Supplementary Table S1. Volume-matched wound infiltration protocol and corresponding study-drug doses by number of operated lumbar segments.

Operated segments (n)	Total infiltration volume (mL)	LB+B group: liposomal bupivacaine volume (mL)	LB+B group: liposomal bupivacaine dose (mg)	LB+B group: 0.5% bupivacaine volume (mL)	LB+B group: plain bupivacaine dose (mg)	RH group: 0.5% ropivacaine volume (mL)	RH group: ropivacaine dose (mg)
2	20	10	133.0	10	50.0	20	100.0
3	30	15	199.5	15	75.0	30	150.0
4	40	20	266.0	20	100.0	40	200.0

Liposomal bupivacaine: bupivacaine liposome injection (Hengrui Pharmaceutical Co., Ltd., Jiangsu, China), 10 mL:133 mg (13.3 mg/mL).

0.5% bupivacaine hydrochloride = 5 mg/mL; 0.5% ropivacaine hydrochloride = 5 mg/mL.

LB+B mixture was prepared 1:1 (v/v); thus, each component accounts for 50% of the total volume (final mixture: 6.65 mg/mL liposomal bupivacaine + 2.5 mg/mL plain bupivacaine).

Total infiltration volume was standardized as 10 mL per operated lumbar segment in both groups (volume-matched).

Dose (mg) = volume (mL) × concentration (mg/mL); values may be rounded.

Supplementary Table S2. Model-based estimated marginal means (EMMs) and exploratory time-point contrasts

Outcome	Time (h)	LB+B EMM (95% CI)	RH EMM (95% CI)	Diff RH−LB+B (95% CI)	*p*	*p* (Holm)	*p* (FDR)
Rest pain-VAS Scores	2	0.85 (0.63–1.06)	1.12 (0.81–1.43)	0.27 (-0.11–0.65)	0.163	0.735	0.407
Rest pain-VAS Scores	6	1.01 (0.74–1.27)	1.32 (0.99–1.66)	0.32 (-0.11–0.74)	0.147	0.735	0.407
Rest pain-VAS Scores	24	1.14 (0.92–1.37)	1.30 (1.01–1.58)	0.15 (-0.21–0.52)	0.406	1.000	0.676
Rest pain-VAS Scores	48	1.44 (1.22–1.66)	1.40 (1.14–1.66)	-0.04 (-0.38–0.30)	0.823	1.000	0.823
Rest pain-VAS Scores	72	1.58 (1.35–1.80)	1.66 (1.38–1.94)	0.08 (-0.28–0.44)	0.660	1.000	0.823
Dynamic pain-VAS Scores	2	2.24 (1.95–2.53)	2.63 (2.30–2.96)	0.39 (-0.06–0.83)	0.088	0.439	0.439
Dynamic pain-VAS Scores	6	2.54 (2.21–2.86)	2.50 (2.23–2.76)	-0.04 (-0.46–0.38)	0.858	1.000	0.858
Dynamic pain-VAS Scores	24	2.70 (2.44–2.95)	2.86 (2.55–3.17)	0.16 (-0.24–0.56)	0.426	1.000	0.540
Dynamic pain-VAS Scores	48	2.90 (2.66–3.14)	3.06 (2.74–3.39)	0.16 (-0.24–0.57)	0.432	1.000	0.540
Dynamic pain-VAS Scores	72	3.20 (2.91–3.48)	3.47 (3.13–3.82)	0.28 (-0.17–0.72)	0.225	0.898	0.540

EMMs and contrasts were derived from the baseline-adjusted GEE models (Exchangeable working correlation; robust SEs). EMMs were estimated at the overall mean baseline VAS. Holm-adjusted p values control the family-wise error rate across the five time-point contrasts within each outcome; FDR p values are Benjamini-Hochberg adjusted.

Supplementary Table S3

Comparison between patients assigned to LB+B Group and patients assigned to RH Group on pain score and opioid consumption over the initial 3 postoperative days.

Time point	LB+B Group (N=44), n (%)			RH Group (N=39), n (%)			Cliff's delta (95% CI) [a]	*p* value
Rest pain-VAS Scores	No-pain	Mild	Moderate	No-pain	Mild	Moderate		
Preoperative	7 (15.9)	36(81.8)	1 (2.3)	1 (2.6)	38(97.4)	0 (0.0)	-0.05 (-0.28, 0.18)	0.697
Postoperative								
Postop-2h	16(36.4)	28 (63.6)	0 (0.0)	11(28.2)	27 (69.2)	1 (2.6)	-0.14 (-0.37, 0.08)	0.241
Postop-6h	14(31.8)	29(65.9)	1 (2.3)	10 (25.6)	28(71.8)	1 (2.6)	-0.17 (-0.40, 0.04)	0.156
Postop-24h	9(20.5)	35 (79.5)	0 (0.0)	8(20.5)	30(76.9)	1 (2.6)	-0.11 (-0.34, 0.12)	0.371
Postop-48h	5 (11.4)	39 (88.6)	0 (0.0)	6 (15.4)	33(84.6)	0 (0.0)	0.02 (-0.22, 0.23)	0.902
Postop-72h	3 (6.8)	40 (90.9)	1 (2.3)	4 (10.3)	35(89.7)	0 (0.0)	-0.08(-0.31, 0.14)	0.508
Dynamic pain-VAS Scores								
Preoperative	1(2.3)	26(59.1)	17(38.6)	0(0.0)	24(61.5)	15(38.5)	-0.09(-0.32, 0.14)	0.436
Postoperative								
Postop-2h	2(4.5)	38(86.4)	4(9.1)	0(0.0)	32(82.1)	7(17.9)	-0.20 (-0.43, 0.02)	0.098
Postop-6h	1(2.3)	39(88.6)	4(9.1)	0(0.0)	35(89.7)	4(10.3)	-0.04 (-0.29, 0.20)	0.711
Postop-24h	0(0.0)	37(84.1)	7(15.9)	0(0.0)	33 (84.6)	6(15.4)	-0.10(-0.35, 0.13)	0.419
Postop-48h	0(0.0)	36(81.8)	8(18.2)	0(0.0)	26(66.7)	13(33.3)	-0.09(-0.33, 0.15)	0.463
Postop-72h	0(0.0)	31(70.5)	13(29.5)	0(0.0)	24(61.5)	15(38.5)	-0.14 (-0.38, 0.09)	0.255
Rescue analgesian,n(%)								
Yes	21(47.73)			22(56.41)			Relative risk [b]	0.429
No	23(52.27)			17(43.59)			0.85(0.56,1.29)	
Rescue opioid consumption (MME)	0(0, 10)			0(0, 10)				0.727

VAS categories were defined as: no pain = 0; mild = 1-3; moderate = 4-6; severe = 7-10. Opioid consumption refers to ward-based rescue tramadol exposure converted to MME over the initial 48 h; flurbiprofen axetil was not included in the MME calculation. PCIA-delivered sufentanil was reported separately.

a Statistical analysis for VAS score (non-normally distributed) was performed using the Cliff's delta via bootstrap resampling (1000 iterations) to quantify the effect size for ordinal categorical data.

b Relative risk was estimated from generalized linear regression model with log link.