Effect of malaria on the dynamics and rheological properties of blood flow in a microvasculature

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1. Blood flow is pre-requisite for oxygen transport.

Tissue cells need nutrients and oxygen in order to **survive**. It is the **blood flow** which is **oscillatory in nature** that ensures their survival in the body.

The inevitability of blood for **life sustenance** led to modelling its **dynamics**.

This can help in comparing between it healthy and disease state, particularly in **malaria**.

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Unfortunately many existing blood flow models neglect the **physiology of the blood and its residence**, making them **unreliable**.

Hence the need of new model that takes into account the intrinsic behaviour of the blood's environment.

2. Physiological environment of the blood

Capillaries are made of thin monolayer called the endothelial cells (EC) that strongly influence the flow of blood. EC is potent to shear stress which is a crucial hemorheological parameter.

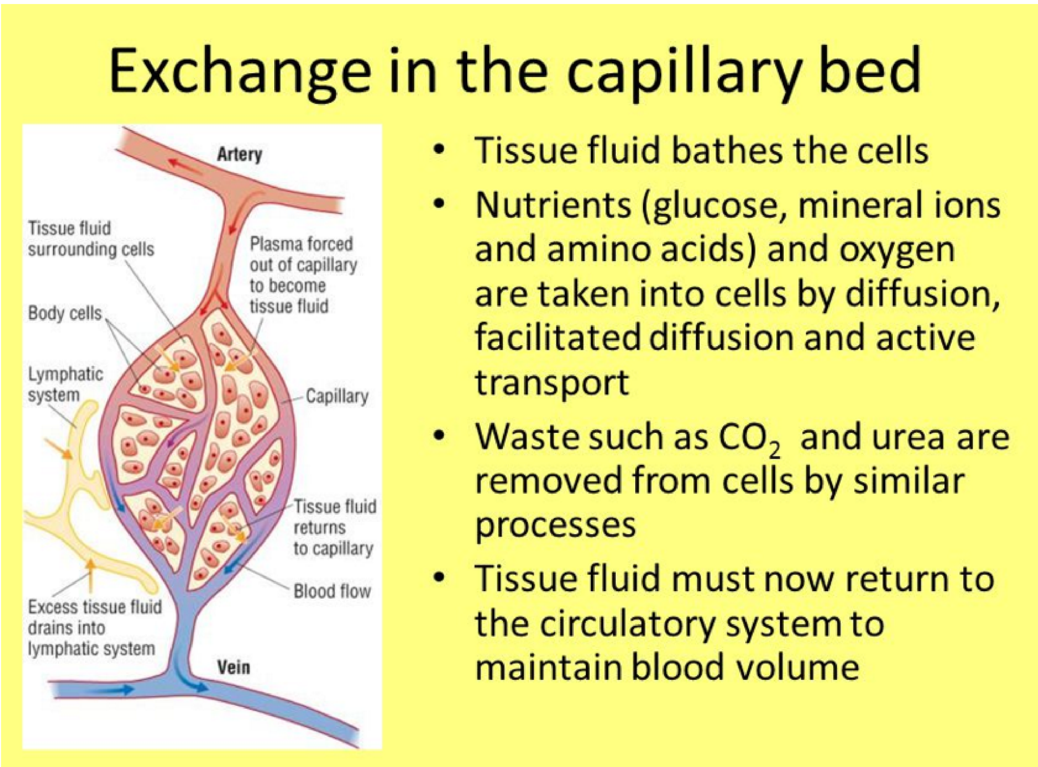

Fig. 1: Illustration showing the Exchange in the capillary bed

Image credit: Eustace Mathew

3. Why malaria?

Malaria is a parasitic disease transmitted form person to person whenever a **mosquito takes blood meal**.

It infects about **500 million** people worldwide and **kills more than 200 million each year**.

Any attempt to reduce its mortality and morbidity will be highly appreciable.

The present malaria diagnostic methods are invasive and have many drawbacks, e.g revelation false negative result and requirement of high skilled staffs among others.

Hence the need for new noninvasive diagnostic method could help to reduce its morbidity and mortality as well as preventing the abnormal use of antimalaria drugs.

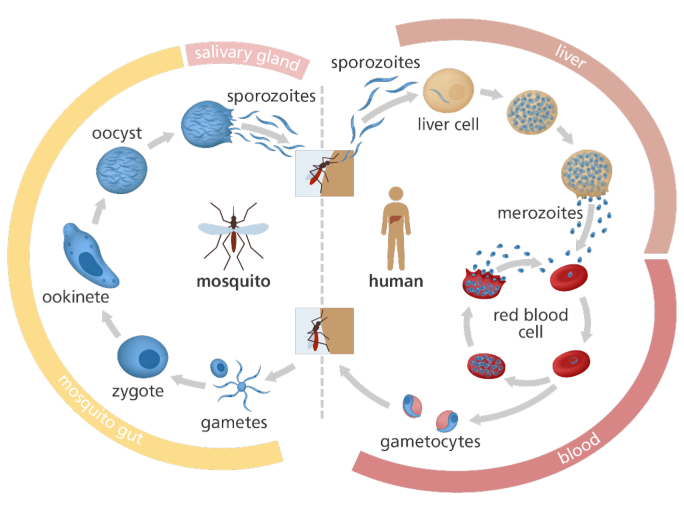

Fig. 2: Illustration showing the life cycle of the malaria parasite

Image credit: Genome Research Limited

4. Blood flow model

Blood is modelled as couple oscillator due to several oscillations that manifest in its dynamics.

$$\begin{cases} \dot{x}_i = -x_i q_i - y_i 2\pi f_i \\ \dot{y}_i = -y_i q_i + x_i 2\pi f_i, \; q_i = \alpha_i((x_i^2 + y_i^2)^{1/2} - a_i) \end{cases}$$

The index i denotes the the ith oscillator thst manifest in the blood dynamics:

- **i= 1 is the heart, i= 2 the respiration,**
- **i= 3 the myogenic, i= 4 the neurogenic,**
- **i= 5 the endothelium, a_i is the amplitude,**
- **f_i the characteristic frequency and α_i is the stability of the limit cycle.**

5. Capturing time varying blood dynamics

- Blood dynamic is measured in micro vessel using laser Doppler flowmetry (LDF).
- It provides insights into the properties of microvascular flow.

Capturing and comparing the blood dynamics in healthy and malaria infected patients will provide useful information for clinical and diagnostics approaches.

300 million lives lost due to malaria will be saved annually.

6. Analysing blood flow time series

The ability to discern the mysterious information contained in a blood flow signal depends on the strength of the analysis.

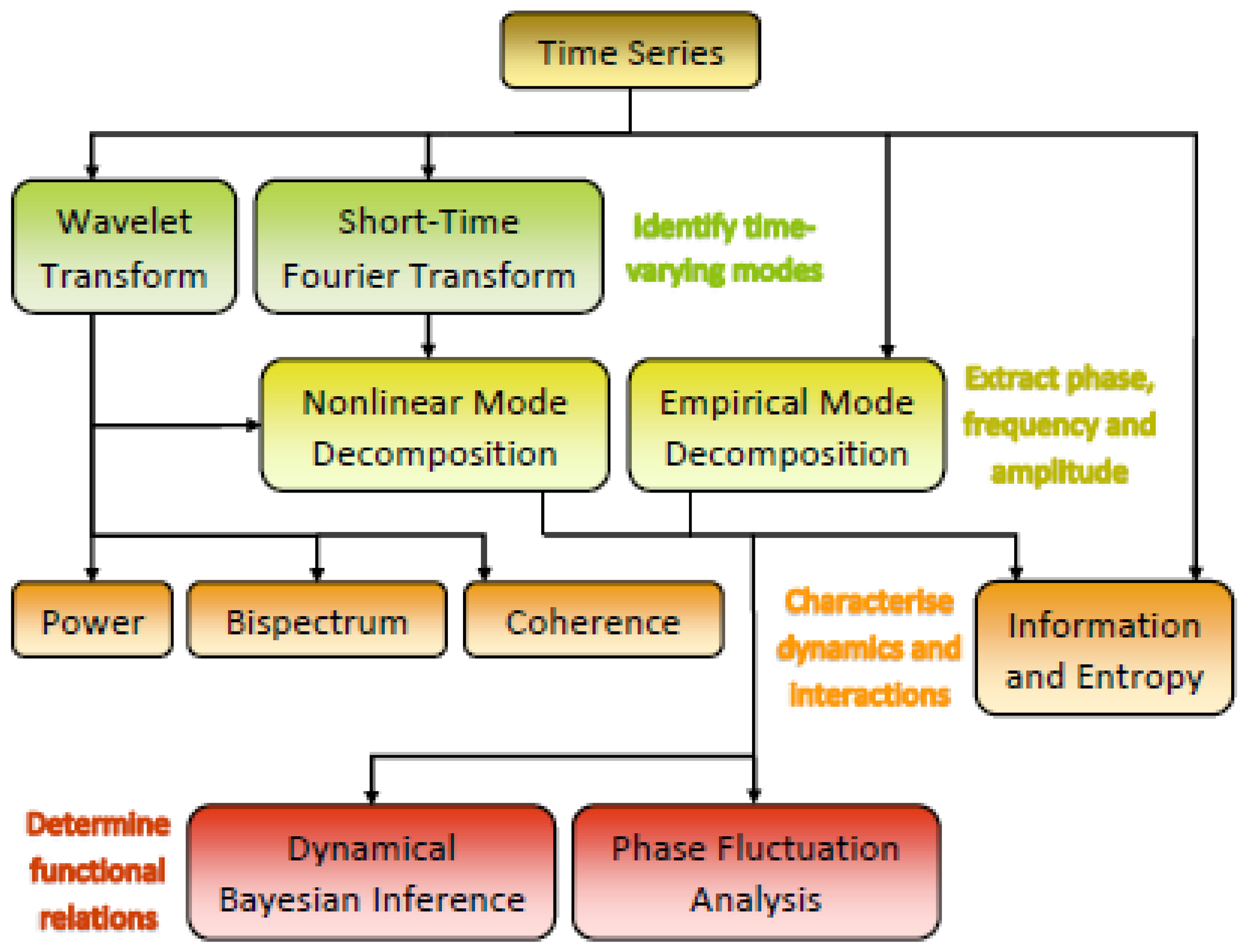

Fig. 3: A sequence of methods used in analysing captured blood dynamics.

7. Conclusion

- High deformability of red cells (RBCs) is a prerequisite for oxygen delivery, but in malaria the parasite invades the RBCs, thus impairing its deformability which is potent to the shear rate.
- This leads to increased rigidity and cytoadherence of the Plasmodium parasitized RBCs with the inner linings of the capillaries, hence hemorheological properties such as blood viscosity are likely to be altered.
- Due to the abnormal adhesion of parasitized RBCs with the endothelium, we will seek evidence of manifestation of these changes in endothelial-related oscillations observed in LDF signal.
- It is therefore proposed that the net result will impair oscillatory processes that manifests in blood dynamics.

8. References

- Lee G.Y.H., Lim C. T. 2007 Biomechanics approaches to studying human diseases. *Trends in biotechnology*.
- Clemson P., Lancaster G. and Stefanovska A. 2015 Reconstructing time-dependent dynamics. *Proceedings of the IEEE*.