Using Artificial Intelligence to Predict Discharges from a Day Surgical Unit in a District Hospital

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Abstract

Artificial intelligence is changing the way we approach healthcare problems. A new day-case trauma pathway was developed and commenced in July 2017 at Withybush general hospital, a district hospital in west Wales. In a recent retrospective analysis to assess the number of successful emergency orthopaedics patients treated on a day case basis, a same-day discharge rate of 52% was found. A logistic regression machine learning model was trained on the data of patients who were treated via this pathway. A 5-fold grid search cross-validation method was applied for hyper-parameter tuning and model evaluation. The model has a prediction accuracy of 73.3%, the area under the ROC curve is 0.7, and the average precision of the model is 0.75. The model efficiently predicts discharge outcomes of patients on admission. This will help in tailoring care for identified patients to improve discharge outcomes and will result in an efficient allocation of hospital resources.

Key words: Day Surgery, Quality Improvement, Artificial Intelligence.

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Introduction

Artificial intelligence is changing the way we approach healthcare problems.

Machine learning, a subset of artificial intelligence, is popularly classified into supervised, unsupervised, and reinforcement learning. Supervised learning algorithms learn from labelled data sets. Using labelled datasets, the algorithms can learn how the known input variables relate to the labelled outputs. These algorithms then predict outcomes or classify data using the new inputs and become efficient by learning by trial and error.

Withybush hospital is a district general hospital situated in the coastal town of Haverfordwest. It caters to a population of approximately 375,000 in Pembrokeshire, Carmarthenshire, and Ceredigion in west Wales.

A new day-case trauma pathway was developed and commenced in the hospital in July 2017 [1]. In a recent retrospective analysis to assess the number of successful emergency orthopaedics patients treated on a day case basis, we found a same-day surgery and discharge rate of 52% [2].

We propose a supervised machine learning model to improve the efficiency of this pathway.

Methods

We trained a logistic regression supervised machine learning model on the data of patients treated via the day surgery pathway in our hospital using the sci-kit-learn machine learning library.

Scikit-learn is an open-source machine learning library that supports supervised and unsupervised learning.

Age (median age of 48.5(15-92) years), gender (male/female), and the type of injury sustained (upper limb injury, upper limb fracture, lower limb injury, lower limb fracture) were used as input variables/features (represented by variable 'X').

The target variable (represented by variable 'y') was defined as whether the patient was discharged from the day surgery unit on the same day or not.

Categorical variables (sex, type of limb injury) were converted into dummy variables.

The dataset was split into training (75% of the total dataset) and testing datasets (25% of the total dataset) and was stratified according to the target variable. A logistic regression model was trained on the training dataset. The GridSearchCV method was used to find the best fitting parameters for the logistic regression algorithm using a 5-fold cross-validation strategy (hyper-parametric tuning).

The model was retrained using these parameters, and prediction accuracy over the testing dataset was calculated.

Results

Demographics of patients treated via the day surgery pathway

240 patients were treated as emergency day surgery cases with the orthopaedics department in Withybush hospital, from July 2017 to December 2019.

52.5% of patients were female (126/240). The median (range) age of all patients was 48.5 (15-92) years. 124 (51.7%) patients were admitted with upper limb fractures and 44 (18.3%) patients were admitted with other upper limb injuries. 38 (15.8%) patients had lower limb fractures on admission and 24 (14.2%) patients had other lower limb injuries.

Description of the machine learning model

- The trained logistic regression machine learning model with its parameters is as follows:

```
LogisticRegression(C=3.2374575428176464, class_weight=None, dual=False,
                   fit_intercept=True, intercept_scaling=1, l1_ratio=None,
                   max_iter=100, multi_class='auto', n_jobs=None, penalty='l2',
                   random_state=None, solver='lbfgs', tol=0.01, verbose=0,
                   warm_start=False)
```

- The model has a prediction accuracy of 73.3% on the testing dataset.
- The area under the ROC curve for the model is 0.70 (Figure 1).
- The normalized confusion matrix for the model is shown in Figure 2.
- The Precision-Recall curve for the model demonstrates an average precision of 0.75 (Figure 3).

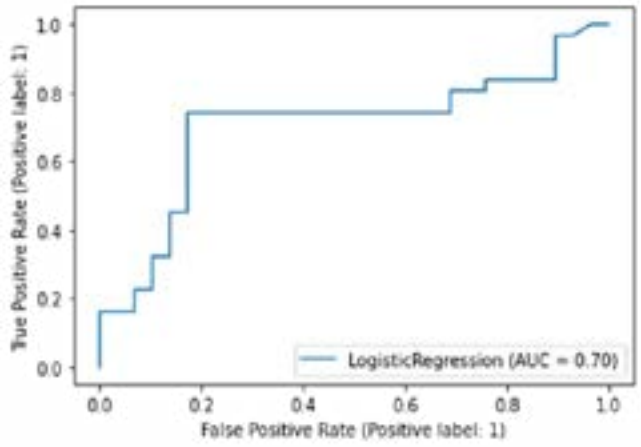

Figure 1 Receiver Operating Characteristic curve for the Machine Learning Model.

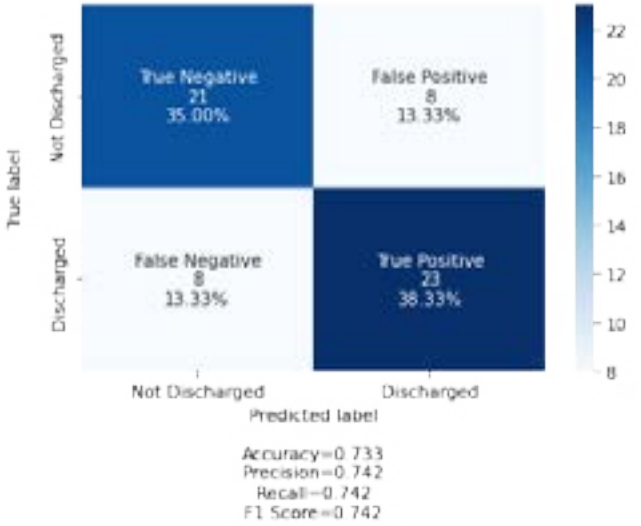

Figure 2 Normalized confusion matrix for the machine learning model with accuracy, precision, recall, and F1 Score.

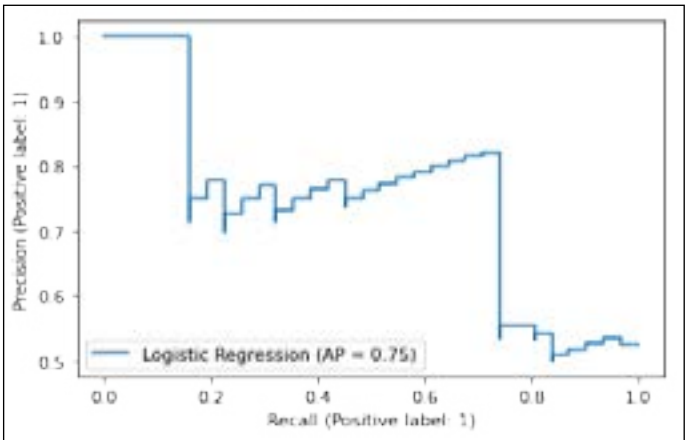

Figure 3 Precision-Recall curve for the machine learning model (X Average Precision(AP)).

Discussion

Applications of artificial intelligence to solve healthcare problems are increasing in modern medicine. Healthcare-related problems could be effectively dealt with by machine learning approaches that limit human error.

Strengths

Our model efficiently predicts discharge outcomes of patients on admission.

Integration of the model with the existing patient records / PAS can help identify patients who are less likely to be discharged on the same day from the day surgery unit.

This will help in tailoring care for identified patients to improve discharge outcomes and will result in an efficient allocation of hospital resources.

Limitations

Our model has a few limitations.

Firstly, the model does not directly highlight all the factors that could preclude same-day patient discharge. These include the patients' comorbidities and functional status. These also include post-operative conditions of the patient or cancellation of surgery for the patient due to hospital-related issues.

Secondly, the accuracy of the model could be further improved. This could be achieved using other machine learning algorithms or a deep learning neural network.

We trained other machine learning algorithms on the same dataset (K-Nearest neighbour classifier (KNN), Support vector machine (SVM), Random Forest classifier, and Decision tree classifier) and achieved the following accuracies on the testing dataset (Table 1).

Table 1 Prediction accuracies of different machine learning algorithms.

Machine Learning Algorithms	Prediction Accuracy on the testing dataset
Logistic Regression	73.3%
K- Nearest Neighbor classifier (KNN)	60%
Support Vector Machine (SVM)	70%
Decision Tree Classifier	58.3%
Random Forest Classifier	51.6%

As more patients are treated within the day surgery unit, we believe this could increase the prediction accuracy of the model (due to an increase in sample size).

As the sample size increases, a deep learning neural network could be trained on the data to get superior prediction accuracy.

Additionally, more patient characteristics can be used as variables to train the model to increase the prediction accuracy.

We will plan to implement the model in our day surgery unit for further validation and retrain the model with a 'learning-from-shortcomings' approach.

References

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2. Bamania AM, Belfield F, Deshmukh N. Evaluation of a Newly Developed Day-Case Trauma Pathway in a Rural District General Hospital. ***Ambulatory Surgery*** 2021;**27**.3:53-56.