

**Supplementary Material of Manuscript**

**Vibration motor-integrated low-cost, miniaturized system for  
rapid quantification of red blood cell aggregation**

Bumseok Namgung,<sup>‡a</sup> Taewoo Lee,<sup>‡a</sup> Justin Kok Soon Tan,<sup>ab</sup> Daren  
Kiat How Poh,<sup>a</sup> Soyeon Park,<sup>ab</sup> Kevin Ziyang Chng,<sup>ab</sup> Rupesh  
Agrawal,<sup>c</sup> Sung-Yong Park,<sup>d</sup> Hwa Liang Leo<sup>a</sup> and Sangho Kim<sup>\*abe</sup>

<sup>a</sup> *Department of Biomedical Engineering, National University of Singapore, 9  
Engineering Drive 1, 117575, Singapore.*

<sup>b</sup> *Institute for Health Innovation and Technology, National University of  
Singapore, 117599, Singapore*

<sup>c</sup> *Department of Ophthalmology, National Healthcare Group Eye Institute, Tan  
Tock Seng Hospital, 308433, Singapore*

<sup>d</sup> *Department of Mechanical Engineering, San Diego State University, San  
Diego, CA, 92182, USA*

<sup>e</sup> *The N.1 Institute for Health, National University of Singapore, 117456,  
Singapore*

**‡These authors contributed equally to this work.**

\* Corresponding author:

Sangho Kim, Prof.

Department of Biomedical Engineering, National University of Singapore, 9  
Engineering Drive 1, 117575, Singapore

[bieks@nus.edu.sg](mailto:bieks@nus.edu.sg)

**Table S1.** Comparison matrix of erythrocyte aggregometers

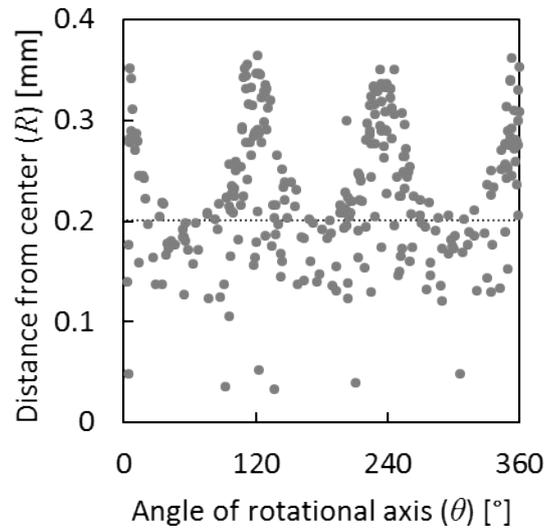
<b>Aggregometer</b>	<b>CVM-based aggregometer</b>	<b>ESR</b>	<b>Myrenne</b>	<b>RheoScan</b>	<b>LoRRca</b>
Price [\$]	~80	150	11,000	23,000	64,000
Size [cm <sup>3</sup> ]	6.5 × 11 × 13	10 × 20 × 20	10 × 30 × 30	28 × 32 × 26	47 × 40 × 30
Blood volume [μL]	6	1,000	35	8	1,000
Key mechanism	Vibration-induced vortex	Red cell sedimentation rate	Rotational cone and plate	Magnetic stirrer	Rotational cylinder

**Table S2.** Cost of each component

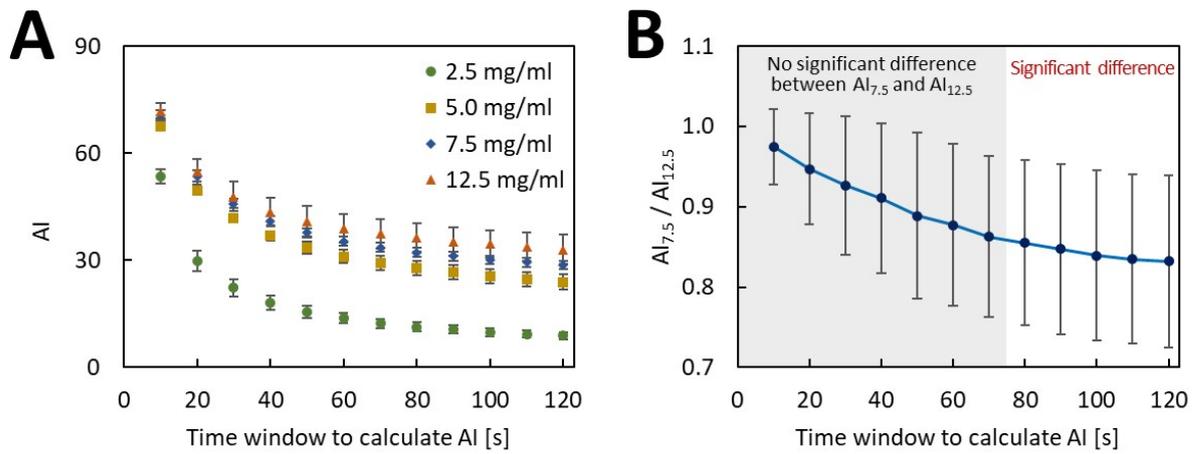
<b>Item</b>	<b>Manufacturer</b>	<b>Qty</b>	<b>Unit price (\$)</b>	<b>Amount (\$)</b>
Raspberry Pi Zero W	Raspberry Pi	1	9.00	9.00
Pi Camera V2	Raspberry Pi	1	13.59	13.59
Double Side Donut Board PC-643	Generic	1	0.20	0.20
Rocker Switch	Generic	1	1.00	1.00
SPST Switch	Generic	1	0.70	0.70
Resistor	Generic	4	0.10	0.40
OLED Screen	Generic	1	12.00	12.00
PowerBoost 1000 Charger	Adafruit Industries	1	15.96	15.96
Lithium Polymer Battery 3.7V 2200mAh	Adafruit Industries	1	1.39	1.39
Coin vibratory motor	Pololu	1	0.80	0.80
Neutral White LED	Luxeon Star LEDs	1	10.40	10.40
Polymer Optics 50° 15 mm Circular Beam Optic	Khathod	1	5.54	5.54
Glass Slide	Citotest	1	0.50	0.50
Spring	Duratool	4	0.03	0.12
3D printed case (Material only)	SmartFile	1	6.50	6.50
<b>Total cost</b>				<b>78.10</b>

**Table S3.** Material parameters for fluid flow simulation.

<b>Material</b>	<b>Property</b>	<b>Value</b>
RBC	Mass [kg]	$1 \times 10^{-12}$
	Density [ $\text{kg m}^{-3}$ ]	1100
Blood	Density [ $\text{kg m}^{-3}$ ]	1125
	Viscosity [Pa s]	$3.2 \times 10^{-3}$



**Figure S1. Localization of scattered particles (Fig. 2F) within the pillar array.** Particles within 0.2 mm from the center of the ROI circulate within the virtual well. During oscillation, particles close to the boundary of the virtual well migrated away from the center ( $R = 0.347 \pm 0.012$  mm) when flowing away from the pillars (at positions  $\theta = 0^\circ, 120^\circ$  or  $240^\circ$ ) and subsequently moved closer to the center ( $R = 0.197 \pm 0.006$  mm) when they approached the pillars (at positions  $\theta = 60^\circ, 180^\circ$  or  $300^\circ$ ).



**Figure S2. Effect of measurement duration on the calculated AI.** **A:** More distinct differences in AI for different aggregating conditions were found with increasing time window. **B:** Difference in AI between 7.5 and 12.5 mg/ml dextran concentrations was plotted against time window. There was no significant difference in the calculated AI below 70 s, but significant difference after 80 s ( $p < 0.05$ ).



**Movie S1.** Demonstration of the CVM-based aggregometer with three simple steps; 1) turn on device, 2) load sample into chip and 3) run test. The test can be done within 4 min.