Applied Mechanics and Materials Vol. 595 (2014) pp 263-268
© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.595.263

Submitted: 2014-05-26
Accepted: 2014-05-27
Online: 2014-07-18

Predictive Models for Pre-operative Diagnosis of Rotator Cuff Tear: A Comparison Study of Two Methods between Logistic Regression and Artificial Neural Network

Chen-Chiang Lin[1,a], Hsin-Hui Chan[2,b], Chen-Yuan Huang[3,c], Nang-Shu Yang* [4,d]

[1,2]No.579, Sec. 2, Yunlin Rd., Douliou City, Yunlin County 640, Taiwan, R.O.C.

[1,2,3,4]123, Section 3, University Rd, Touliu, Yunlin, Taiwan, R.O.C.

[1,2]Department of Orthopedics, National Taiwan University Hospital Yun-Lin Branch

[1,3,4]Department of Industrial Engineering and Management

[2]raduate School of Health Industry Management

National Yunlin University of Science and Technology

[a]g9821806@yuntech.edu.tw, [b]y00220@ms1.ylh.gov.tw, [c]g9821803@yuntech.edu.tw, [d]yangns@yuntech.edu.tw

Keywords: Rotator Cuff Tear, Predictive Mode, Logistic regression, Artificial Neural Network

Abstract. Rotator cuff tears are the most common disorder of the shoulders.agnetic resonance Image (MRI) is the diagnostic gold standard of rotator cuff tears. However, there are some dilemmas in the rotator cuff tears treatment. Clinically, surgical results of rotator cuff tears are sometimes different from MRI results of rotator cuff tears. The main purpose of this study is to build up predicative models for pre-operative diagnosis of rotator cuff tears There are two models of this study are proposed: logistic regression model and artificial neural network model. Patients are divided into two sets: Set1 is patients with full thickness rotators cuff tears. Set 2 is patients with partial thickness rotators cuff tears. The charts of 158 patients are completely reviewed and the collected data were analyzed. The results showed that the predictive accuracy of artificial neural networks model is higher than the predictive accuracy of logistic model. The application of this study can assist doctors to increase the accuracy rate of pre-operative diagnosis and to decrease the legal problems.

Introduction

A rotator cuff injury includes any type of irritation or damage to the rotator cuff muscles or tendons. Rotator cuff tears (RCT) are tears of one or more of the four tendons of the rotator cuff muscles which are among the most common conditions affecting the shoulder and a common source of shoulder pain. Their incidence increases with age[1]; especially in people aged 60 years and older[2]. Rotator cuff tears account for almost 50% of major shoulder injuries. If the patients with rotator cuff tear do not accept correct treatment, most of them are not able to act smoothly in daily living. Rotator cuff tear has been listed as one of the occupational hazards by Council of Labor Affairs, R.O.C since 01, May of 2009.

Correct detection of rotator cuff tears clinically is important not only to guide further decision-making to avoid unnecessary, expensive or painful diagnostic procedures, but also save the patient from further diagnostic tests that are more costly, painful, inconvenient and risky. But sometimes rotator cuff tears are difficult to diagnose. Magnetic resonance imaging (MRI) is a gold standard for diagnosis of rotator cuff tears, and be used increasingly as the non-invasive approaches. Because the outcome for patients after having surgery and diagnosis by MRI are sometimes differentIt is necessary to develop an approach to aid physicians for diagnosing rotator cuff tears before operation. For the purpose of the medical decision assistant, this research will apply data mining methodologies to establish predictive models for pre-operative diagnosis of rotator cuff tear. Rotator cuff tears can be corrected diagnose based on patients' demographic data, symptoms and MRI .

Literature Review

Research shows that the clinic diagnosis has a high false positive rate, which inferring that a high portion of the shoulder pains suspected as a rotator cuff tear during the initial clinic test turns out with no tear injury after the imaging test[3]. This could be due to doctors don't have sufficient confidences to rule out the diseases. Nowadays, early diagnosis and correct assessment of diseases tend to have great importance in disease treatment. Therefore, diagnostic and classification process of a disease to be made by using today's technology and demographic data would present many uses. MRI is a noninvasive and pain free, provides direct visualization of the entire cuff. For full thickness tear, it has a reported sensitivity of 80%; specificity of 94% and accuracy of 89%. For both full thickness tear and partial thickness tear, it has a reported sensitivity of 69%; specificity of 94% and accuracy of 84% [4]. According to the ROC curve of Toby's research[5], the accuracy of diagnosis of MRI for full thickness tear is higher than partial thickness tear.

The treatments of rotator cuff tear include non-operative treatment and operation. According to the outcome of non-operative treatment, the 33-90% symptoms of partial thickness tear are improved. Patients have operations if the symptoms are not improved after taking non-operative treatment. The goals of operations are relieving pain and improving functions. The outcomes of operations depend on the age; tear size and rehabilitation, which are difficult to forecast before operation.

Data mining is the computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems [6]. Data mining process is to extract information from a data set and transform it into an understandable structure for further use. Artificial Intelligence (AI) can be used for medical diagnostic processes. In this paper, the predictive models of rotator cuff tears by using data mining approaches are proposed. There are some methods of data mining can be used for outcome prediction of medical diagnostic processes, such as Artificial Neural Network (ANN) and Logistic Regression. ANN has already proven its effectiveness and popularity for the medical diagnostic processes with different existing applications worldwide, which was used for the diagnosis of acute coronary occlusion[7] and myocardial infarction [8]. Logistic Regression is a kind of generalized linear regression model that widely used to predict the probability of occurrence of an event [9]. Logistic regression is used with increasing frequency in the health sciences because of its ability to model dichotomous outcomes. Logistic regression analysis was performed to obtain the coefficients for risk variables included in the logistic model [10].

In this retrospective study, the charts of 158 patients who had preliminary diagnosis by MRI and confirm with rotator cuff tear at the Department of Orthopedics, National Taiwan University Hospital Yun-Lin Branch from January of 2008 to June of 2012 are reviewed. Inclusion criteria were patients: (1) had surgery for partial thickness tear; (2) had surgery for full thickness tear. On the other hand, exclusion criteria were patients with full thickness tear or partial thickness tear, but did not have operations. This included 138 patients who were confirmed to have rotator cuff tears and 40 patients with no rotator cuff tear. The study was approved by the hospital Institutional Review Board and all subjects provided informed, signed consent. Symptoms of rotator cuff tears include pain and limitation of actives of daily living (ADL). Pain assessment is used to measure 11 different painful levels which are shown as 0-10 scores. After taking pain assessment and confirming the painful level is higher than 4, patients are given some treatment and non-pharmacologic interventions. The functional actives of daily living include eat; clean; bath; toilet and dress. In this study, non-pharmacologic interventions and functional assessment are decided by three orthopedists.

The predictor variables were patients' clinic assessment results containing 12 attributes as shown in Table 1.

Table 1 Variable list

Variables (input)	Type	Coding
Age	Numerical	
Gender	Nominal	2 codes (1 for male, 0 for female)
Active of daily living	Ordinal	5 codes (1 for eat, 2 for clean, 3 for bath, 4 for toilet, 5 for dress)
Types of Pain	Ordinal	9 codes
Pain Index	Ordinal	11 codes (0 no pain ~ 10 severe)
Non-pharmacologic interventions	Ordinal	8 codes
Injury history	Nominal	2 codes (1 for yes, 0 for no)
Night pain	Nominal	2 codes (1 for yes, 0 for no)
Drop arm test (Jobe Test)	Nominal	2 codes (1 for positive, 0 for negative)
Sport test (ROM)	Nominal	2 codes (1 for yes, 0 for no)
Analgesic	Ordinal	3 codes (2 for 2 kinds, 1 for one kind, 0 for no)
MRI	Nominal	2 codes (2 for partial tear, 1 for full tear)
Variable (output)		
Outcome of operation	Nominal	2 codes (2 for partial tear, 1 for full tear)

In this study, the predictive models are evaluated by accuracy. The true positive rate (TP) is the proportion of positive cases that were correctly identified. The false positive rate (FP) is the proportion of negatives cases that were incorrectly classified as positive. The true negative rate (TN) is defined as the proportion of negatives cases that were classified correctly. The false negative rate (FN) is the proportion of positives cases that were incorrectly classified as negative. The accuracy (AC) is the proportion of the total number of predictions that were correct. It is determined using the equation: (TP+TN)/(TP+TN+FP+FN). The average accuracy (AAC) is the average of the total number of predictions that were correct. It is determined using the equation: [(TP)/(TP+FP)+(TN)/(TN+FN)]/2.

Table 2 Matrix of outcomes and diagnosis

Outcomes after operation / Diagnosis before operation	Full thickness tear	Partial thickness tear
Full thickness tear	TP	FP
Partial thickness tear	FN	TN

Logistic regression modelling. Logistic regression is a kind of generalised linear regression model that widlely ised for prediction of the probablity of occurrence of an event. In logistic regression model, the linear combination of predictors was used for prediction the occurrence of an event by a link function:

$$f(x)=\frac{1}{1+e^{-z}}\,. \tag{1}$$

where $Z=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+...+\beta_kx_k$.

$x_1, x_2, x_3...x_n$ indicated the predictor.

$\beta_1, \beta_2, \beta_3...\beta_n$ Indicated the weight coeifficient.

Statistical analyses were performed using Clementine 12.0 software. The database of 158 patients was divided randomly into two sets: half for training and half for testing. The binary variables for tear or non-tear was the output variable of the prediction models. The other 12 variables shown in Table 1 were selected as input variables. There are two logistic regression models were developed: stepwise regression model and full-factorial regression model. The accuracy of logistic regression models is presented in table 3.

Table 3 The accuracy of logistic regression model

models	training		testing		training	testing
	output	accuracy	output	accuracy	AC/AAC	AC/AAC
Stepwise regression model	1	95%	1	96.61%	77.50%/60%	75.64%/53.57%
Stepwise regression model	2	25%	2	10.53%		
Full-factorial regression model	1	90%	1	81.36%	81.25%/72.50%	70.51%/59.10%
Full-factorial regression model	2	55%	2	36.84%		
Output: 1for full thickness tear; 2 for partial thickness tear The accuracies of full-factorial regression models are higher than stepwise regression models.						

The stepwise regression model for pre-operative diagnosis of rotator cuff tear is

$$Z=-0.06778*Age+-21.26*(\text{night pain}=0)+2.984. \tag{2}$$

The main factors of stepwise regression model are age and night pain.

The full-factorial regression model for pre-operative diagnosis of rotator cuff tear is

$$\begin{aligned}Z=&-0.05839*Age+0.322*(Sex=0)+-0.6241*(MRI=1)+-0.6297*(MRI=2)\\&+-0.06694(\text{active for daily living}=0)+1.055*(\text{active of daily living}=1)\\&+-1.668*(\text{active of daily living}=2)+15.81*(\text{types of Pain}=1)+15.51*(\text{Types of Pain}=2)\\&+-1.274*[\text{ Pain index}(1)=3] +-2.349*[\text{Pain index}(1)=4]+-2.063*[\text{Pain index}(1)=5]\\&+-17.38*[\text{Non-pharmacologic interventions }=1]\\&+-16.12*[\text{Non-pharmacologic interventions }=2]+1.09*[\text{Injury history }=0]\\&+-16.38*[\text{night pain}=0]+-0.09224*[Drop=0]+-0.02876*[ROM=0]\\&+-0.4225*[\text{ Analgesic }=0] +2.066*[\text{ Analgesic }=0] +3.314.\end{aligned} \tag{3}$$

Artificial neural networks modelling. Artificial neural networks (ANNs) are commonly known as biologically inspired, highly sophisticated abalytical techniques, capable of modelling extremely complex non-linear functions. The ANN models we used had three layers: one input layer, one hidden layer, and one output payer, each payer was consist of a set of nodes that simulate human's neurons. Statistical analyses were performed using Clementine 12.0 software. The database was divided randomly into two sets: half for training and half for testing. The binary variables for tear or non-tear was the output variable of the prediction models. The other 12 variables shown in Table 1 were selected as input variables. The numbers of neurons in the hidden layer were 5,10,15,20,25. The laerning rate was set as 0.3. The stopping criterion was set at 500 epochs.Transfer function is sigmoid function. The accuracies of ANN models are presented in table 4. Amongst the four ANN models, the model with 15 hidden layers had the highest accutacies of 100% both in traing and testing datasets. The importances of different factors are shown as table 5. Prediction accuracy was evaluated by comparing the logistic regression and ANN models. According to the results of models, the accuracies of ANN models are higher than logistic regression models.

Table 4 Summary of the accuracy of ANN models

Input variables-hidden layers-output variable	epochs	training			testing		
		output	accuracy	AC/AAC	output	accuracy	AC/AAV
12-5-1	500	1	100%	98.75%/97.50%	1	77.97%	66.67%/64.29%
12-5-1	500	2	95%		2	31.58%	
12-10-1	500	1	100%	100%/100%	1	81.36%	70.51%/59.10%
12-10-1	500	2	100%		2	36.84%	
12-15-1	500	1	100%	100%/100%	1	83.05%	75.64%/67.84%
12-15-1	500	2	100%		2	52.63%	
12-20-1	500	1	100%	100%/100%	1	79.66%	69.23%/58.25%
12-20-1	500	2	100%		2	36.84%	
12-25-1	500	1	100%	100%/95%	1	79.66%	69.23%/58.25%
12-25-1	500	2	95%		2	36.84%	
Outcome: 1 for full tear, 2 for partial tear							

Table 5 The importance of factors

Input variables	Importance
Night pain	0.0236
Active of daily living	0.0293
Types of pain	0.0645
Non-pharmacologic interventions	0.0748
Drop	0.0775
Analgesic	0.0854
Sport test (ROM)	0.0908
Injury history	0.0973
MRI	0.1021
Sex	0.1024
Age	0.1235
Pain index	0.1286

In this study, two data mining models (ANN and logistic regression) are proposed for the prediction of rotator cuff tears based on 12 features. The results demonstrated that artificial neural networks models have higher predictive accuracy than logistic regression models, perhaps because they are not affected by interactions between fractors. Although the proposed artificial neural network model could reach 76.54% accuracy and 67.84% average accuracy, some of the research extensions to compensate the limitations of the present effort are suggested. First, to overcome generalization issue due to sample size or variables selected [11], future studies may consider including other patient characteristics or collected more subjects to enhance our predict models. Second, more promising data mining methods such as support vector machines or Bayesian network could be adopted to explore if the prediction sensitivity and specificity can be further improved.

References

[1] Norwood LA. Barrack R. Jacobson KE. Clinical presentation of complete tears of the rotator cuff. *J Bone Joint Surg [Am]* Vol. 71-A (1989), p. 499-505.

[2] Murrell GA, Walton JR . Diagnosis of rotator cuff tears. *Lancet* Vol 357 (2001), p. 769-70

[3] Beaudreuil J. et al., Contribution of clinical examinations to the diagnosis of rotator cuff disease: A systematic literature review. *Joint Bone Spine.* Vol 76(1) (2009), p. 15-9.

[4] Evancho AM, et al., MR image diagnosis of rotator cuff tears. *AJR AmJ Roentgenol.* Vol 150(4) (1988) p. 751-4.

[5] Smith TO, et al., The diagnostic accuracy of MRI for the detection of partial- and full-thickness rotator cuff tears in adults. *Magnetic Resonance Imaging.* Vol 30 (2012), p. 336-346

[6] Han J, Kamber M, Pei J. Data Mining, Concepts and Techniques ", *Elsevier,* 3rd Edition, (2012).

[7] Baxt WG. Use of an artificial neural network for data analysis in clinical decision-making: the diagnosis of acute coronary occlusion. *Neural Computation.* Vol 2(4) (1990), p. 480-9.

[8] Baxt WG. Use of an artificial neural network for the diagnosis of myocardial infarction. *Annals of Internal Medicine* . Vol 115(11) (1991), p. 843-8.

[9] Lin CC, Ou YK, Chen SH, Liu YC, Lin J. Comparison of artificial neural network and logistic regression models for predicting mortality in elderly patients with hip fracture. *Injury, Int. J. Care Injured.* Vol 41 (2010), p. 869-73.

[10] Bagley SC. White H. Golomb BA. Logistic regression in the medical literature: Standards for use and reporting, with particular attention to one medical domain. *Journal of Clinical Epidemiology.* Vol 54 (2001), p. 979-85

[11] Steve Lawrence and C. Lee Giles. Overfitting and Neural Networks: Conjugate Gradient and Backpropagation, International Joint Conference on Neural Networks, Como, Italy, July 24–27, IEEE Computer Society, Los Alamitos, CA (2000), p. 114–119.

Recent Engineering Decisions in Industry
10.4028/www.scientific.net/AMM.595

Predictive Models for Pre-Operative Diagnosis of Rotator Cuff Tear: A Comparison Study of Two Methods between Logistic Regression and Artificial Neural Network
10.4028/www.scientific.net/AMM.595.263