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# A Preliminary Study on Multivariate Prediction of Seizure Outcome after Epilepsy Surgery

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## Abstract

Surgical outcomes of epilepsy surgery vary across patients, and clinicians need to estimate possible outcomes before surgery. The aim of this study was to identify predictors of seizure outcome one year after surgery for patients with drug-resistant epilepsy. Twenty-three patients with Temporal Lobe Epilepsy (TLE) who underwent surgery were included in the study. Their demographical information, seizure history, findings of EEG and neuroimaging tests (mainly Magnetic Resonance Imaging (MRI) and Magnetic Resonance Spectroscopy (MRS), intracranial EEG (icEEG) findings, seizure outcome and pathological findings were reviewed. Bivariate analyses were performed to examine the univariate association of each variable with the outcome, and exclude the most insignificant ones. The remaining data were randomly assigned to the training and test sets, and three multivariate analysis approaches (Logistic Regression (LR), Linear Discriminant Analysis (LDA) and Artificial Neural Network (ANN)) were performed repetitively. Model performance was compared using Receiver-Operating Characteristic (ROC) analysis. Resampling the data to the training and test sets resulted in large variations in the classification accuracies of each multivariate approach. The ROC results indicated that the medium classification performances were moderate. Important outcome predictors identified included EEG lateralization score, icEEG lateralization score, and the presence of Hippocampal Sclerosis (HS). The results suggested that multivariate models could predict seizure outcome after TLE surgery with moderate accuracy. Further studies are needed to improve prediction accuracy and identify reliable predictors of seizure outcome.

**Keywords:** Epilepsy surgery; Outcome prediction; Multivariate analysis

## Introduction

Epilepsy surgery opens the possibility of complete seizure control and brings the hope of seizure-free outcome for patients with drug-resistant epilepsy. Over decades, epilepsy surgery has improved gradually and approached 60% to 90% seizure-free outcome in patients with Temporal Lobe Epilepsy (TLE) and 40% to 60% in Extra Temporal Lobe Epilepsy (ETLE) [1]. However, surgical outcomes vary across patients, and clinicians need to weigh the risks of this procedure and estimate possible outcomes before surgery. erefore, identi cation of prognostic factors for surgical outcome is important for outcome research, which may reduce the uncertainties in surgical candidates.

A number of clinical and demographic factors have been found associated with or unrelated to postsurgical seizure outcome. For example, factors such as lesional epilepsy, abnormal MRI, partial seizures, and complete resection were found to be positively associated with seizure outcome, and factors such as nonlesional epilepsy, poorly de ned and localized epileptic focus, generalized seizures, and incomplete resection are negatively associated with outcome, while factors such as age at surgery and side of surgery are unrelated to seizure outcome for TLE and lesional ETLE [2].

However, prognostic factors identi ed vary across patient groups and studies. For a speci c group of patients who underwent epilepsy surgery at a local epilepsy center, it is still unclear which factor in the presurgical or pathological ndings is associated with postsurgical seizure outcome. In addition, previous studies showed that combining multiple prognostic factors in multivariate models to predict postoperative seizure outcome achieved moderate accuracy, e.g., Receiver Operating Characteristic (ROC) area of 0.63 [3]-0.74 [4]. en, the question is: How accurate such outcome prediction is in a local patient population? Further, due to di culties in data collection, patient data of small sample size are sometimes acquired and when the subject sample is small, how to obtain stable results?

In this study, we investigated the associations of the presurgical and pathological ndings with seizure outcome one year a er surgery in patients with drug-resistant Temporal Lobe Epilepsy (TLE) and identi ed factors that might indicate seizure outcome. Due to the relatively small sample size, multiple statistical analyses and bootstrap resampling were used to reduce bias.

## Methods

### Subjects

24 consecutive patients with drug-resistant epilepsy were admitted to the Department of Functional Neurology and Neurosurgery, Beijing Haidian Hospital during 2010 (July)-2012 (April) and were assessed for presurgical evaluation. 23 of them (8 females, 15 males, mean age at surgery: 26.9 ± 10.5 years) underwent surgery and were included in this study. e patients were diagnosed as TLE and underwent presurgical evaluation. Surgical outcomes were evaluated with Engel classi cation during patients 'post-operative revisits and the patients' follow up lasted for 1.5~3 years. is study was approved by the Institutional Review Board (IRB) at the Capital Medical University.

Surgery consisted of temporal lobe resection including amygdala hippocampectomy (15/23, 65.2%), and temporal lobe resection

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LR, LDA and ANN

With variable interactions, LR can be viewed as a generalized linear model (like linear model LDA); while without interactions, it may be viewed as a special case of a generalized nonlinear model like ANN [9]. An advantage of LR and ANN is that few assumptions are made, while LDA has a number of assumptions on the predictors (e.g., normal distribution). Further, ANN might achieve better prediction with fewer restrictions on the structure of the predictive model than LR [9]. An obvious advantage of ANN is that the structure of the model (e.g., a hidden layer) is less dependent on the data (e.g., in the training or test set) which makes it possible to obtain better classi cation and prediction, while the structure of a LR or LDA model is largely dependent on the data. On the other hand, ANN is like a black box—its model and results are hard to be interpreted, while the predictive models and results of LR and LDA are interpretable.

In this study, the data tted the LR and ANN models well. With ANN, it is easy to prevent too extreme predictions such as overtraining, which is not straightforward in LR (or LDA). For LDA, although some of the predictor variables (e.g., the categorical variable the presence of HS) did not satisfy the assumptions of the LDA model, the model characteristics (such as Wilks' lambda and its associated chi-square test) indicated the e cacy of the LDA discriminant function (it did better than chance at separating the data into the two outcome groups, Table 2B). In addition, although the medium classi cation performances were moderate and there were no statistical di erences between the three multivariate analysis approaches (LR, LDA, and ANN) in this dataset, ANN still had the potential to obtain better classi cation and prediction.

In recent years, newer classi ers such as Support Vector Machine (SVM) have been applied to the detection and classi cation of abnormalities on neuroimaging in epilepsy and other brain disorders and high classi cation accuracy (>=90%) has been achieved [10-12]. e promising classi er SVM may be applied to this and other related dataset(s) to improve classi cation and prediction in the future.

### e predictive value of presurgical neuroimaging

In this study, the low signi cance of the imaging lateralization score obtained from multivariate analyses made it a less important predictor compared with other predictors in this dataset (Table 3).

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