A preliminary prediction model using deep learning software for prolonged hospitalization after cardiovascular surgery

Ryota Murase[1], Yasushige Shingu[1] and Satoru Wakasa[1]

Brief Title: Deep learning software for prediction of prolonged hospitalization

[1]Department of Cardiovascular and Thoracic Surgery, Faculty of Medicine and Graduate School of Medicine, Hokkaido University, Sapporo, Japan

Address for correspondence:
Yasushige Shingu
Department of Cardiovascular and Thoracic Surgery
Faculty of Medicine and Graduate School of Medicine, Hokkaido University
Kita 15, Nishi 7, Kitaku, Sapporo, 060-8638
Japan
Tel: +81-11-716-1161 (ext. 6042)
Fax: +81-11-706-7612
Email: shingu@huhp.hokudai.ac.jp

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Abstract

Prolonged length of hospital stay (LOS) has been an important issue for patients undergoing cardiovascular surgery in aging society. However, there have been no established prediction models for prolonged LOS. We aimed to create a prediction model of prolonged LOS using deep learning software (Prediction One, Sony Network Communications Inc.) using preoperative data. Subjects were 157 patients (121 for training data, 36 for validation data). The prolonged LOS was defined as more than a 30-day postoperative stay due to physical inactivity. The area under the receiver operating characteristic curve and accuracy of the model in the validation data were 0.806 and 67%, respectively. In conclusion, the preliminary model demonstrated acceptable performance for the prediction of prolonged LOS after cardiovascular surgery.

In the aging society, prolonged length of hospital stay (LOS) has been an important issue for patients undergoing cardiovascular surgery [1]. Although several studies have suggested preoperative predictors, there have been no established prediction models for prolonged LOS. Prediction One (Sony Network Communications Inc. Tokyo, Japan) is a predictive analytic software that uses its original deep learning algorithm. This software enables us to predict variable events without technical knowledges of deep learning or artificial intelligence. We aimed to create a prediction model for prolonged LOS using Prediction One by entering preoperative data.

Subjects were 157 patients who underwent elective adult cardiovascular surgery with or without cardiopulmonary bypass at our institution from 2018 to 2020. The prolonged LOS was defined as more than a 30-day hospital stay due to the inability to do daily activities without the help of others. We created a prediction model for prolonged LOS using Prediction One with 33 preoperative factors (**Table 1**). To train the prediction model, we used the data of 121 patients operated from 2018 to 2019 (training data). We validated the model using the other data from 36 patients operated in 2020 (validation data). Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software (version 26, SPSS, Inc, IL, USA). This study was approved by the institutional review board (No. 021-0062).

The planned procedures were comparable between the training and validation data. Prolonged LOS occurred in 31% of the training data and 44% of the validation data. Validation results were as follows: area under the receiver operating characteristic curve, 0.806 (**Fig. 1a**); sensitivity, 75%; specificity, 55%; positive predictive value, 59%; negative predictive value, 79%; accuracy, 67%. The top five contributing factors were age, serum creatinine, LVEF, ABI, and hypnotic use (**Fig. 1b**). We can recognize the importance of the factors with nonlinear contribution.

Recently, efforts to establish risk models using artificial intelligence have been actively conducted. In cardiovascular surgery, machine learning showed better accuracy in predicting mortality after cardiac surgery than EuroSCORE II [2]. Although there have been a few reports using Prediction One in the field of neurosurgery, there are no reports in cardiovascular surgery [3]. The small sample size is one of the limitations of the present study. Further studies with more subjects would improve the accuracy of the model. Another limitation is that our model needs external validations from other institutions. Furthermore, more accurate models would be produced by using intraoperative factors in anesthetic charts. However, in this study, we did not use intraoperative factors; we aimed to predict the prolonged LOS before surgery. This model would enable us to conduct preventive interventions before surgery (e.g., preoperative rehabilitation).

In conclusion, the validation results of Prediction One were acceptable for the prediction of prolonged LOS after cardiovascular surgery. The prediction of prolonged LOS using preoperative factors would help identify high-risk patients who should be treated by preventive interventions.

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Conflict of interest

All authors have no conflicts of interest to disclose.

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Figure captions

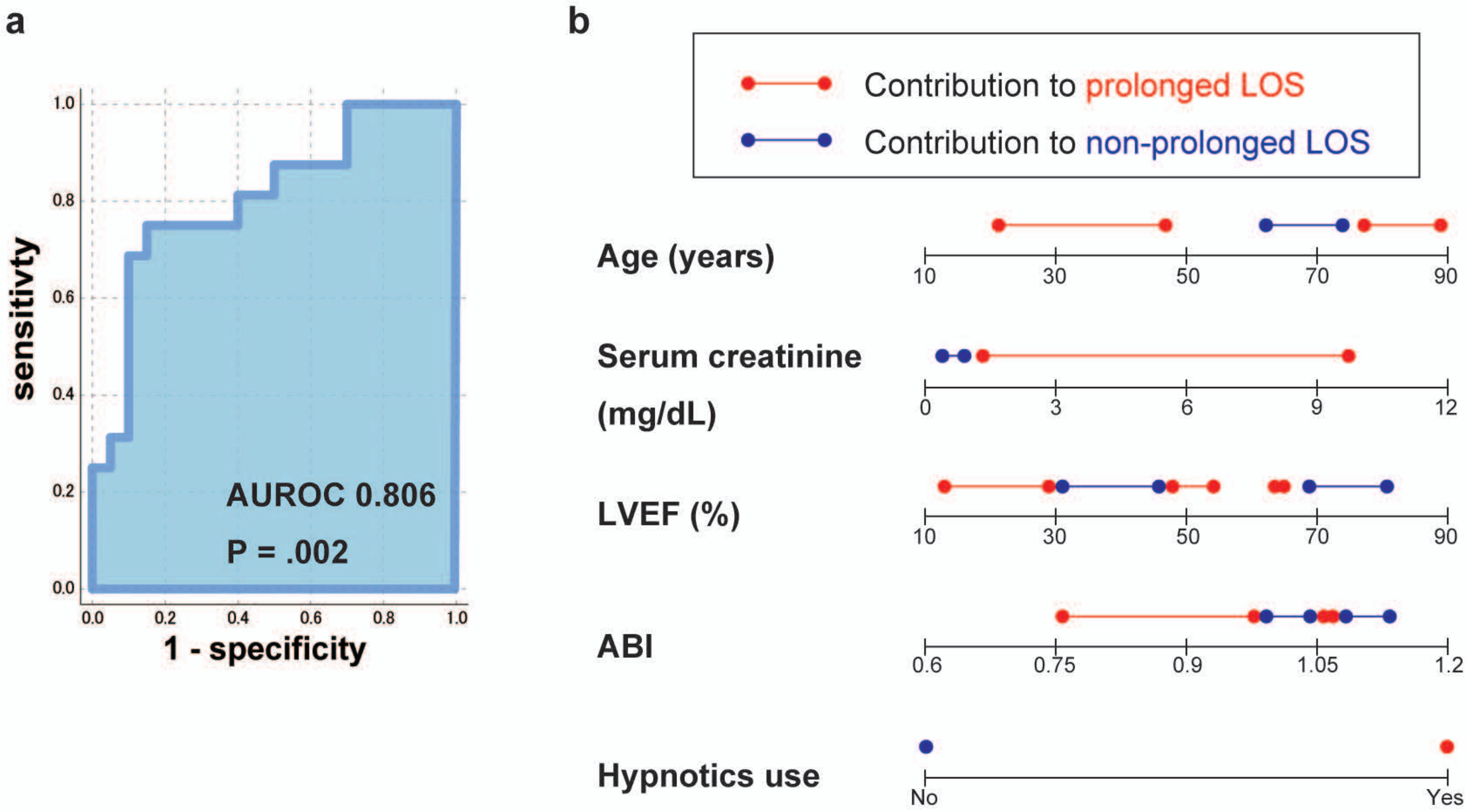
Fig. 1 Analytical results of the model. (a) AUROC for the prediction of prolonged LOS in validation data by the model using Prediction One. (b) The ranges of contribution to prolonged LOS in the top five preoperative factors. ABI, ankle brachial pressure index; AUROC, area under receiver operating characteristic curve; LOS, length of hospital stay; LVEF, left ventricular ejection fraction

Table 1. Preoperative factors used for the prediction model

Patient characteristics	Comorbidities and medications	Laboratory data	Physical examinations	Planned surgical procedures
Sex	Comorbidities	Hemoglobin	Ankle brachial pressure index	Aortic valve surgery
Age	Diabetes mellitus	Platelet counts	Respiratory function	Mitral valve surgery
Body mass index	History of stroke	Serum total protein	Normal	Tricuspid valve surgery
Katz index (daily activity)	Dementia	Serum albumin	Mild (%FEV1.0, 60%–75%)	Coronary artery bypass grafting
History of smoking	Medications	Serum creatinine	Moderate (%FEV1.0, 50%–59%)	Tumor resection surgery
Current smoker	Hypnotics	Serum urea nitrogen	Severe (%FEV1.0, < 50%)	Arrhythmia surgery
Alcohol drinking	ACE inhibitor		Transthoracic echocardiography	Aortic root surgery
	Immuno-suppressive drugs		LVEF	Thoracic aorta surgery
				Use of frozen elephant trunk
				Thoraco-abdominal aorta surgery
				Reoperation

ACE, angiotensin converting enzyme; FEV, forced expiratory volume; LVEF, left ventricular ejection fraction

Fig. 1



a
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
sensitivty
1 - specificity
AUROC 0.806
P = .002
b
Contribution to prolonged LOS
Contribution to non-prolonged LOS
Age (years)
10
30
50
70
90
Serum creatinine (mg/dL)
0
3
6
9
12
LVEF (%)
10
30
50
70
90
ABI
0.6
0.75
0.9
1.05
1.2
Hypnotics use
No
Yes