images could reflect its viability information. (2) The output prediction results.

Statistics	Precision	Accuracy	Recall	Specificity
Percentage	92.0%	94.9%	97.0%	93.3%



Potential Clinical Applications

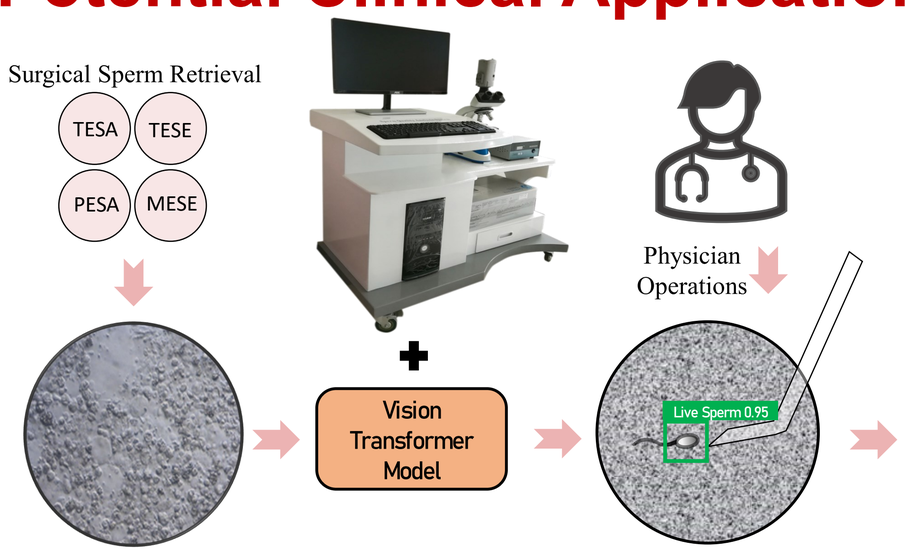


Figure 5 The technique could be applied in various scenarios, from infertility diagnosis to IVF treatment.

(1) For infertility treatment, the technique could facilitate embryologists in picking live sperm from surgically retrieved sperm samples where most sperm are immotile.

(2) For male infertility diagnosis, the technique could be used as an add-on module to current sperm analysis systems to provide instant sperm viability without tedious staining process.

Conclusion

- **We tested and confirmed the hypothesis that microscopic images of immotile sperm inherently contain viability information;**
- **The developed ViT model enables the non-invasive prediction of sperm viability using a single image (at one glance).**
- **The ViT model is able capture subtle morphological changes in sperm nucleus that humans may not be able to reveal.**

香港中文大學（深圳）
The Chinese University of Hong Kong, Shenzhen

MMRL Medical Micro Robotics Lab