An externally validated model predicts complications and unplanned readmission after anterior cervical fusion

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INTRODUCTION:

Anterior cervical spinal fusion procedures have grown in popularity due to excellent clinical outcomes and reduced length of hospitalization. As the prevalence of cervical spondylosis increases in an aging population, the number of cervical fusions is expected to grow rapidly. Given the increased morbidity and cost associated with perioperative complications and unplanned readmission, it would be of utility to predict risk of adverse outcomes. Unfortunately, prediction of complication risk for anterior cervical fusion with conventional methods is challenging given the generally favorable outcomes with low incidence of perioperative complications. We primarily aim to build a model for prediction of major complications or 30-day readmission after anterior cervical fusion and identify novel features important for model performance. Additionally, we aim to externally validate this model with an institutional cohort.

METHODS:

This is a retrospective study of patients who underwent anterior cervical fusion at any non-federal California hospital between 2015-2017. The primary outcome was 30-day readmission or major perioperative complication – defined as acute myocardial infarction, pneumonia, sepsis, pulmonary embolism, surgical site bleeding or wound infection. We built standard machine learning (ML) and regression models for prediction of complication risk: XGBoost, gradient boosting, AdaBoost, random forest. Additionally, we built an ensemble model comprising of components of ML-based models and traditional statistics. We rank the contribution of included variables to model performance. The best-performing model was validated on an external cohort. To build the validation cohort, we included consecutive adult patients who underwent instrumented cervical fusion at our institution between 2013-2020. We assessed discrimination with the area under the receiver operating characteristic curve (AUROC) and area under the precision-recall curve (AUPRC). Calibration was assessed using the Brier score.

RESULTS:

A total of 23,184 patients were included to build the derivation cohort; there were 1,886 cases of major complication or 30-day readmission (8.1%). The ensemble model was well-calibrated and demonstrated moderate-to-high discrimination with an AUROC of 0.728 and AUPRC of 0.273 (Table 1). The variables most important for the ensemble model were male sex, musculoskeletal infection, history of implant complication, malnutrition, prior complication, cardio-respiratory failure, teaching hospital, metastatic cancer, chronic obstructive pulmonary disease (COPD), and dementia (Table 2). The validation cohort comprised of 524 patients; 42 patients (8.0%) developed a major complication or 30-day readmission. The ensemble model was then evaluated on the validation cohort with an AUROC of 0.875 and AUPRC of 0.446. The ensemble algorithm was used to build a web-based risk calculator: https://risk-calculator-anterior-cervc.herokuapp.com/.

DISCUSSION AND CONCLUSION:

We report derivation and external validation of an ensemble algorithm for prediction of major perioperative complications and 30-day readmission after anterior cervical fusion. This model has excellent discrimination and is well-calibrated when tested on a contemporaneous external cohort. While ML-driven models have increased in popularity in the spine literature, external validation of these models remains scarce. To our knowledge, this represents the first externally validated ML model predicting complication risk in patients undergoing anterior cervical fusion. By providing accurate prognostic information, this algorithm may facilitate improved pre-operative shared decision-making and appropriate patient selection. We also identify potentially modifiable risk factors for complications such as malnutrition and COPD; pre-operative optimization of these features may minimize the risk of developing complications after anterior cervical fusion. To encourage direct use of this algorithm by healthcare providers, we incorporated this model into a web-based digital interface.

Table 1. Model performance for ML and logistic regression models

Model	AUROC	AUPRC	Brier score
Ensemble	**0.728 ± 0.011**	**0.273 ± 0.021**	0.071 ± 0.006
XGBoost	0.723 ± 0.019	0.261 ± 0.024	0.068 ± 0.001
Gradient boosting	0.722 ± 0.015	0.258 ± 0.021	0.068 ± 0.001
AdaBoost	0.719 ± 0.013	0.256 ± 0.018	0.246 ± 0.002
Logistic regression	0.717 ± 0.012	0.248 ± 0.021	0.069 ± 0.001
Random forest	0.668 ± 0.016	0.162 ± 0.012	0.080 ± 0.001

Table 2. Relative feature importance for the ensemble model predicting complications and 30-day readmission after anterior cervical fusion

Feature	Rank
Male sex	1
Musculoskeletal infection	2
Implant complication	3
Protein-calorie malnutrition	4
Complication of medical care	5
Cardio-respiratory failure	6
Teaching hospital	7
Metastatic cancer or leukemia	8
COPD	9
Dementia	10