Lab 4: Estimating Blood Flow Using Fick's Principle

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1. Introduction

Fick's Principle is a fundamental method used in biomedical engineering to estimate blood flow based on the concentration of a tracer or indicator substance. It relates the amount of a substance delivered to an organ (such as oxygen or dye) with the rate at which it is consumed or accumulated. Where F(t) is the estimated flow, m (t) is the cumulative amount of indicator introduced, and C(t) is the concentration of indicator in the bloodstream. The most important variables in Fick's Principle are the rate of uptake or injection of a substance, concentration of the substance in venous and arterial blood, and determination of blood flow from these values. Measuring the change in concentration after the substance has been injected allows for blood flow to be accurately estimated.

Understanding this method is vital in various real-world medical applications such as cardiac output monitoring and diagnostic imaging.

Key concepts:

Blood flow – Continuous movement of blood that transports oxygen and nutrients throughout the body

Blood concentration – The measurement and analysis of various components and their mass concentrations.

Injection rate – The volume of fluid delivered per unit of time during an injection or infusion.

Integration of signals over time – The analysis and processing signals to extract meaningful information.

2. Methods & Materials

Materials: Computer with MATLAB software

Procedure:

1. **Code implementation**: A MATLAB script was developed to:

- Create a 1-minute time vector with 100 samples
- Simulate the concentration in blood and a constant injection rate
- Use a loop to iterate through the time vector and calculate Fick's method.
- Generate three plots: estimated flow over time, cumulative amount of indicator, and concentration.

3. Results

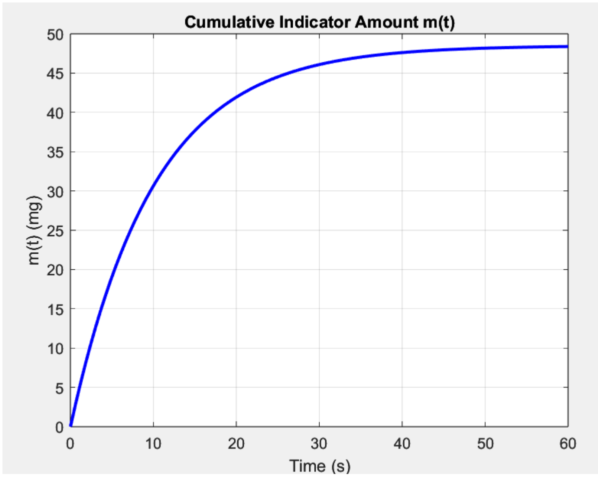

Figure 1- Cumulative Indicator Amount

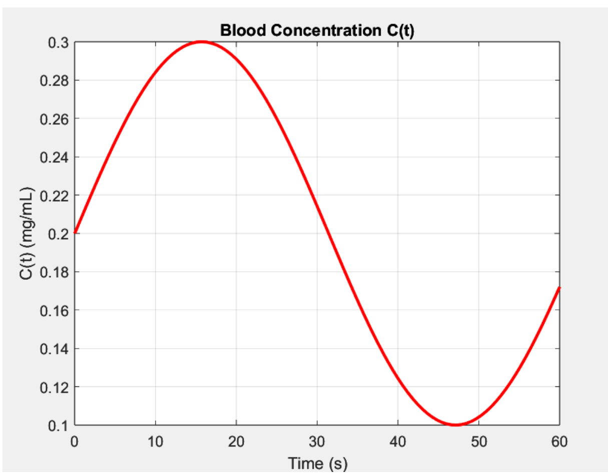

Figure 2- Blood Concentration

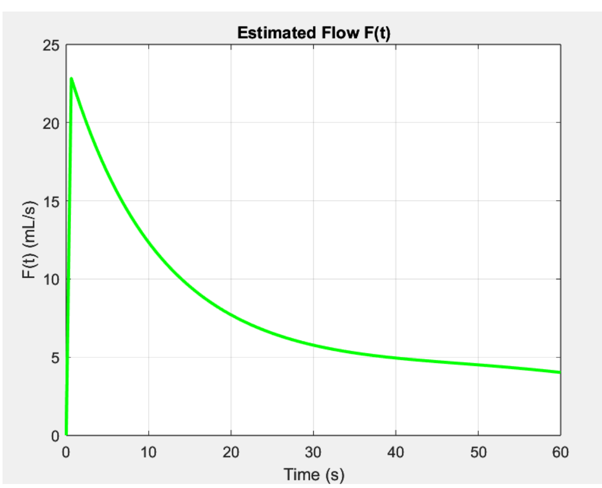

Figure 3- Estimated Flow

Figure 1 showcases the cumulative indicator amount which is a steadily increasing curve reflecting a continuous injection. Figure 2 on the other hand illustrates the indicator concentration in the blood sample and is representative of an initial spoke and gradual tapering. Lastly, figure 3 is the estimated blood flow over time and depicts the stabilization of flow as the indicator reaches equilibrium.

1. How does the estimated flow F(t) behave over time?

The estimated flow initially shows variation as the indicator begins circulating but gradually stabilizes as the indicator disperses uniformly throughout the bloodstream.

2. What could affect the accuracy of this flow measurement in real life?

Factors such as inconsistent injection rate, errors in concentration measurement, mixing delays in the bloodstream, or sensor noise can impact the accuracy of. Biological variability and signal processing artifacts also play a role.

4. Discussion

The results align with theoretical expectations based on Fick's Principle. Initially, the variability in is due to low concentration readings which amplify noise, but as time progresses, measurements stabilize. In a real-world biomedical context, such methods are foundational in non-invasive flow estimation in organs, useful in both diagnostic and therapeutic applications.

One challenge our group faced was understanding the theory behind Fick's Principle and implementing it correctly in a loop structure. We initially had persistent errors in our code due to a lack of conceptual clarity, particularly with how to use cumulative integration in MATLAB. Resolving these bugs took time, trial and error, and collaboration.

5. References

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