

Supplementary Material

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Supplementary Table S1. Comparison of all clinical and laboratory characteristics and outcomes based on the occurrence of anastomotic leakage.

		AL group (n=55)	non-AL group n=301)	P
Gender	Male	48 (87.27%)	241 (80.07%)	0.280
	Female	7 (12.73%)	60 (19.93%)	
Age, year		65.44 (7.2)	64.82 (7.96)	0.640
Hight, m		1.68 (0.07)	1.66 (0.07)	0.077
Weight, kg		65.93 (9.44)	63.93 (10.65)	0.150
BMI, kg/m2		23.41 (3.04)	23.14 (3.51)	0.340
Smoking	yes	23 (41.82%)	126 (41.86%)	1.000
	no	32 (58.18%)	175 (58.14%)	
Alcohol History	yes	23 (41.82%)	112 (37.21%)	0.620
	no	32 (58.18%)	189 (62.79%)	
Past Medical History	yes	21 (38.18%)	145 (48.17%)	0.220
	no	34 (61.82%)	156 (51.83%)	
Hypertension	yes	15 (27.27%)	74 (24.58%)	0.800
	no	40 (72.73%)	227 (75.42%)	
Population Distribution	Rural	8 (14.55%)	39 (12.96%)	0.920
	Urban	47 (85.45%)	262 (87.04%)	
lesion length, cm		3.56 (1.4)	3.15 (1.27)	0.016*
Esophageal Dilation	yes	11 (20%)	26 (8.64%)	0.020*
	no	44 (80%)	275 (91.36%)	
Echocardiogram	unnormal	26 (47.27%)	164 (54.49%)	0.400
	normal	29 (52.73%)	137 (45.51%)	
LVEF, %		0.63 (0.04)	0.63 (0.04)	0.200
Arterial Ultrasound	unnormal	29 (52.73%)	167 (55.48%)	0.820
	normal	26 (47.27%)	134 (44.52%)	
FEV1, L		2.56 (0.57)	2.55 (0.66)	0.910
MVV, %		90.24 (24.76)	87.13 (27.4)	0.410
Laparoscopic Surgery	yes	46 (83.64%)	178 (59.14%)	0.000**
	no	9 (16.36%)	123 (40.86%)	
Surgery Type	Sweet	9 (16.36%)	124 (41.2%)	0.000**
	Ivor-Lewis	1 (1.82%)	22 (7.31%)	
	McKeown	45 (81.82%)	155 (51.5%)	
intraoperative blood loss, ml		117.64 (80.51)	129.27 (96.46)	0.190
conversion to thoracotomy	yes	5 (9.09%)	58 (19.27%)	0.100
	no	50 (90.91%)	243 (80.73%)	
Postoperative Sputum Culture	yes	19 (34.55%)	56 (18.6%)	0.010*
	no	36 (65.45%)	245 (81.4%)	
Chest Drain POD 1, ml		140.55 (158.88)	165.01 (170.04)	0.450
		157.82	171.47	
Chest Drain POD 2, ml				0.650

		(135.31)	(155.01)	
Chest Drain POD 3, ml		108.45	118.93	0.500
		(138.47)	(139.68)	
GID volume on POD 1, ml		53.07 (70.87)	85.68 (103.87)	0.002**
GID volume on POD 2, ml		120.82	196.71	0.000**
		(183.09)	(183.04)	
GID volume on POD 3, ml		127.09	202.61	0.000**
		(170.68)	(186.73)	
Pathology Type	Adenocarcinoma	6 (10.91%)	56 (18.6%)	
	Squamous Cell Carcinoma	47 (85.45%)	229 (76.08%)	
	other	2 (3.64%)	16 (5.32%)	0.310
Tumor Length, cm		4.74 (1.86)	4.57 (2.19)	0.340
Nerve Invasion	no	40 (72.73%)	228 (75.75%)	
	yes	15 (27.27%)	73 (24.25%)	0.760
Margin Status	R0	53 (96.36%)	296 (98.34%)	
	R1	2 (3.64%)	5 (1.66%)	0.660
Tumor T Stage	T1	8 (14.55%)	69 (22.92%)	
	T2	9 (16.36%)	49 (16.28%)	
	T3	35 (63.64%)	174 (57.81%)	
	T4	3 (5.45%)	9 (2.99%)	0.450
Lymph Node Stage	N0	25 (45.45%)	140 (46.51%)	
	N1	14 (25.45%)	75 (24.92%)	
	N2	13 (23.64%)	64 (21.26%)	
	N3	3 (5.45%)	22 (7.31%)	0.950
Total Lymph Nodes		22.42 (8.81)	22.23 (11.51)	0.540
Positive Lymph Nodes		2.02 (3.43)	2.31 (4.45)	0.900
Positive Lymph Node Ratio, %		0.09 (0.14)	0.1 (0.17)	0.870
Ki67, %		50.45 (19.59)	54.9 (20.1)	0.140
Preoperative Total Protein, g/L		66.3 (6.4)	65.82 (5.58)	0.750
Preoperative Alanine Aminotransferase, U/L		13.42 (7.02)	14.67 (9.71)	0.490
Preoperative Albumin, g/L		41.01 (3.78)	41.29 (3.88)	0.550
Preoperative Globulin, g/L		25.29 (4.61)	24.53 (4.1)	0.280
Preoperative Albumin Globulin Ratio,		1.67 (0.32)	1.73 (0.34)	0.250
Preoperative Prealbumin, mg/dL		22.49 (5.18)	21.16 (4.48)	0.086
Preoperative Total Bile Acids, µmol/L		4.47 (5.83)	4.24 (3.26)	0.220
Preoperative Nucleotidase, U/L		5 (2.59)	5.03 (3.04)	0.720
Preoperative Cholinesterase, U/L		7442.81	7152.23	0.290
		(1668.4)	(1580.66)	
Preoperative Glutamate Dehydrogenase, U/L		3.16 (2.49)	4.11 (4.78)	0.035*
Preoperative Aspartate Aminotransferase, U/L		17.16 (5.9)	18.48 (6.86)	0.180
Preoperative Fucosidase, U/L		16.45 (4.07)	15.77 (4.75)	0.140
Preoperative Creatinine, µmol/L		70.47 (12.71)	71.07 (14.56)	0.950
Preoperative Urea, mmol/L		4.93 (1.37)	5.08 (1.5)	0.700

Preoperative Cystatin C, mg/L	0.99 (0.18)	1.03 (0.19)	0.081
Preoperative Uric Acid, $\mu\text{mol/L}$	281.79 (69.53)	276.33 (75.23)	0.810
Preoperative Retinol Binding Protein, mg/L	38.05 (11.66)	35.99 (9.22)	0.260
Preoperative Glucose, mmol/L	5.51 (1.42)	5.38 (1.16)	0.120
Preoperative Potassium, mmol/L	4.11 (0.32)	4.19 (0.35)	0.087
Preoperative Sodium, mmol/L	140.32 (2.33)	140.35 (2.6)	0.820
Preoperative Chloride, mmol/L	103.26 (2.63)	103.76 (2.98)	0.230
Preoperative Calcium, mmol/L	2.27 (0.1)	2.28 (0.12)	0.570
Preoperative Magnesium, mmol/L	0.89 (0.07)	0.9 (0.09)	0.630
Preoperative Phosphorus, mmol/L	1.18 (0.15)	1.19 (0.17)	0.750
Preoperative EGFR, ml/min.m ²	101.46 (16.34)	100.7 (21.09)	0.520
Preoperative Total Bilirubin, $\mu\text{mol/L}$	12.56 (5.69)	11.74 (5.97)	0.310
Preoperative Direct Bilirubin, $\mu\text{mol/L}$	4.5 (1.92)	4.38 (2.17)	0.580
Preoperative Indirect Bilirubin, $\mu\text{mol/L}$	8 (3.99)	7.19 (3.75)	0.200
Preoperative Conjugated Bilirubin, $\mu\text{mol/L}$	1.81 (0.98)	1.63 (0.85)	0.420
Preoperative Sigma Bilirubin, $\mu\text{mol/L}$	2.69 (1.06)	2.73 (1.47)	0.800
Preoperative Lymphocyte Percentage, %	25.09 (7.51)	27.08 (8.21)	0.080
Preoperative Monocyte Percentage, %	7.82 (2)	8.05 (2.41)	0.720
Preoperative Eosinophil Percentage, %	1.95 (1.94)	2.07 (1.94)	0.310
Preoperative Basophil Percentage, %	0.5 (0.27)	0.54 (0.29)	0.360
Preoperative Neutrophil Count, $\times 10^9/\text{L}$	4.15 (1.84)	3.78 (1.73)	0.120
Preoperative Lymphocyte Count, $\times 10^9/\text{L}$	1.48 (0.42)	1.53 (0.49)	0.780
Preoperative Monocyte Count, $\times 10^9/\text{L}$	0.48 (0.17)	0.47 (0.18)	0.530
Preoperative Mean Platelet Volume, fL	10.18 (1.05)	9.99 (0.81)	0.440
Preoperative WBC Count, $\times 10^9/\text{L}$	6.25 (1.92)	5.93 (1.98)	0.160
Preoperative Eosinophil Count, $\times 10^9/\text{L}$	0.11 (0.11)	0.12 (0.11)	0.560
Preoperative Basophil Count, $\times 10^9/\text{L}$	0.03 (0.02)	0.03 (0.02)	0.680
Preoperative RBC, $\times 10^{12}/\text{L}$	4.41 (0.44)	4.21 (0.52)	0.004**
Preoperative Hb Concentration, g/L	136.23 (14.86)	130 (18.16)	0.014*
Preoperative Hematocrit, %	41.75 (4.02)	38.85 (5.14)	0.000**
Preoperative Mean Corpuscular Volume, fL	93.84 (5.1)	93.53 (6.01)	0.960
Preoperative Mean Hb Content, pg	30.93 (1.94)	30.92 (2.42)	0.520
Preoperative Mean Hb Concentration, g/l	329.6 (10.32)	330.46 (11.9)	0.410
Preoperative Platelet Count, $10^9/\text{L}$	230.75 (53.54)	237.51 (66.46)	0.630
Preoperative Neutrophil Percentage, %	64.64 (9.26)	62.26 (9.42)	0.086
Preoperative Platelet Distribution Width, fL	11.83 (2.08)	11.32 (1.88)	0.120
Preoperative Large Platelet Ratio, %	26.37 (8.13)	24.78 (6.58)	0.330
Postoperative Alanine Aminotransferase, U/L	28.3 (27.07)	28.89 (33.43)	0.990
Postoperative Aspartate Aminotransferase, U/L	38.54 (20.79)	43.14 (29.48)	0.120
Postoperative Glutamate Dehydrogenase, U/L	7.87 (10.45)	8.17 (24.82)	0.790
Postoperative Glucose, mmol/L	8.11 (3.15)	7.46 (3.15)	0.066
Postoperative Total Protein, g/L	58.73 (5.62)	59.3 (5.49)	0.510
Postoperative Albumin, g/L	36.28 (3.99)	35.83 (4.47)	0.830
Postoperative Uric Acid, $\mu\text{mol/L}$	183.08 (63.2)	184.87 (80.2)	0.790

Postoperative Retinol Binding Protein, mg/L	22.19 (8.22)	22.43 (8.13)	0.850
Postoperative Magnesium, mmol/L	0.83 (0.1)	0.8 (0.11)	0.044*
Postoperative Globulin, g/L	22.45 (3.82)	23.47 (4.64)	0.130
Postoperative Albumin Globulin Ratio, 0	1.66 (0.32)	1.59 (0.38)	0.130
Postoperative Total Bile Acids, μ mol/L	1.51 (1.85)	1.23 (1.06)	0.970
Postoperative Prealbumin, mg/dL	15.52 (4.32)	15.82 (4.43)	0.530
Postoperative Nucleotidase, U/L	3.69 (1.78)	3.88 (1.98)	0.300
Postoperative Cholinesterase, U/L	6222.63 (1541.58)	6210.23 (1517.06)	0.790
Postoperative Fucosidase, U/L	20.38 (4.6)	18.28 (5.11)	0.003**
Postoperative Urea, mmol/L	6.3 (2.15)	6.38 (2.33)	0.970
Postoperative Creatinine, μ mol/L	72.43 (17.89)	71.44 (20.42)	0.590
Postoperative Cystatin C, mg/L	0.92 (0.18)	0.92 (0.24)	0.250
Postoperative Potassium, mmol/L	4.29 (0.37)	4.34 (0.52)	0.820
Postoperative Sodium, mmol/L	136.16 (3.08)	136.51 (3.56)	0.480
Postoperative Chloride, mmol/L	101.64 (3.18)	102.44 (4.04)	0.260
Postoperative Calcium, mmol/L	2.12 (0.11)	2.12 (0.13)	0.660
Postoperative Phosphorus, mmol/L	0.79 (0.26)	0.87 (0.29)	0.061
Postoperative EGFR, ml/min.m2	101.04 (24.26)	100.79 (25.83)	0.940
Postoperative Total Bilirubin, μ mol/L	13.51 (8.36)	12.79 (6.59)	0.870
Postoperative Direct Bilirubin, μ mol/L	5.4 (2.8)	5.21 (2.57)	0.670
Postoperative Indirect Bilirubin, μ mol/L	7.75 (4.93)	7.39 (4.48)	0.750
Postoperative Conjugated Bilirubin, μ mol/L	2.27 (1.33)	1.88 (1.27)	0.047*
Postoperative Sigma Bilirubin, μ mol/L	3.05 (1.9)	3.12 (1.78)	0.520
Postoperative Lymphocyte Count, $\times 10^9$ /L	0.74 (0.29)	0.83 (0.4)	0.260
Postoperative Basophil Count, $\times 10^9$ /L	0.02 (0.01)	0.02 (0.01)	0.630
Postoperative RBC, $\times 10^{12}$ /L	4.19 (0.53)	4.04 (0.55)	0.047*
Postoperative Mean Corpuscular Volume, fL	94.13 (5.06)	94.1 (5.87)	0.860
Postoperative Mean Hb Content, pg	31.27 (2.12)	31.2 (2.55)	0.920
Postoperative Mean Hb Concentration, g/l	332.29 (11.89)	331.44 (15.18)	0.630
Postoperative Platelet Count, 10^9 /L	187.58 (53.67)	198.77 (65.86)	0.290
Postoperative Platelet Distribution Width, fL	12.97 (2.16)	12.82 (2.29)	0.560
Postoperative Large Platelet Ratio, %	30.92 (7.8)	29.5 (7.6)	0.280
Postoperative Monocyte Percentage, %	6.67 (2.16)	6.29 (2.23)	0.220
Postoperative Basophil Percentage, %	0.18 (0.1)	0.19 (0.12)	0.840
Postoperative WBC Count, $\times 10^9$ /L	12.53 (3.35)	12.44 (4.16)	0.550
Postoperative Hb Concentration, g/L	130.96 (17.3)	125.61 (17.44)	0.038*
Postoperative Hematocrit, %	39.4 (4.84)	37.87 (4.86)	0.033*
Postoperative Neutrophil Percentage, %	86.77 (3.78)	86.1 (4.61)	0.410
Postoperative Mean Platelet Volume, fL	10.75 (0.96)	10.57 (0.96)	0.290
Postoperative Neutrophil Count, $\times 10^9$ /L	10.91 (3.11)	10.8 (3.91)	0.540
Postoperative Monocyte Count, $\times 10^9$ /L	0.83 (0.33)	0.76 (0.33)	0.160
Postoperative Eosinophil Count, $\times 10^9$ /L	0.04 (0.07)	0.04 (0.06)	0.990
Postoperative Lymphocyte Percentage, %	6.07 (2.33)	7.06 (3.3)	0.081

Postoperative Eosinophil Percentage, %	0.31 (0.53)	0.36 (0.69)	0.960
Postoperative C reactive protein, mg/L	127 (64.48)	110.36 (63.17)	0.068
Total Protein difference, g/L	7.57 (7.33)	6.52 (6.22)	0.320
Alanine Aminotransferase difference, U/L	-14.88 (25.27)	-14.22 (33.4)	0.590
Albumin difference, g/L	4.73 (4.56)	5.46 (4.7)	0.520
Globulin difference, g/L	2.84 (4.13)	1.06 (4.49)	0.008**
Albumin Globulin Ratio difference,	0.01 (0.28)	0.14 (0.34)	0.002**
Prealbumin difference, mg/dL	6.97 (4.96)	5.34 (4.39)	0.031*
Total Bile Acids difference, μ mol/L	2.96 (5.86)	3.01 (3.37)	0.110
Nucleotidase difference, U/L	1.31 (1.64)	1.14 (2.08)	0.300
Cholinesterase difference, U/L	1220.18 (1287.24)	942 (1289.01)	0.160
Glutamate Dehydrogenase difference, U/L	-4.71 (10.09)	-4.06 (25.35)	0.057
Aspartate Aminotransferase difference, U/L	-21.38 (20.09)	-24.66 (29.55)	0.440
Fucosidase difference, U/L	-3.94 (4)	-2.51 (4.14)	0.030*
Creatinine difference, μ mol/L	-1.96 (12.83)	-0.37 (14.62)	0.210
Urea difference, mmol/L	-1.37 (2.14)	-1.3 (2.48)	0.560
Cystatin C difference, mg/L	0.06 (0.17)	0.11 (0.19)	0.059
Uric Acid difference, μ mol/L	98.71 (74.01)	91.47 (74.82)	0.450
Retinol Binding Protein difference, mg/L	15.85 (9.3)	13.56 (8.66)	0.093
Glucose difference, mmol/L	-2.6 (2.81)	-2.08 (2.97)	0.100
Potassium difference, mmol/L	-0.18 (0.48)	-0.15 (0.56)	0.340
Sodium difference, mmol/L	4.16 (3)	3.84 (3.68)	0.490
Chloride difference, mmol/L	1.63 (3.07)	1.32 (4.31)	0.630
Calcium difference, mmol/L	0.14 (0.11)	0.15 (0.14)	0.850
Magnesium difference, mmol/L	0.06 (0.1)	0.09 (0.12)	0.027*
Phosphorus difference, mmol/L	0.39 (0.26)	0.32 (0.32)	0.098
EGFR difference, ml/min.m2	0.42 (18.27)	-0.09 (20)	0.630
Total Bilirubin difference, μ mol/L	-0.96 (7.22)	-1.05 (5.8)	0.310
Direct Bilirubin difference, μ mol/L	-0.9 (2.37)	-0.83 (2.2)	0.890
Indirect Bilirubin difference, μ mol/L	0.25 (4.3)	-0.2 (3.97)	0.150
Conjugated Bilirubin difference, μ mol/L	-0.46 (1.04)	-0.26 (1.21)	0.250
Sigma Bilirubin difference, μ mol/L	-0.36 (1.79)	-0.4 (1.54)	0.460
Lymphocyte Percentage difference, %	19.03 (6.95)	20.01 (7.99)	0.350
Monocyte Percentage difference, %	1.15 (2.27)	1.76 (2.75)	0.110
Eosinophil Percentage difference, %	1.64 (1.63)	1.71 (1.74)	0.640
Basophil Percentage difference, %	0.32 (0.26)	0.35 (0.26)	0.320
Neutrophil Count difference, $\times 10^9/L$	-6.76 (3.02)	-7.02 (3.52)	0.940
Lymphocyte Count difference, $\times 10^9/L$	0.74 (0.38)	0.71 (0.48)	0.410
Monocyte Count difference, $\times 10^9/L$	-0.35 (0.32)	-0.29 (0.3)	0.190
Mean Platelet Volume difference, fL	-0.58 (0.53)	-0.58 (0.67)	0.740
WBC Count difference, $\times 10^9/L$	-6.28 (3.2)	-6.51 (3.64)	0.990
Eosinophil Count difference, $\times 10^9/L$	0.07 (0.08)	0.08 (0.11)	0.870
Basophil Count difference, $\times 10^9/L$	0.01 (0.01)	0.01 (0.02)	0.460

RBC difference, $\times 10^{12}/L$	0.21 (0.5)	0.17 (0.46)	0.450
Hb Concentration difference, g/L	5.26 (16.36)	4.39 (14.4)	0.610
Hematocrit difference, %	2.34 (5.24)	0.99 (4.29)	0.079
Mean Corpuscular Volume difference, fL	-0.3 (2.27)	-0.57 (2.49)	0.260
Mean Hb Content difference, pg	-0.34 (1)	-0.28 (1.36)	0.530
Mean Hb Concentration difference, g/l	-2.69 (10.52)	-0.97 (14.09)	0.230
Platelet Count difference, $10^9/L$	43.16 (43.41)	38.74 (45.29)	0.570
Neutrophil Percentage difference, %	-22.13 (8.57)	-23.84 (9.31)	0.190
Platelet Distribution Width difference, fL	-1.15 (1.89)	-1.49 (2.11)	0.460
Large Platelet Ratio difference, %	-4.55 (4.1)	-4.72 (4.66)	0.990

Qualitative data are presented as frequency (percentage), and Chi-square tests were applied to compare categorical data. Quantitative data are presented as mean (standard deviation), and independent sample t-tests were conducted for comparison. *denotes $\geq 0.01p < 0.05$, ** denotes $p < 0.01$.

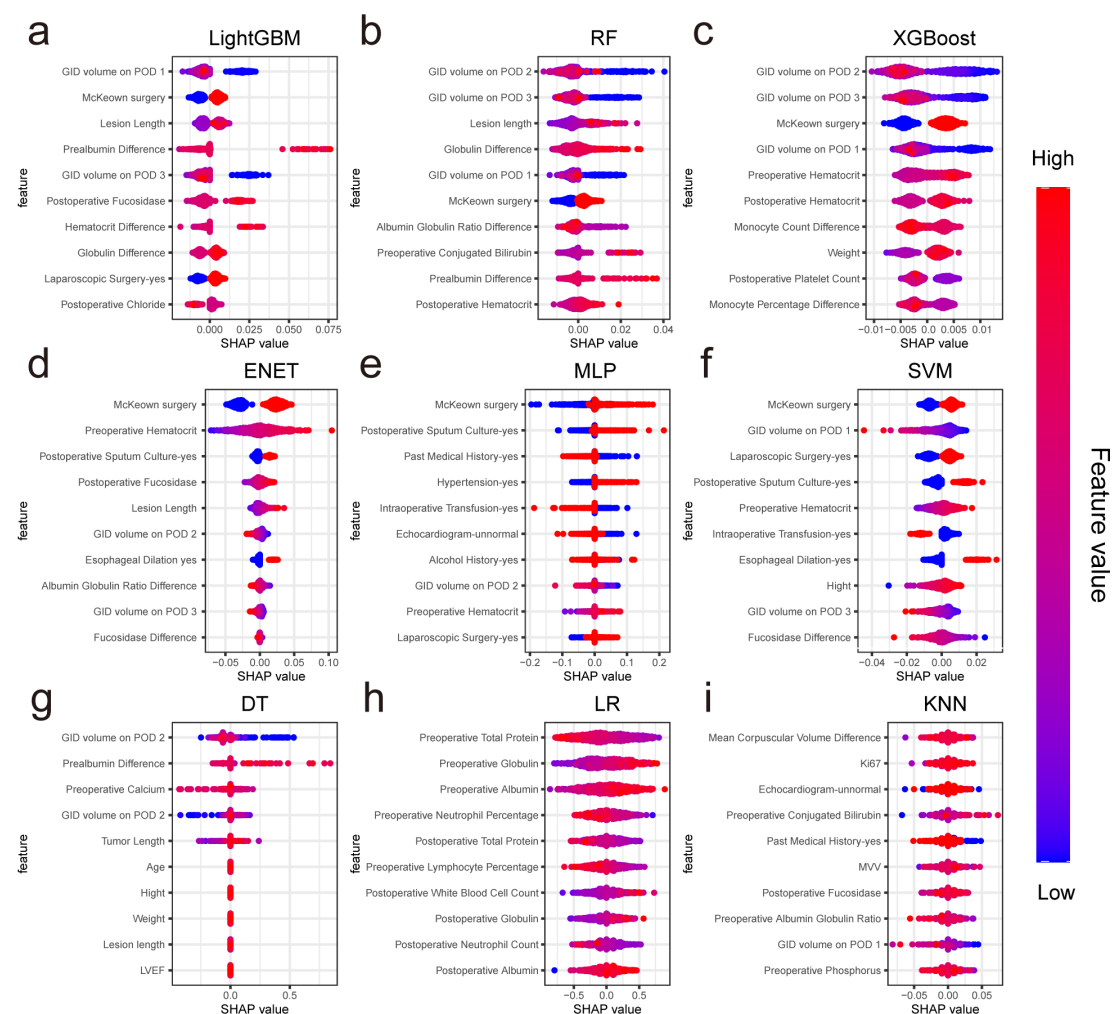
Abbreviations: **AL**: anastomotic leakage, **GID**: Gastrointestinal Decompression Drainage; **POD**: Postoperative Day, **BMI**: Body Mass Index, **LVEF**: Left Ventricular Ejection Fraction, **FEV1**: Forced Expiratory Volume in 1 second, **MVV**: Maximum Voluntary Ventilation, **RBC**: Red Blood Cell Count, **Hb**: Hemoglobin, **EGFR**: estimated Glomerular Filtration Rate, **WBC**: White Blood Cell.

Supplementary Table S2. Comparison of 4 feature variables among the external validation cohorts.

		AL group (n=55)	non-AL group n=301)	P
McKeown Surgery (%)	yes	2 (40%)	10 (35.71%)	1
	no	3 (60%)	18 (64.29%)	
GID volume on POD 1, ml		40 (36.74)	115.79 (123.58)	0.25
Lesion Length, cm		6.8 (4.7)	4.4 (2.17)	0.26
Prealbumin difference, mg/dL		9.48 (5.67)	6.48 (4.49)	0.31

Abbreviations: **GID**: Gastrointestinal Decompression Drainage; **POD**: Postoperative Day.

Supplementary Fig. S1. SHAP summary dot plots of the top 10 features of the nine ML models.



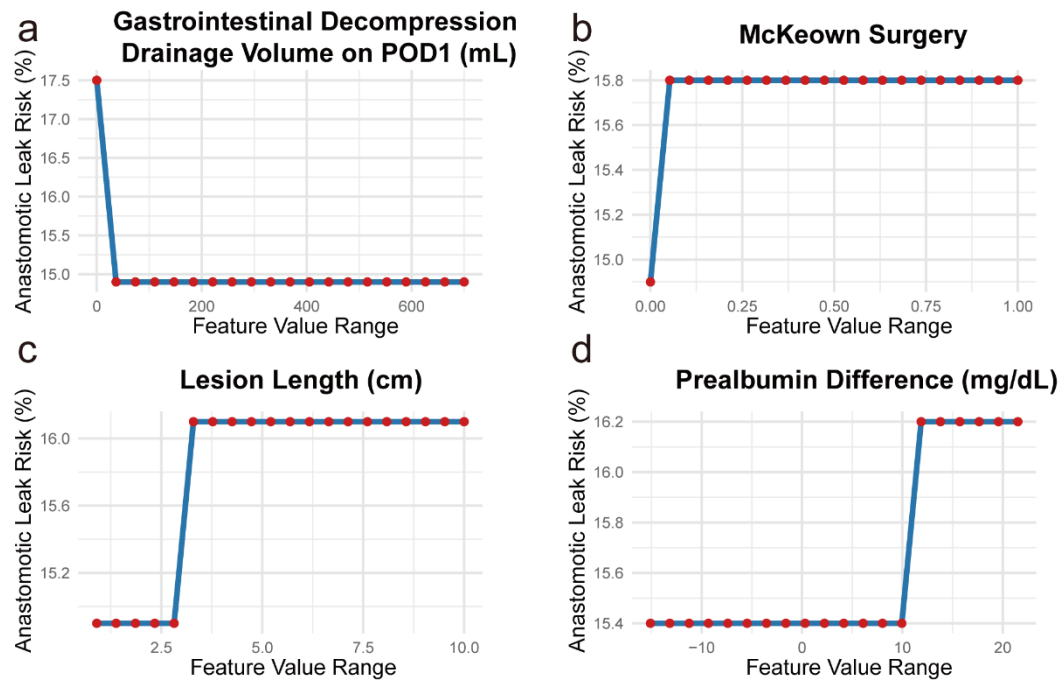
(a) LightGBM, (b) RF, (c) LightGBM, (d) ENET, (e) MLP, (f) SVM, (g) DT, (h) LR, (i) KNN.

The plots display the feature importance rankings across various ML models within the internal validation cohort.

An increased SHAP value for a feature corresponds to a higher probability of AL occurrence. Each dot represents the attribution value of a feature for a single patient, with one dot per patient on each feature line. Dot color reflects the actual value of the feature for each patient, where red represents higher values and blue indicates lower values. The dots are stacked vertically to show the density of points.

Abbreviations: **DT**: Decision Tree; **RF**: Random Forest; **XGBoost**: Extreme Gradient Boosting; **ENET**: Elastic Net; **SVM**: Support Vector Machine; **MLP**: Multilayer Perceptron; **LR**: Logistic Regression; **LightGBM**: Light Gradient Boosting Machine; **KNN**: K-Nearest Neighbors; **GID**: Gastrointestinal Decompression Drainage; **POD**: Postoperative Day, **ML**, Machine Learning, **AL**: Anastomotic Leak.

Supplementary Fig. S2. Partial dependence plots of key predictors for anastomotic leak risk.



(a) **McKeown surgery:** Binary classification (0=non-McKeown, 1=McKeown) showing elevated risk. (b) **Gastrointestinal decompression drainage (GID) volume on POD1:** Risk escalation below 20 mL (threshold marked by dashed line). (c) **Lesion length:** Progressive risk increase beyond 3.2 cm. (d) **Prealbumin difference:** Risk stabilization above 12 mg/dL decrease.

Axes: X-axis = feature value range, Y-axis = predicted anastomotic leak risk (%). Curves depict marginal effect analysis with other variables fixed.