The Bone & Joint Journal

Supplementary Material

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Table i. Description of predictors.

Predictor	Description	Categorization
Age	Estimated in years, using date of birth from the personal identifier and date of surgical admission	Continuous
Sex	Male or female	Binary
Height	Based on self-reported height, in cm	Continuous
Weight	Based on self-reported weight, in kg	Continuous
BMI	Based on self-reported height and weight, in kg/m2	Continuous
Symptom duration	Self-reported duration of symptom, including back pain, leg pain, or numbness, etc., in month	Continuous
CCI	Charlson Comorbidity Index,[1] measured by the surgeon	Continuous
Osteoporosis	Defined as T-score ≤ -2.5 according to Dual-energy x-ray absorptiometry scans,[2] categorized as yes or no	Binary
Frailty	Measured by the surgeon, based on the frailty phenotype proposed by Fried et al,[3] categorized as frail or normal/pre-frail	Binary
Malnutrition	Measured by the surgeon, based on the mini-nutritional assessment scale,[4] categorized as normal or malnutrition	Binary
Anxiety	Measured by the surgeon, based on the Zung Scale,[5] categorized as yes or no	Binary
Depression		Binary
Currently smoker	Non-smoker or current smoker	Binary
rTCSA	Relative total/functional cross-sectional area of paraspinal muscles,[6] measured by the surgeon, take the average of each lumbar segments	Continuous
rFCSA		Continuous

IVDD severity	Measured by the surgeon, based on the modified Pfirrmann grading system,[7] take the average of each lumbar segments	Continuous
FPC	Measured by the surgeon, based on the criteria proposed by Wang and colleagues,[6] categorized as yes or no.	Binary
Surgical levels	Number of surgical levels operated on (range 4 to 15)	Continuous
UIV location	The location of upper instrumented vertebra, recorded by the surgeon, categorized as upper thoracic region or lower thoracic/thoracolumbar region	Binary
Injection of cement at UIV+1	Recorded by the surgeon, categorized as yes or no	Binary
Operating time	Based on the electronic surgical record, in mins	Continuous
EBL	Based on the electronic surgical record, in ml	Continuous
Intraoperative transfusion	Based on the electronic surgical record, in ml	Continuous
TK (pre- and postoperative)	Cobb angle between the superior endplate of T4 and inferior endplate of T12, in degree	Continuous
TLK (pre- and post-operative)	Cobb angle between the superior endplate of T10 and inferior endplate of L2, in degree	Continuous
LL (pre- and postoperative)	Cobb angle between the superior endplates of both L1 and S1, in degree	Continuous
SS (pre- and postoperative)	The angle between the superior endplate of the sacrum and the horizontal line, in degree	Continuous
PT (pre- and postoperative)	The angle between the line linking the midpoint of the superior endplate of S1 and the centre of the femoral heads and the vertical line, in degree	Continuous
PI (pre- and postoperative)	The angle between the line linking the midpoint of the superior endplate of S1 and the centre of the femoral heads and the line vertical to the superior endplate of the sacrum, in degree	Continuous
SVA (pre- and postoperative)	The distance between the posterosuperior corner of S1 and the vertical line from the C7 body centre, in mm	Continuous
TPA (pre- and postoperative)	The angle between the line from the femoral head axis to the centre of the T1 vertebra and the line from the femoral head axis to the middle of the S1 superior endplate, in degree	Continuous

PI-LL match	Measured by the surgeon, based on the sagittal age-adjusted score for adult spinal deformity proposed by Lafage et al,[8] categorized as match or mismatch	Binary
PT match		Binary
TPA match		Binary
SAAS match		Binary

CCI, Charlson Comorbidity Index; DVT, deep venous thrombosis; EBL, estimated blood loss; FPC, failure of pelvic compensation; IVDD, intervertebral disc degeneration; LL, lumbar lordosis; MCID, minimal clinically important difference; PJF, proximal junctional failure; PI, pelvic incidence; PI-LL, pelvic incidence minus lumbar lordosis; PJK, proximal junctional kyphosis; PT, pelvic tilt; rFCSA, relative functional cross-sectional area; rTCSA, relative total cross-sectional area; SAAS, sagittal age-adjusted score; SRS-22r, Scoliosis Research Society-22r; SS, sacral slope; SVA, sagittal vertical axis; TLK, thoracolumbar kyphosis; TK, thoracic kyphosis; TPA, T1 pelvic angle; UIV, upper instrumented vertebra; UTI, urinary tract infection.

Table ii. Hyperparameters for machine-learning models.

Model	Hyperparameter	Searched value	Chosen value
LR	-	-	-
RF	mtry	2, 6, 10	2
	trees	200, 350, 500	500
	min_n	20, 35, 50	35
XGBoost	mtry	2, 4, 6, 8	2
	min_n	5, 8, 12, 15, 18	8
	tree_depth	1, 2, 3	3
	learn_rate	0.001, 0.002, 0.005, 0.01, 0.02	0.01
	loss_reduction	0.004, 0.015, 0.041, 0.075, 0.158, 0.171	0.171
	sample_size	0.847, 0.871, 0.882, 0.907, 0.922, 0.943	0.922
LightGBM	mtry	2, 4, 6, 8	2
	min_n	5, 6, 7, 8, 9, 10	9
	trees	245, 311, 358, 398, 447, 498	398
	tree_depth	1, 2, 3	1
	learn_rate	0.013, 0.022, 0.033, 0.045, 0.05	0.033
	loss_reduction	0.144, 0.196, 0.291, 0.355, 0.514, 0.572	0.514
MLP	hidden_units	16, 18, 20, 22, 24	16
	penalty	0.02, 0.04, 0.08, 0.33, 0.8	0.8
	epochs	63, 77, 84, 92, 101, 127	77

LightGBM, light gradient boosting machine; LR, logistic regression; MLP, multilayer perceptron; RF, random forest; XGBoost, extreme gradient boosting.

Table iii. Selection of key variables. Values in italics and bold represent the variables which were selected by all three methods.

RFE	LASSO	Boruta
rFCSA	***PT match***	***rFCSA***
PT match	***rFCSA***	***PT match***
Postop SS	***Postop SS***	***Frailty***
Frailty	***Osteoporosis***	***Postop SS***
SAAS match	Malnutrition	Post-op TPA
FPC	***Frailty***	***FPC***
Postop SVA	PILL match	***Osteoporosis***
Osteoporosis	***FPC***	TPA match
Depression	Postop TK	Postop SVA
Preop SVA	***Depression***	***Depression***
Postop PT	Operation duration	Operation duration
rTCSA	***SAAS match***	***SAAS match***
TPA match	Cement injection	
Preop SS	Postop LL	
Postop TPA	Postop PT	
Symptom duration	Transfusion	
PI-LL match	Preop PT	
Cement injection		

FPC, failure of pelvic compensation; LL, lumbar lordosis; PI, pelvic incidence; PI-LL, pelvic incidence minus lumbar lordosis; PT, pelvic tilt; rFCSA, relative functional cross-sectional area; rTCSA, relative total cross-sectional area; SAAS, sagittal age-adjusted score; SS, sacral slope; SVA, sagittal vertical axis; TK, thoracic kyphosis; TPA, T1 pelvic angle.

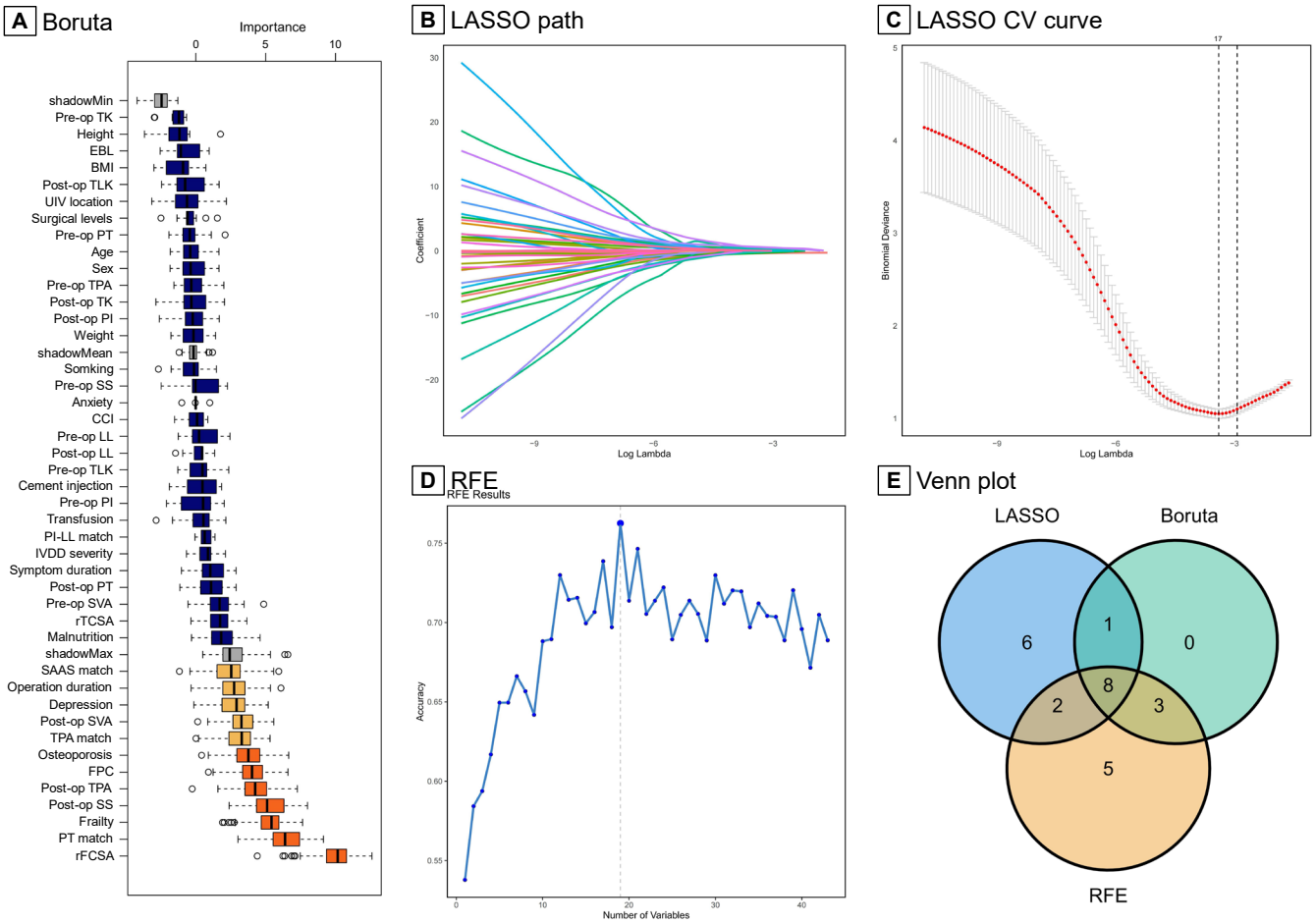

Fig a. Screening process of key variables. CCI, Charlson Comorbidity Index; DVT, deep venous thrombosis; EBL, estimated blood loss; FPC, failure of pelvic compensation; IVDD, intervertebral disc degeneration; LL, lumbar lordosis; MCID, minimal clinically important difference; PJF, proximal junctional failure; PI, pelvic incidence; PI-LL, pelvic incidence minus lumbar lordosis; PJK, proximal junctional kyphosis; PT, pelvic tilt; rFCSA, relative functional cross-sectional area; rTCSA, relative total cross-sectional area; SAAS, sagittal age-adjusted score; SRS-22r, Scoliosis Research Society-22r; SS, sacral slope; SVA, sagittal vertical axis; TLK, thoracolumbar kyphosis; TK, thoracic kyphosis; TPA, T1 pelvic angle; UIV, upper instrumented vertebra; UTI, urinary tract infection.

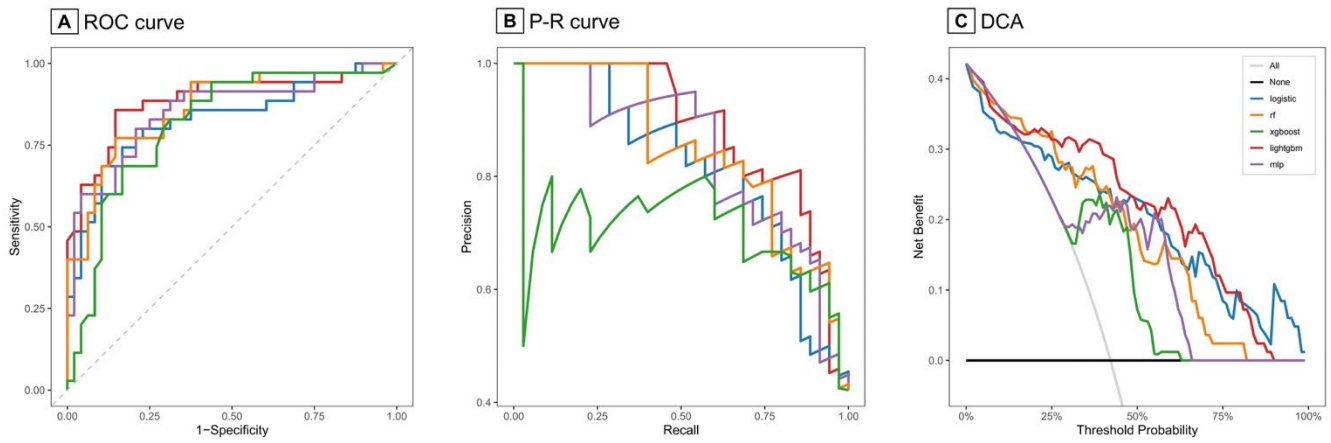

Fig b. a) Receiver operating characteristic (ROC), b) precision-recall (PR), and c) decision curve analysis (DCA) curves of machine-learning models. LightGBM, light gradient boosting machine; MLP, multilayer perceptron; RF, random forest; XGBoost, extreme gradient boosting.

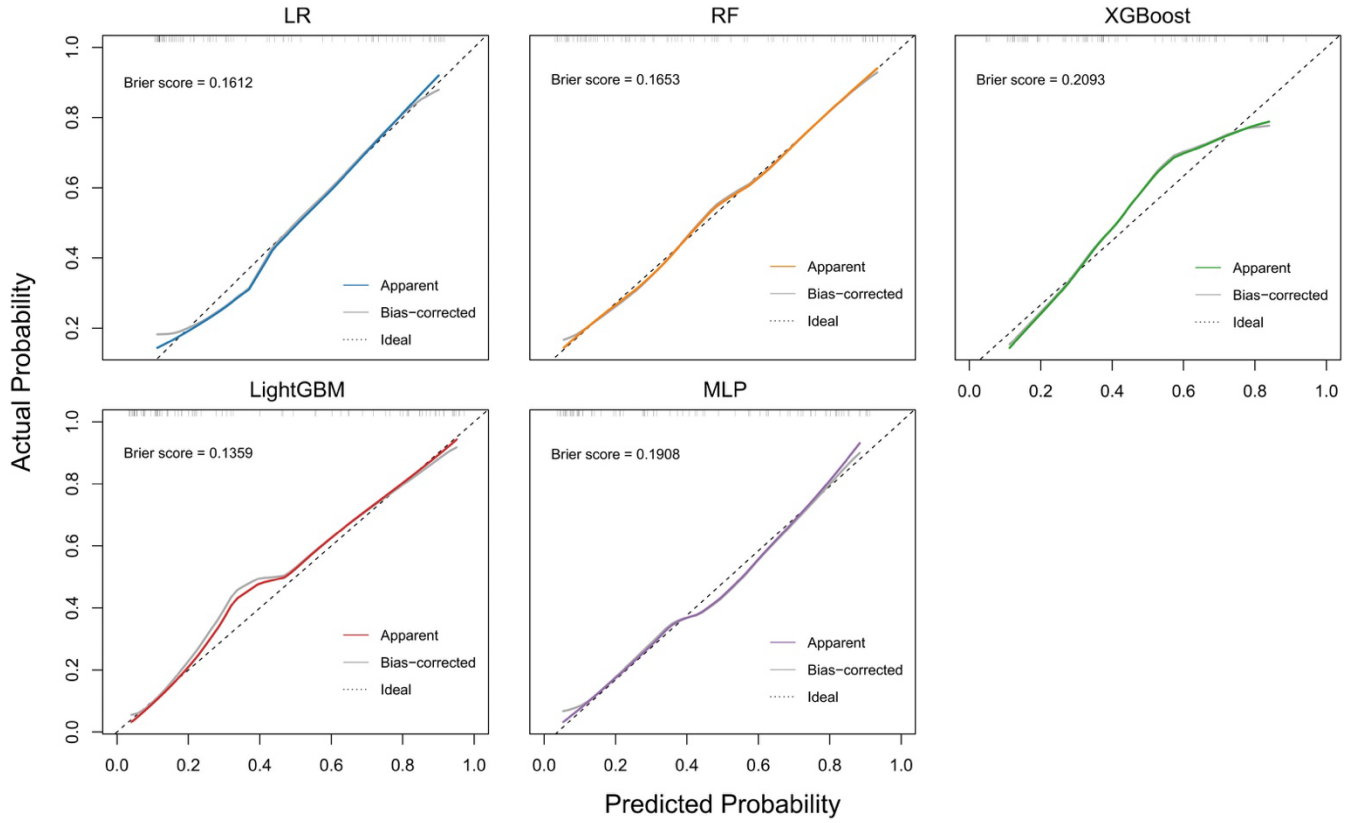

Fig c. Calibration curves of machine- learning models. LightGBM, light gradient boosting machine; LR, logistic regression; MLP, multilayer perceptron; PPV, positive predictive value; NPV, negative predictive value; RF, random forest; XGBoost, extreme gradient boosting.

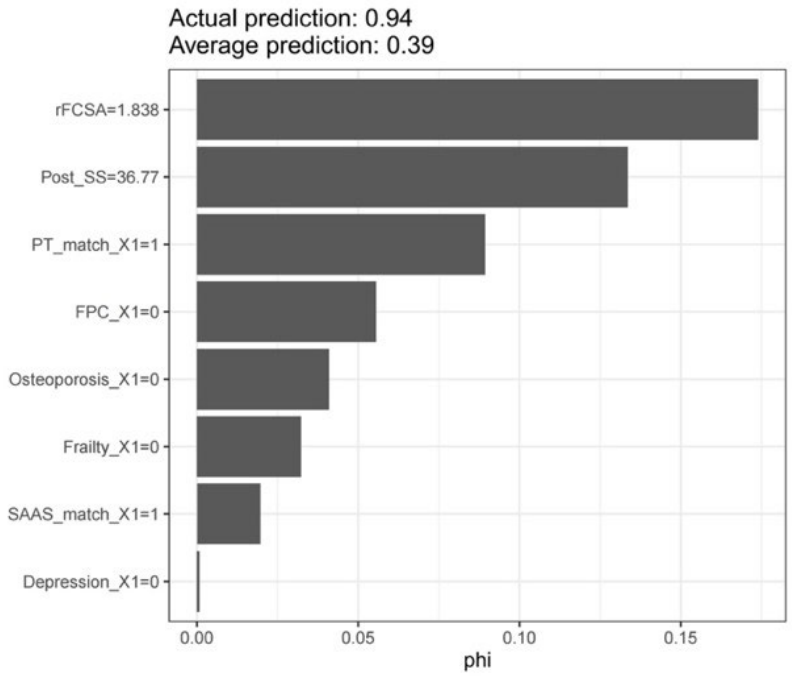

Fig d. Shapley additive explanations (SHAP) force plot of the patient with the highest SHAP value in the test set. This patient had no comorbidities, no failure of pelvic compensation (FPC), no obvious paraspinal muscle atrophy, and satisfactory sagittal alignment. At the final follow-up, the patient achieved an ideal surgical outcome. rFCSA, relative functional cross-sectional area; PT, pelvic tilt; SAAS, sagittal age-adjusted score; SS, sacral slope.

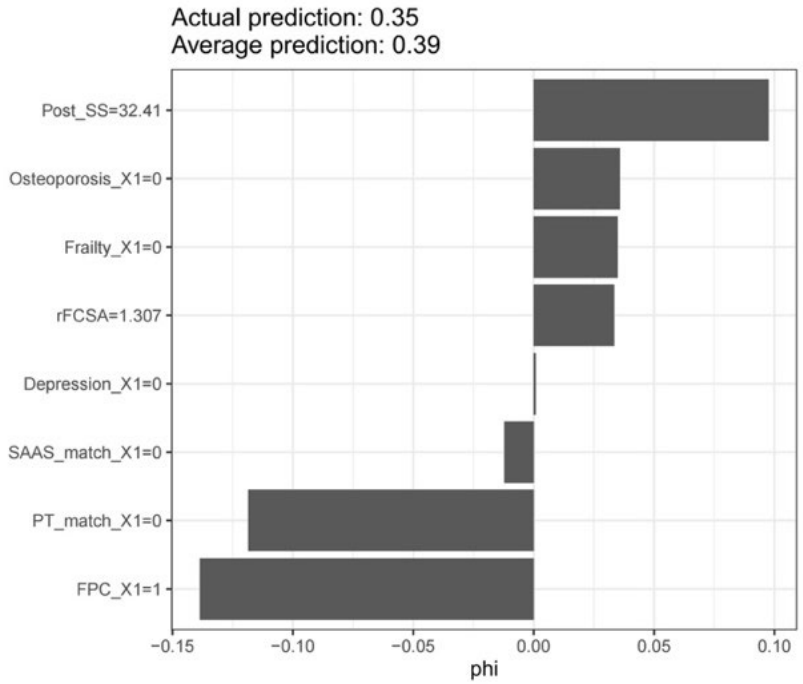

Fig e. Shapley additive explanations (SHAP) force plot of the patient with the median SHAP value in the test set. This patient had failure of pelvic compensation (FPC), mild paraspinal muscle atrophy, and suboptimal sagittal alignment. At the final follow-up, the patient did not achieve an ideal surgical outcome. rFCSA, relative functional cross-sectional area; PT, pelvic tilt; SAAS, sagittal age-adjusted score; SS, sacral slope.

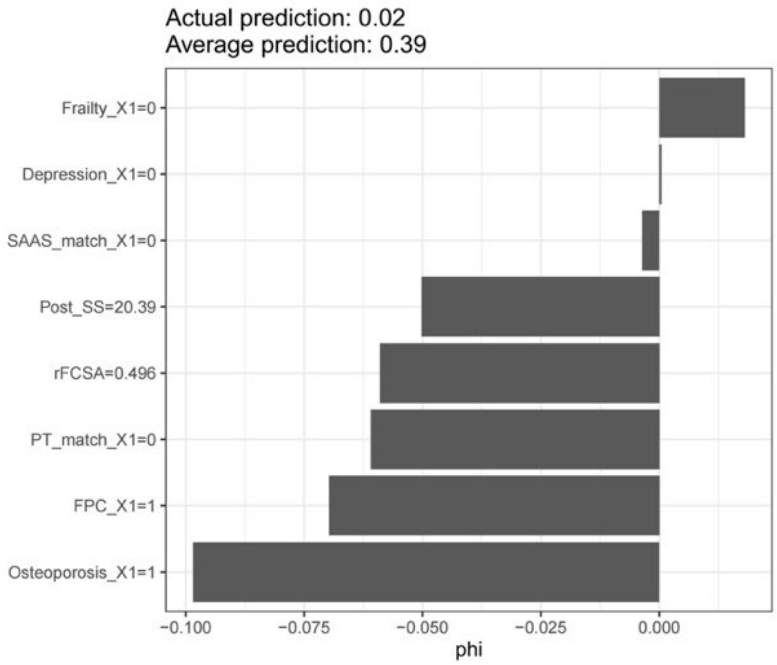

Fig f. SHAP force plot of the patient with the lowest SHAP value in the test set. This patient had failure of pelvic compensation (FPC), severe paraspinal muscle atrophy, osteoporosis, and suboptimal sagittal alignment. At the final follow-up, the patient did not achieve an ideal surgical outcome. rFCSA, relative functional cross-sectional area; PT, pelvic tilt; SAAS, sagittal age-adjusted score; SS, sacral slope.

References

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