Rheotaxis of a sperm cell in shear flow near an infinite plane wall

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Abstract

Mammalian sperm cells must maintain the correct orientation throughout their journey from ejaculation to potential fertilisation. The overall distance typically exceeds 10 cm, while the length of the sperm, from head to tail, is between 50 to 100 μm. In such a long way, how sperm cells find a correct swimming direction? Though many possible navigation factors, such as chemotaxis, geotaxis, thermotaxis, have been suggested, detailed navigation mechanism has not been clarified at all. One newly possible long-distance navigation mechanism, rheotaxis, was reported recently [1]-[3]. In these former studies, human and bull sperm cells were subjected shear flow or Poiseuille flow, and resulted in sperm cells actively swimming against the flow. In the oviduct, where the egg might be fertilised, mucus flows from the ovary down into the uterus. The sperm cells must therefore swim upstream to meet the ovum, with the rheotaxis potentially assisting fertilisation. In this study, we numerically investigated sperm cell locomotion in shear flow near a plane wall, and clarified detailed mechanism of rheotaxis of sperm cells from fluid mechanical aspect [4].

Since small scale of a sperm cell, inertia effects of fluid motion become negligibly small compared to viscous effects, fluid flow around the cell thus can be assumed as Stokes flow. The flow field was then described as a boundary integral equation, which was solved by a boundary element method. We also assumed that free swimming of a sperm cell, and we set force-free and torque-free swimming conditions during the computation.

The results showed that, under shear flow, the sperm was able to hydrodynamically change its swimming direction, allowing it to swim upwards against the flow. We also developed a phase diagram to show the sperm cell motions in parameter space of beat chirality and shear rate strength. We see that the beat chirality dominates the stability of the upstream swimming. To see the upward swimming more detail, we also investigated torque balance of the sperm cell. Contribution of near surface motion to the rotation in the vorticity direction can be stably balanced the shear-induced rotation, which allows the cell to keep staying near the wall, whereas the cell tends to escape from the wall in the unstable upward. These results suggest that the upward swimming of sperm cells can be explained using fluid mechanics, and this can then be used to further understand physiology of sperm cell navigation.

Keywords: **Sperm Cell, Rheotaxis, Stokes Flow, Boundary Element Method.**

References

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