Supporting Materials

Hydrodynamic determinants of cell necrosis and molecular delivery produced by pulsed laser microbeam irradiation of adherent cells

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Table S1: Values for sharpness S of the error function, plasma threshold energy E_{th}, and plasma threshold irradiance I_{th} for pulse durations of 180–1100 ps.

Pulse duration t_{p} [ps]	Sharpness S $[1/\mu\text{J}]$	Threshold Energy E_{th} [μJ]	Threshold Irradiance I_{th} [W/mm^2]
1100	2.1±0.1	2.13±0.01	3.76 $\times 10^9$
540	2.9±0.2	1.21±0.01	4.35 $\times 10^9$
360	5.0±0.3	0.97±0.01	5.21 $\times 10^9$
280	6.7±0.6	0.86±0.01	5.94 $\times 10^9$
180	8.1±0.3	0.45±0.01	4.85 $\times 10^9$

Table S2: Values for the maximum wall shear stress $\tau_{w,\,max}$ provided by the Gilmore model computed at R_{necr} and R_{perm} 180, 540, and 1100 ps at energies corresponding to $1\times$, $2\times$, $3\times$, and $5\times E_{th}$. The mean and standard deviation $\tau_{w,max}$ for each pulse duration are also shown.

			Maximum wall shear stress $\tau_{w,max}$ [kPa]	
Pulse Duration t_p		E_p [μJ]	@$r = R_{necr}$	@$r = R_{perm}$
180 ps	$1\times$ Threshold	0.45	24 ± 7	12 ± 3
	$2\times$ Threshold	0.90	28 ± 5	15 ± 4
	$3\times$ Threshold	1.35	31 ± 6	12 ± 2
	$5\times$ Threshold	2.25	24 ± 5	11 ± 2
Mean$\pm$SD			27 ± 6	13 ± 3
540 ps	$1\times$ Threshold	1.2	35 ± 7	13 ± 4
	$2\times$ Threshold	2.4	33 ± 6	9 ± 2
	$3\times$ Threshold	3.6	32 ± 5	8 ± 1
	$5\times$ Threshold	6.0	25 ± 4	8 ± 1
Mean$\pm$SD			31 ± 6	10 ± 3
1100 ps	$1\times$ Threshold	2.1	34 ± 7	12 ± 3
	$2\times$ Threshold	4.2	24 ± 4	8 ± 2
	$3\times$ Threshold	6.3	22 ± 3	9 ± 2
	$5\times$ Threshold	10.5	17 ± 2	7 ± 1
Mean$\pm$SD			24 ± 5	9 ± 2
6 ns	$1\times$ Threshold	8.0	28 ± 5	12 ± 2
	$2\times$ Threshold	16.0	15 ± 3	6.2 ± 0.5
	$3\times$ Threshold	24.0	15 ± 2	6.7 ± 0.5
	$5\times$ Threshold	40.0	15 ± 1	6.2 ± 0.4
Mean$\pm$SD			18 ± 4	8 ± 1

Table S3: Values for the shear impulse provided by the Gilmore computed at R_{necr} and R_{perm} for 180, 540, and 1100 ps at energies corresponding to 1×, 2×, 3×, and 5×E_{th}. The mean and standard deviation impulse for each pulse duration are also shown.

			Impulse, J [Pa s]	
Pulse Duration t_p		E_p [μJ]	@$r = R_{necr}$	@$r = R_{perm}$
180 ps	1× Threshold	0.45	$(3.6 \pm 1) \times 10^{-2}$	$(1.8 \pm 0.4) \times 10^{-2}$
	2× Threshold	0.90	$(6.7 \pm 1) \times 10^{-2}$	$(3.4 \pm 1) \times 10^{-2}$
	3× Threshold	1.35	$(9 \pm 2) \times 10^{-2}$	$(3.5 \pm 0.7) \times 10^{-2}$
	5× Threshold	2.25	$(8.5 \pm 2) \times 10^{-2}$	$(3.8 \pm 0.7) \times 10^{-2}$
Mean±SD			$(7 \pm 2) \times 10^{-2}$	$(3.0 \pm 0.8) \times 10^{-2}$
540 ps	1× Threshold	1.2	$(9 \pm 2) \times 10^{-2}$	$(3 \pm 1) \times 10^{-2}$
	2× Threshold	2.4	$(11 \pm 2) \times 10^{-2}$	$(3.1 \pm 0.7) \times 10^{-2}$
	3× Threshold	3.6	$(13 \pm 2) \times 10^{-2}$	$(3.2 \pm 0.4) \times 10^{-2}$
	5× Threshold	6.0	$(13 \pm 2) \times 10^{-2}$	$(3.8 \pm 0.6) \times 10^{-2}$
Mean±SD			$(12 \pm 2) \times 10^{-2}$	$(3.3 \pm 0.8) \times 10^{-2}$
1100 ps	1× Threshold	2.1	$(10 \pm 2) \times 10^{-2}$	$(4 \pm 1) \times 10^{-2}$
	2× Threshold	4.2	$(10 \pm 2) \times 10^{-2}$	$(3.4 \pm 0.7) \times 10^{-2}$
	3× Threshold	6.3	$(11 \pm 1) \times 10^{-2}$	$(4.1 \pm 0.7) \times 10^{-2}$
	5× Threshold	10.5	$(10 \pm 1) \times 10^{-2}$	$(4.1 \pm 0.4) \times 10^{-2}$
Mean±SD			$(10 \pm 2) \times 10^{-2}$	$(3.8 \pm 0.8) \times 10^{-2}$
6 ns	1× Threshold	8.0	$(11 \pm 2) \times 10^{-2}$	$(4.5 \pm 0.7) \times 10^{-2}$
	2× Threshold	16.0	$(7 \pm 2) \times 10^{-2}$	$(2.8 \pm 0.2) \times 10^{-2}$
	3× Threshold	24.0	$(10 \pm 1) \times 10^{-2}$	$(4.2 \pm 0.3) \times 10^{-2}$
	5× Threshold	40.0	$(12 \pm 1) \times 10^{-2}$	$(5.0 \pm 0.3) \times 10^{-2}$
Mean±SD			$(10 \pm 2) \times 10^{-2}$	$(4.1 \pm 0.5) \times 10^{-2}$

Table S4: Laser pulse energy (E_p), mechanical bubble energy (E_B), bubble transduction efficiency (E_B/E_p). number of necrotic cells, number of permeabilized cells, and the ratio of permeabilized cells to necrotic cells for pulse durations of 180, 540, and 1100 ps at energies corresponding to $1\times$, $2\times$, $3\times$, and $5\times E_{th}$.

Pulse Duration t_p [ps]	E_p/E_{th} [–]	E_p [μJ]	E_B [μJ]	E_B/E_p [%]	# Necrotic Cells	# Injected Cells	Inj./Necr. Cells
180 ps	1	0.45	0.02	3.92	4±1	4±2	1.04
	2	0.90	0.07	8.24	7±1	6±4	0.94
	3	1.35	0.14	10.1	8±2	13±5	1.59
	5	2.25	0.27	11.9	15±3	18±8	1.23
540 ps	1	1.2	0.10	8.51	6±1	10±5	1.80
	2	2.4	0.25	10.6	10±2	27±9	2.66
	3	3.6	0.44	12.4	14±2	44±9	3.19
	5	6.0	0.85	14.2	24±5	56±16	2.34
1100 ps	1	2.1	0.17	7.83	8±2	15±7	1.84
	2	4.2	0.44	10.4	20±4	39±14	1.93
	3	6.3	0.71	11.2	25±4	39±13	1.58
	5	10.5	1.29	12.1	42±7	55±16	1.32