

Tharp – Position and Obesity Alter Lung Mechanics in Robotic Surgery

Supplementary Data

Supplementary Table 1 – Bed Angles, Insufflation Pressures, and Esophageal Balloon Depths

	Total	Lean	Overweight	Class I	Obesity	
					Class II	Class III
Trendelenburg angle	30° [14° – 33°]	30° [17° – 33°]	30° [24° – 31°]	29° [23° – 30°]	30° [29° – 31°]	26° [19° – 29°]
Insufflation Pressures (mmHg)	15 [12 – 16]	15 [15 – 15]	15 [15 – 15]	15 [15 – 15]	15 [15 – 15]	15 [12 – 15]
Balloon Depth (cm)	31 [27 – 36]	34 [28 – 35]	32 [30 – 35]	31 [28 – 32]	30 [29 – 32]	30 [29 – 30]

All data presented as median [interquartile range]. Body Mass Index (BMI) categories: lean = BMI <25 kg/m², overweight = BMI 25–29.9, obesity class I = BMI 30–34.9, obesity class II = BMI 35–39.9, obesity class III = BMI ≥ 40.

Supplementary Table 2 – Ventilator Modes

BMI Class	Ventilator Mode	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
< 25	Volume Control	24	23	24	13
	Pressure Control	0	0	0	0
	Spontaneous / Triggered	0	0	0	5
25 – 29.9	Volume Control	26	24	24	7
	Pressure Control	0	0	1	0
	Spontaneous	0	0	0	4
30 – 34.9	Volume Control	16	15	15	9
	Pressure Control	0	0	1	1
	Spontaneous / Triggered	0	0	0	1
35 – 39.9	Volume Control	10	9	10	6
	Pressure Control	0	0	0	0
	Spontaneous / Triggered	0	0	0	1
≥ 40	Volume Control	12	11	11	9
	Pressure Control	1	0	2	0
	Spontaneous / Triggered	0	0	0	2
Total	Volume Control	88	82	84	44
	Pressure Control	1	0	4	1
	Spontaneous / Triggered	0	0	0	13

Body Mass Index, BMI (kg/m^2). Data are presented as number of subjects. Spontaneous / Triggered modes include manual spontaneous, pressure support, continuous positive airway pressure, and synchronized intermittent mandatory ventilation modes.

Supplementary Table 3 – Tidal Volumes

BMI Class	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
< 25	6.4 ± 0.8	6.4 ± 0.9	6.4 ± 0.8	6.5 ± 0.8
25 – 29.9	6.6 ± 0.8	6.7 ± 0.8	6.8 ± 0.8	7.0 ± 1.0
30 – 34.9	6.9 ± 0.8	6.8 ± 0.6	7.0 ± 0.8	6.7 ± 0.8
35 – 39.9	7.1 ± 0.7	7.2 ± 0.6	7.0 ± 0.6	7.1 ± 0.6
≥ 40	7.5 ± 1.0	7.6 ± 0.9	7.3 ± 1.0	7.5 ± 1.1
Average	6.8 ± 0.9	6.8 ± 0.9	6.8 ± 0.8	6.9 ± 1.0

Body Mass Index, BMI (kg/m²). Tidal volumes in mL / kg ideal body weight.
Data presented as mean ± SD.

Supplementary Table 4 – Fraction of Inspired Oxygen

BMI Class	Fraction of				
	Inspired Oxygen	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
< 25	≤ 40%	0	1	2	0
	40 – 70%	17	20	22	16
	≥ 70%	8	4	1	9
25 – 29.9	≤ 40%	2	4	4	2
	40 – 70%	18	19	20	7
	≥ 70%	6	3	2	17
30 – 34.9	≤ 40%	2	4	3	3
	40 – 70%	12	11	11	6
	≥ 70%	2	1	2	7
35 – 39.9	≤ 40%	2	2	1	2
	40 – 70%	8	7	9	4
	≥ 70%	0	1	0	4
≥ 40	≤ 40%	1	1	1	0
	40 – 70%	9	6	6	8
	≥ 70%	4	7	7	6
Total	≤ 40%	7	12	11	7
	40 – 70%	64	63	68	41
	≥ 70%	20	16	12	43

Body Mass Index, BMI (kg/m²). Data are presented as number of subjects.

Supplementary Table 5 – Esophageal Pressures and Chest Wall Mechanical Parameters

Parameter	BMI Class	Stage			
		Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
Esophageal Pressure (cm H ₂ O)	< 25	9.2 ± 3.6	15.1 ± 4.9 *	17.7 ± 4.1 *	10.1 ± 4.1
	25 – 29.9	11.1 ± 4.4	17.5 ± 6.9 *	20.5 ± 6.7 *	10.6 ± 4.8
	30 – 34.9	13.4 ± 3.4 #	19.7 ± 5.4 *	25.5 ± 5.0 * #	13.5 ± 1.7
	35 – 39.9	15.2 ± 5.2 #	23.8 ± 4.8 * #	28.9 ± 4.1 * #	15.6 ± 2.2 #
	≥ 40	18.6 ± 5.5 #	25.9 ± 7.5 * #	29.9 ± 6.2 * #	17.8 ± 6.3 #
Esophageal Driving Pressure (Δcm H ₂ O)	< 25	2.4 ± 0.9	5.9 ± 2.7 *	7.7 ± 2.6 *	2.6 ± 1.1
	25 – 29.9	2.1 ± 1.3	6.7 ± 3.3 *	7.9 ± 3.7 *	1.1 ± 2.1
	30 – 34.9	2.1 ± 1.4	5.9 ± 2.5 *	8.9 ± 2.7 *	1.5 ± 2.0
	35 – 39.9	2.3 ± 1.0	7.0 ± 2.6 *	10.4 ± 3.3 *	3.0 ± 1.3
	≥ 40	2.1 ± 1.7	4.9 ± 3.4 *	7.8 ± 3.7 *	1.4 ± 3.1
End-Expiratory Esophageal Pressure (cm H ₂ O)	< 25	6.8 ± 3.4	9.2 ± 4.3 *	9.9 ± 3.6 *	7.5 ± 4.0
	25 – 29.9	9.0 ± 4.1	10.9 ± 5.4	12.6 ± 5.4 *	9.5 ± 5.4
	30 – 34.9	11.4 ± 3.6 #	13.8 ± 5.5	16.6 ± 5.7 * #	12.0 ± 3.0 #
	35 – 39.9	12.8 ± 5.1 #	16.8 ± 5.2 * #	18.4 ± 5.4 * #	12.6 ± 2.5 #
	≥ 40	16.5 ± 5.8 #	21.1 ± 7.8 * #	22.1 ± 7.0 * #	16.3 ± 5.6 #
Chest Wall Elastance (cm H ₂ O / L)	< 25	7.8 ± 3.2	19.4 ± 8.7 *	24.5 ± 8.9 *	7.3 ± 3.1
	25 – 29.9	6.6 ± 4.0	19.6 ± 10.9 *	22.5 ± 11.3 *	3.1 ± 5.7
	30 – 34.9	6.8 ± 4.8	18.5 ± 8.6 *	26.8 ± 8.7 *	4.5 ± 7.1
	35 – 39.9	7.3 ± 3.0	21.4 ± 7.7 *	32.0 ± 10.0 *	8.4 ± 4.9
	≥ 40	6.0 ± 5.8	13.0 ± 7.8 *	22.9 ± 10.3 *	4.1 ± 8.0
Chest Wall Resistance (cm H ₂ O * L ⁻¹ * sec ⁻¹)	< 25	0.6 ± 0.7	-0.3 ± 0.8 *	-0.5 ± 0.9 *	-0.1 ± 1.0
	25 – 29.9	0.4 ± 0.5	-0.1 ± 0.7 *	-0.3 ± 0.6 *	-0.5 ± 1.6
	30 – 34.9	0.6 ± 0.5	-0.3 ± 0.7 *	-0.2 ± 0.8 *	-0.0 ± 0.8
	35 – 39.9	0.9 ± 0.5	0.6 ± 0.9	0.4 ± 1.0	0.5 ± 0.6
	≥ 40	0.6 ± 0.6	0.0 ± 0.6	-0.1 ± 0.8	0.0 ± 1.4

Body Mass Index, BMI (kg/m²). Data are presented as mean ± standard deviation. P-values from pairwise comparison after generalized estimating equation modeling of BMI and position interaction with Bonferroni correction. * p ≤ 0.001 compared to Baseline within BMI class. || p ≤ 0.001 compared to Pneumoperitoneum within BMI class. # p ≤ 0.001 compared to BMI < 25 kg/m² at a given position.

Supplementary Table 6 – Subjects with Negative End-Expiratory Transpulmonary Pressure

BMI Class	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
< 25	14 (58%)	20 (87%)	20 (83%)	10 (56%)
25 – 29.9	21 (80%)	20 (83%)	24 (96%)	8 (73%)
30 – 34.9	14 (88%)	14 (93%)	15 (94%)	9 (82%)
35 – 39.9	9 (90%)	9 (100%)	10 (100%)	7 (100%)
≥ 40	12 (92%)	10 (82%)	13 (93%)	10 (91%)
Total	70 (79%)	73 (88%)	82 (95%)	44 (80%)

Body Mass Index, BMI (kg/m²).

Data presented as count (% of data points at that position / BMI category)

Supplementary Table 7 – Pulmonary Mechanical Force Partitioning

Parameter	Stage				
	BMI Class	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
Esophageal Plateau Pressure / Airway Plateau Pressure (%)	< 25	74 ± 27	83 ± 23	82 ± 18	69 ± 25
	25 – 29.9	78 ± 29	82 ± 31	79 ± 25	67 ± 28
	30 – 34.9	82 ± 15	88 ± 18	91 ± 14	76 ± 14
	35 – 39.9	80 ± 24	90 ± 8	91 ± 10	79 ± 4
	≥ 40	80 ± 21	88 ± 21	85 ± 15	76 ± 23
Transpulmonary Plateau Pressure / Airway Plateau Pressure (%)	< 25	26 ± 27	17 ± 23	18 ± 18	31 ± 25
	25 – 29.9	22 ± 29	18 ± 31	21 ± 25	33 ± 28
	30 – 34.9	18 ± 15	12 ± 18	9 ± 14	24 ± 14
	35 – 39.9	20 ± 24	10 ± 8	9 ± 10	20 ± 4
	≥ 40	20 ± 21	11 ± 21	15 ± 15	24 ± 23
Esophageal Driving Pressure / Airway Driving Pressure (%)	< 25	38 ± 19	47 ± 23 *	51 ± 20 *	35 ± 21
	25 – 29.9	26 ± 16	43 ± 20 *	42 ± 20 *	11 ± 23
	30 – 34.9	22 ± 15	38 ± 16 *	43 ± 12 *	16 ± 20
	35 – 39.9	20 ± 10 #	37 ± 12 *	44 ± 14 *	25 ± 10
	≥ 40	16 ± 14 #	23 ± 15 * #	31 ± 15 * #	9 ± 23 #
Transpulmonary Driving Pressure / Airway Driving Pressure (%)	< 25	62 ± 19	53 ± 23 *	48 ± 20 *	65 ± 21
	25 – 29.9	74 ± 16	57 ± 20 *	58 ± 20 *	89 ± 23
	30 – 34.9	78 ± 15 #	62 ± 16 *	57 ± 12 *	84 ± 19
	35 – 39.9	80 ± 10 #	63 ± 13 *	56 ± 14 *	75 ± 10
	≥ 40	84 ± 14 #	77 ± 15 * #	69 ± 15 * #	91 ± 23 #

Body Mass Index, BMI (kg/m^2). Esophageal plateau pressure, $P_{es,plat}$. Airway plateau pressure, $P_{aw,plat}$. Transpulmonary plateau pressure, $P_{tp,plat}$. Esophageal driving pressure, ΔP_{es} . Airway driving pressure, ΔP_{aw} . Transpulmonary driving pressure, ΔP_{tp} . Data are presented as mean \pm standard deviation. P-values from pairwise comparison after generalized estimating equation modeling of BMI and position interaction with Bonferroni correction. * $p \leq 0.001$ compared to Baseline within BMI class. # $p \leq 0.001$ compared to BMI < 25 kg/m^2 at a given position.

Supplementary Table 8 – Train of Four Data in each BMI class and Surgical Stage

BMI Class	Baseline	Pneumoperitoneum	Trendelenburg	Desufflation
< 25	14 / 7 / 0 / 1 / 0	12 / 6 / 1 / 2 / 0	7 / 11 / 2 / 1 / 2	1 / 8 / 3 / 2 / 2
25 – 29.9	16 / 7 / 1 / 0 / 0	14 / 7 / 2 / 0 / 0	12 / 9 / 1 / 0 / 1	2 / 5 / 1 / 2 / 1
30 – 34.9	10 / 4 / 1 / 0 / 0	5 / 8 / 1 / 0 / 0	4 / 11 / 0 / 0 / 0	2 / 5 / 1 / 1 / 2
35 – 39.9	7 / 2 / 1 / 0 / 0	7 / 2 / 0 / 0 / 0	6 / 3 / 1 / 0 / 0	2 / 4 / 1 / 0 / 0
≥ 40	7 / 4 / 0 / 0 / 1	6 / 4 / 0 / 0 / 0	6 / 5 / 2 / 0 / 0	2 / 3 / 2 / 1 / 2
Total	54 / 24 / 3 / 1 / 1	44 / 27 / 4 / 2 / 0	35 / 39 / 6 / 1 / 3	9 / 25 / 8 / 6 / 7

Body Mass Index, BMI (kg/m²).

Data are presented as number of subjects with Train of Four counts (0 / 1 / 2 / 3 / 4).

Supplementary Table 9 – Effect of Depth of Neuromuscular Blockade on Pulmonary Mechanics

Parameter	Coefficient	95% Confidence Interval		P-value
Airway Plateau Pressure	0.105	-0.786	0.996	0.818
Airway Driving Pressure	-0.124	-1.056	0.809	0.795
End-Expiratory Airway Pressure	0.275	-0.368	0.917	0.402
Respiratory System Elastance	0.919	-1.580	3.418	0.471
Respiratory System Resistance	-0.189	-1.368	0.990	0.753
Esophageal Plateau Pressure	-0.591	-1.856	0.674	0.360
Esophageal Driving Pressure	0.169	-0.545	0.882	0.643
End-Expiratory Esophageal Pressure	-0.980	-2.203	0.243	0.116
Chest Wall Elastance	1.217	-0.995	3.430	0.281
Chest Wall Resistance	-0.272	-0.564	0.020	0.068
Transpulmonary Plateau Pressure	0.927	-0.393	2.246	0.169
Transpulmonary Driving Pressure	-0.200	-1.064	0.663	0.649
End-Expiratory Transpulmonary Pressure	1.134	-0.249	2.517	0.108
Lung Elastance	0.005	-2.297	2.301	0.997
Lung Resistance	0.124	-0.969	1.217	0.824