Estimation of the blood volume to contact the GILUPI CellCollector®

This report summarizes* some analytical considerations aiming to estimate the volume of blood contacting the GILUPI CellCollector® (DC01) during the application time of 30 minutes in the arm vein.

General assumptions:

- Reynolds number of flow past a cylinder (DC01): $Re_{cc} \approx 6$

$$Re_{cc} = \frac{0.5 * 10^{-3}m * 4 * 10^{-2}\frac{m}{s}}{3.5 * 10^{-6}\frac{m^2}{s}} \sim 6$$

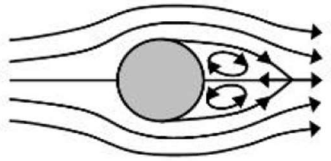
Diameter DC01
Average blood velocity
Kinematic blood viscosity

- Reynolds number of vein flow: $Re_v \approx 36$

$$Re_v = \frac{3 * 10^{-3}m * 4 * 10^{-2}\frac{m}{s}}{3.5 * 10^{-6}\frac{m^2}{s}} \sim 36$$

Diameter vein
Average blood velocity
Kinematic blood viscosity

Based on that, we assume that the flow past the DC01 corresponds to the flow shown in Figure 1 at Re ≈ 20. This flow past a cylinder forms a boundary layer till flow separation, as is shown in Figure 2B.



Re ≈ 20

Figure 1: Model of flow past a cylinder at Reynolds number Re ≈ 20.

Ultrasound analyses indicate that the DC01 is located in an inclined position in the vein, as depicted in Figure 2A. This is of key importance, as a cylinder perpendicular to the flow direction develops a boundary layer of about 300 µm till flow separation. Hence, only a very small central band of path lines is able to contact the DC01 and the major part of the incoming blood is displaced to the side (Figure 2B).

However, in the inclined position, the incoming flow could be separated into two components: a flow component perpendicular to the cylindrical DC01 (described above) and a flow component parallel to the DC01 (Figure 2C). The perpendicular flow is deflected along the DC01, resulting in flow with lower kinetic energy as the neighboring flow layer, which deflects the flow along the DC01 again towards axial direction and thus gains the ability to contact the surface of the DC01

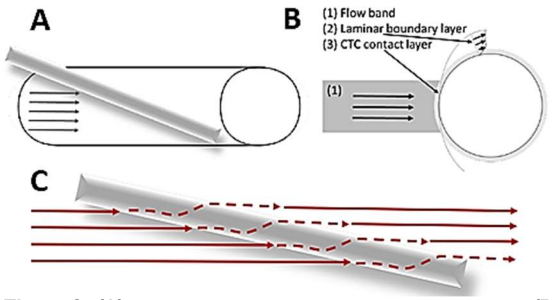


Figure 2: **(A)** Inclined position of the DC01 in the vein. **(B)** Cross-section of a cylinder that is perpendicular to the incoming flow. **(C)** Two flow components along inclined DC01.

Calculation of blood volume

Considering these assumptions, we can approximate the blood volume which is able to contact the DC01, by estimation of the flow through a projection area A_P of the DC01 as well as an averaged velocity in this area (v_{aa}).

$$Projected\ area\ A_p = D_{vein} * D_{DC01}$$
$$Blood\ Volume\ Flow\ V_{DC01} = A_p * v_{aa} * t$$

Based on the Reynolds number Re ≈ 20, a laminar flow with a fully developed parabolic velocity profile could be assumed. In this case, the following approximations can be made for the estimation of the averaged velocity v_{aa} at the DC01: Along a line (2D profile) the averaged velocity v_{aa} is v_{2Dmean}, and v_{2Dm} can be calculated from the average velocity in the vein (v_{3Dmean}):

$$v_{3Dmean} = av.\ velocity\ in\ the\ vein$$
$$v_{max} = 2 * v_{3Dmean}$$
$$\rightarrow v_{aa} = v_{2Dmean} = \frac{2}{3}v_{max} = \frac{4}{3} * v_{3Dm}$$

Consequently, the integrated blood volume flowing through the projected area A_p during a time period t can be calculated:

$$\rightarrow V_{DC01} = D_{vein} * D_{DC01} * \frac{4}{3}v_{3Dmean} * t$$

Mean velocity v_{3Dmean}	Vein diameter 2 mm	3 mm
3 cm/s	72 ml	108 ml
5 cm/s	120 ml	180 ml

Conclusion

The estimated volume of blood, which contacts the surface of the GILUPI CellCollector® during the application time of 30 minutes is in the range between 70 and 180 ml.

*Summarized from report *"GILUPI CellCollector: Estimation of blood volume contacting CellCollector"* by Prof. Dr.-Ing. L. Goubergrits and PD Dr.-Ing. U. Kertzscher, Charité, Berlin, Institute for Imaging Science and Computational Modelling in Cardiovascular Medicine