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Prediction of Successful Weight Reduction after Bariatric Surgery by Data Mining Technologies

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Background: Surgery is the only long-lasting effective treatment for morbid obesity. Prediction on successful weight loss after surgery by data mining technologies is lacking. We analyze the available information during the initial evaluation of patients referred to bariatric surgery by data mining methods for predictors of successful weight loss.

Methods: 249 patients undergoing laparoscopic mini-gastric bypass (LMGB) or adjustable gastric banding (LAGB) were enrolled. Logistic Regression and Artificial Neural Network (ANN) technologies were used to predict weight loss. Overall classification capability of the designed diagnostic models was evaluated by the misclassification costs.

Results: We studied 249 patients consisting of 72 men and 177 women over 2 years. Mean age was 33 ± 9 years. 208 (83.5%) patients had successful weight reduction while 41 (16.5%) did not. Logistic Regression revealed that the type of operation had a significant prediction effect (*P*=0.000). Patients receiving LMGB had a better weight loss than those receiving LAGB (78.54%±26.87 vs 43.65%±26.08). ANN provided the same predicted factor on the type of operation but it further proposed that HbA1c and triglyceride were associated with success. HbA1c is lower in the successful than failed group (5.81±1.06 vs 6.05±1.49; *P*=NS), and triglyceride in the successful group is higher than in the failed group (171.29±112.62 vs 144.07±89.90; *P*=NS).

Conclusion: Artificial neural network is a better modeling technique and the overall predictive accuracy is higher on the basis of multiple variables related to laboratory tests. LMGB, high preoperative triglyceride level, and low HbA1c level can predict successful weight reduction at 2 years.

Key words: Weight reduction, artificial neural network, morbid obesity, bariatric surgery, triglyceride, glycosylated hemoglobin A

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Introduction

Obesity and its associated morbidities have become a major public health problem in both developed and developing countries.[1,2] Compared with conventional pharmacological therapies, bariatric surgery is the only long-lasting effective treatment for morbidly obese patients.[2-4] With the increasing popularity of surgical treatment, primary care physicians will handle more and more patients who have undergone bariatric surgery. Because surgery is the last resort for morbidly obese patients, it is important for the clinicians to provide successful weight loss after surgery. This reinforces the need to identify specific characteristics evident on initial evaluations for predicting weight outcomes in morbidly obese individuals seeking surgical treatment.

Until now, studies compare weight loss by using logistic regression with subtle or major differences in outcome,[5-8] but none has predicted weight loss by using the data mining technique, which includes decision trees, artificial neural network (ANN), support vector machine (SVM), etc. The prediction is a kind of binary decision, in terms of two-class pattern recognition. It has been reported that the classification accuracy of neural network is better than logistic regression technique.[9,10] In the present study, we evaluated weight reduction in obese patients after their bariatric surgery using information typically available during the initial evaluation taken before surgery. The methods for predicting weight reduction performance are logistic regression model and artificial neural network (ANN).

Methods

This prospective study was approved by the ethics committee of our Hospital. Extensive preoperative data on 389 consecutive obese patients with body mass index (BMI) >40 kg/m^2 or those with BMI >35 kg/m^2 combined with major obesity-associated co-morbidities were collected from December 2002 to October 2004. The types of operation included laparoscopic mini-gastric bypass (LMGB)[11] and laparoscopic adjustable gastric banding (LAGB). The starting point for each patient is the day of surgery, and the end-point is 2 years after the operation. Patients with incomplete data during follow-ups were consequently excluded in our study, leaving only 249 patients evaluated. Written informed consents were obtained from all patients who agreed to undergo surgery.

In this study, excess weight loss (EWL) was defined as the excess weight over the ideal body weight calculated according to the Metropolitan Life Weight Tables. The weight reduction success is defined as the percentage of excess weight loss (%EWL) >50% at the point of 2 years after operation. We applied 17 preoperative predicted factors to evaluate successful postoperative weight loss. The preoperative factors included a clinical and familial assessment, a psychiatric assessment and laboratory tests. The two socioeconomic factors were age and gender. Laboratory tests included blood count tests, liver function tests, fasting glucose profile, uric acid, high-sensitivity C-reactive protein (hsCRP), hemoglobin A1c (HbA1c) and metabolic syndrome.

Statistical Analysis

Data is presented as mean ± SD for continuous variables, and as counts for categorical variables. Binary logistic regression analysis was applied in the multivariate model to identify independent preoperative variables associated with the dependent variable (successful EWL) after surgery. *T*-test was used for the comparison of continuous variables, and chi-square was used for categorizing. A *P*-value of <0.05 was considered statistically significant. The SPSS statistical software (SPSS, Inc., Chicago, IL) was used for statistical analysis.

Data Mining Technology

Artificial Neural Networks

Neural networks are mimicking human neurobiological information-processing activities. Each elementary node of a neural network is able to receive an input signal from external sources or other nodes and is sequentially activated to locally transforming the corresponding input signal into an output signal to other nodes or environment. Nodes in the neural network can be divided into three layers: the input layer, the output layer, and one or more hidden layers. The layer receiving the inputs is called the input layer. The final layer providing the target output signal is the output layer. Any layers between the input and output layers are hidden layers.

Back propagation neural network (BPN) is a network essentially using a gradient steepest descent training algorithm and has been the most often utilized paradigm to date. For the gradient descent training algorithm, the step size, called the learning rate, must be specified first. The learning rate is crucial for BPN because smaller learning rates tend to slow down the learning process before convergence while larger ones may cause network oscillation and inability to converge.

Analyses applied in this study were Back Propagation Neural networks (BPN) conformed to a three-layered perception architecture. Seventeen independent variables were set as the input nodes in the input layer, with only one dependent factor (successful weight loss) as the output node in the output layer. As recommended by Cybenko and Hornik et al,[12,13] one-hidden-layer network is sufficient to model any complex system with any desired accuracy; hence, the designed network model will have only one hidden layer. ANN was constructed by using Qnet97 (Vesta Services Inc., 1998).

Results

We studied 249 patients consisting of 72 men and 177 women. The mean age was 33 ± 9 years. Among these, 212 patients underwent laparoscopic mini-gastric bypass and 37 underwent laparoscopic gastric banding. At the point of 2 years after the operation, 208 patients (83.5%, 196 in LMGB and 12 in LAGB) achieved successful weight loss, while 41 (16.5%, 16 in LMGB and 25 in LAGB) did not. Table 1 shows the results of clinical data after operation, and Table 2 reveals the comparison between the two procedures.

Logistic Regression Model

The type of operation had a significant effect on weight reduction (*P*=0.000) by regression analysis. The percentage of excess weight loss in the LMGB group was higher than that of the LAGB group (78.54% ± 26.87 vs 43.65% ± 26.08). Besides the type of operation, other factors showed no significance on weight loss prediction. Sixteen patients with failed weight reduction were misclassified in the success category, and 12 patients with successful weight reduction were misclassified in the failure category. The average correct classification rate of logistic regression was 88.7%.

Artificial Neural Network Model

In the ANN model, we applied 80% (training sample)/ 20% (testing sample) to analyze our database. The training group included 33 patients without successful weight loss, and 166 patients with successful weight loss. We further compared the performance of ANN and Logistic regression model by using the cross-validation method. A non-linear sigmoid function was used as a transfer function for each of the neurons in the hidden and output layers of the networks.

Seventeen clinical variables were assessed as input layer. We used one hidden layer as the designed network model. The initial number of neurons in the hidden layer consisted of hidden nodes number 32, 33, 34, 35 and 36 enrolled within the training process. Successful weight reduction is represented in the output layer. Rumelhart el al[14] suggested that

Table 1. Comparison of clinical data before and after operation

Variables	Before operation	2 years after operation	*P*-value
Weight (kg)	108.80 ± 25.51	74.78 ± 16.43	0.000*
Systolic blood pressure (mmHg)	132.76 ± 18.23	125.84 ± 19.56	0.000*
Diastolic blood pressure (mmHg)	84.33 ± 12.42	75.43 ± 14.71	0.000*
Fasting blood sugar (mg/dl)	110.92 ± 43.92	86.20 ± 9.12	0.000*
Total cholesterol (mg/dl)	200.49 ± 35.41	158.90 ± 33.89	0.000*
Triglycerides (mg/dl)	182.41 ± 177.38	74.17 ± 43.21	0.000*
Uric acid (mg/dl)	7.63 ± 3.53	5.15 ± 1.49	0.000*
AST (IU/L)	36.35 ± 31.61	22.26 ± 8.36	0.000*
ALT (IU/L)	50.93 ± 41.86	26.12 ± 11.69	0.000*
Albumin (g/dl)	6.46 ± 32.04	4.26 ± 0.36	0.005*
WBC ($10^3/\mu l$)	8.31 ± 2.30	6.03 ± 1.34	0.000*
hsCRP (mg/L)	0.71 ± 0.75	0.12 ± 0.29	0.000*
HDL-C (mmol/l)	45.97 ± 12.53	56.49 ± 13.23	0.000*
HbA1c (%)	5.85 ± 1.14	5.22 ± 0.42	0.000*

**P*<0.05 is statistically significant

Table 2. Two years of results comparing LAGB and LMGB

Variables	LMGB (n=212)	LAGB (n=37)	*P*-value
Weight (cm)	72.37 ± 14.60	87.27 ± 19.65	0.000*
BMI (kg/m^2)	26.58 ± 4.8	31.13 ± 5.23	0.000*
Waist (cm)	0.85 ± 0.08	0.89 ± 0.09	0.103
Systolic blood pressure (mmHg)	122.33 ± 16.68	138.24 ± 24.13	0.003*
Diastolic blood pressure (mmHg)	72.75 ± 10.95	84.88 ± 21.54	0.038*
Fasting blood sugar (mg/dl)	85.09 ± 9.12	90.53 ± 7.91	0.020*
Total cholesterol (mg/dl)	150.55 ± 28.96	190.37 ± 32.67	0.000*
Triglycerides (mg/dl)	70.56 ± 41.67	88.61 ± 47.39	0.113
Uric acid (mg/dl)	5.00 ± 1.57	5.72 ± 0.97	0.020*
AST (IU/L)	23.36 ± 8.05	18.25 ± 8.42	0.015*
ALT (IU/L)	27.18 ± 11.39	22.00 ± 12.22	0.085
Albumin (g/dl)	4.25 ± 0.38	4.32 ± 0.25	0.452
WBC (10^3/μl)	6.02 ± 1.25	6.09 ± 1.69	0.825
hsCRP (mg/L)	0.11 ± 0.31	0.17 ± 0.19	0.413
HDL-C (mmol/l)	57.45 ± 11.87	57.48 ± 21.03	0.996
HbA1c (%)	5.22 ± 0.43	5.22 ± 0.38	1.000

LMGB = laparoscopic mini-gastric bypass.
LAGB = laparoscopic adjustable gastric banding.
*P<0.05 is statistically significant.

lower learning rates could provide better network results and predictive rate. We used four sets of learning rate in our study, which included 0.008, 0.009, 0.010 and 0.02 during the training process. The convergence criteria used for training are RMSE (Root Mean Squared Error) ≤0.0001, or a maximum of 3000 iterations. A network topology with the minimum testing RMSE is considered optimal.

As reported by Vellido et al,[15] BPN is used in >75% of application methods for the clinical diagnostic model. The (17-33-1) topology, representing the number of neurons in the input layer, number of neurons in the hidden layer, and number of neurons in the output layer respectively, would give the best result with a learning rate of 0.020 (minimum testing RMSE). To examine the convergence characteristics of the proposed neural networks model, root mean square errors which resulted from the training process of the (17-33-1) network with a learning rate of 0.020 are shown in Figure 1.

Consistent with the logistic regression (LR) model, ANN also provided the same predicted factor on the type of operation. Moreover, HbA1c and serum TG levels were evidently associated with successful weight loss too. HbA1c in the successful group was lower than that in the failure group (5.81±1.06 vs 6.05±1.49; P=NS), and serum TG in the successful group was higher than that in the failure group (171.29±112.62 vs 144.07±89.90; P=NS). Figure 2 shows the relative importance of preoperative predictor variables: type of operation, HbA1c, and TG were relatively important than other factors. The average correct classification rate of the BPN model was 94%. Only one patient with failed weight reduction was misclassified in the successful category, and two patients with a successful result were misclassified in the failure category.

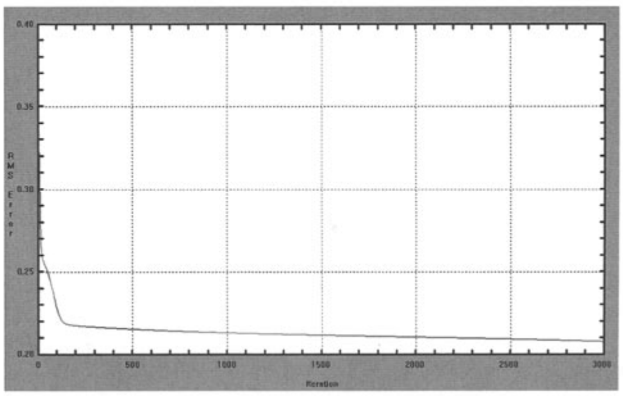

Figure 1. RMSE history of {17-33-1} network during the training process.

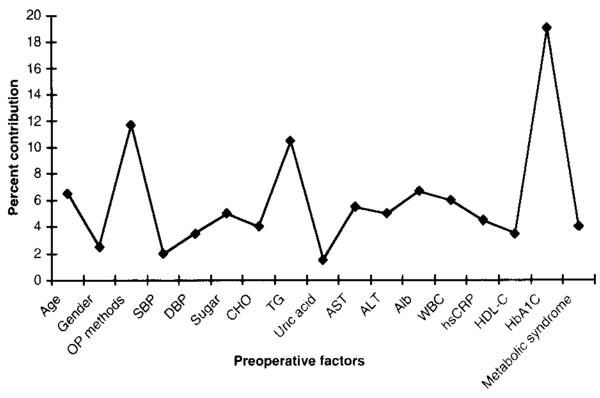

Figure 2. Relative importance of preoperative input variables by artificial neural network.

Type I, Type II Errors of the Constructed Models

To evaluate the overall classification capability of the designed diagnostic models, we further studied the misclassification costs. The costs associated with a Type I error (a patient with successful weight reduction misclassified as without success) and Type II error (a patient without successful weight reduction misclassified as with success) are significantly different. The misclassification costs associated with Type II errors are higher than Type I errors; we therefore paid special attention to Type II errors in order to evaluate the overall diagnostic capability. In comparison to the logistic regression (LR), BPN has lower Type II error (LR:39 vs BPN:12.5). Our study shows that BPN not only has a better average classification rate, but also lower Type II errors, which in turn could successfully reduce the possible risks of wrong prediction due to the high misclassification costs associated with Type II errors. Therefore, artificial neural network is a better predictor model than logistic regression.

Discussion

The predictors for successful weight reduction have not yet been determined.[16-18] This is the first study, to the best of our knowledge, to analyze the predictors for successful weight loss after bariatric surgery using artificial neural network. We developed data mining models for the prediction of weight reduction, and in comparing their predictive accuracies to conventional logistic regression analysis, we conclude that type of operation, serum triglyceride level, and HbA1c level are the predictors for successful weight reduction at 2 years after operation. Logistic regression reveals that type of operation is the only important factor for a successful result. However, ANN finds other important factors, namely HbA1c and TG. The definite successful result of bariatric surgery is still under debate. Criteria such as weight reduction, improvement in quality of life, less long-term complications, improvement in co-morbidities, and reduced need for revisional surgery should all be considered. Albeit for surgical treatment of morbid obesity, weight loss is the first important factor for a successful treatment, and this is the reason for us to focus on the degree of weight reduction.

In clinical studies, gastric bypass has been found to have a better weight reduction compared with purely restrictive procedures.[8] Studies comparing gastric bypass with gastric banding further indicate that gastric bypass establishes a greater weight loss in short- to mid-term results.[19,20] It is reasonable to obtain different results from different procedures, and even different techniques of the same operation will give different results.[7,21] The number of patients undergoing LMGB and gastric banding differed in our series and was considered as an inherent bias. However, ANN is a non-linear function statistical methodology; it effectively analyzes between groups with different case numbers. In our series, LMGB had a better weight reduction at 2 years after operation. In contrast, the maximum effect of gastric banding is not obtained until after 4 or even 5 years and then the effect remains stabilized.[22] The Australian Safety and Efficacy Register of New Interventional Procedures-Surgical (ASERNIP-S) reported that weight loss 4 years after LAGB shows no difference from that of Roux-en-Y gastric bypass.[23] The point of 2 years after operation is adequate for a gastric bypass to focus on the effect of surgery without being masked by body weight regain. However, it is not long enough for the maximum effect of gastric banding. Therefore, the results in this study can only conclude that type of operation was the predictor for successful weight loss at 2 years after the operation. Whether the type of operation is one of the predictors for successful weight loss in the long-term calls for follow-up longer than 5 years.

Metabolic syndrome is a cluster of metabolic and cardiovascular risk factors. It is closely related to obesity, and evidence shows that weight reduction as modest as 5% to 10% will lead to improvement in all components of the metabolic syndrome.[24,25] Our previous study disclosed a higher prevalence of metabolic abnormalities in morbidly obese Taiwanese patients referred for weight reduction surgery.[26] Significant weight reduction 1 year after surgery markedly improved all aspects of the metabolic syndrome and resulted in a cure rate of >95%.[27] In this study, metabolic syndrome is not a predictor of successful weight loss either by logistic regression or by ANN. However, triglyceride level and HbA1c, which are the prediction factors for successful weight loss, are strongly related to the diagnosis of metabolic syndrome. The possible explanation is that metabolic syndrome is a cluster of risk factors and the relation of each factor to obesity differs, and insulin resistance may lie at the heart of metabolic syndrome. Therefore, triglyceride and glucose serum levels weigh more importantly than the waist circumference, cholesterol level and blood pressure to attain successful weight reduction. Many studies have shown improvement of dyslipidemia after bariatric surgery, but no literature has discussed how preoperative high triglyceride level is related to better weight reduction after bariatric surgery. With lower HbA1c as another predictor for successful weight loss, weight reduction is proposed to be the major factor responsible for the significant improvement in insulin sensitivity, demonstrated by a reduction of fasting insulin and glucose level to normal, while reduction in caloric intake due to bariatric surgery may have a greater impact on the degree of hyperglycemia than actual weight loss. Lower HbA1c indicates better insulin sensitivity before operation, and may promote better glucose uptake and oxidation after operation, which ultimately leads to better weight loss.

Our study also shows that ANN is a better modeling technique. The overall predictive accuracy is higher than logistic regression in the prediction of successful weight reduction on the basis of multiple variables related to laboratory tests. The average correct classification rate in ANN is higher than LR, and ANN also has lower Type II errors when compared to other methods. Data mining can play a critical role in medical decision support, because it is effective in multi-factorial analysis. More specifically, data mining can use multiple factors in resolving a medical diagnosis, of which classification is based on multiple factors, thus reducing the errors in the diagnosis for a population of patients. Data mining has drawn serious attention from both researchers and practitioners due to its effective applications in medical research fields.[28,29] Further studies are warranted to collect more important variables that will increase the classification accuracies, by using other data mining techniques. Integrating other artificial intelligence techniques, such as fuzzy discriminate analysis, genetic algorithms and grey theory, with neural networks in further refining the network structure and improving the classification accuracies, may be the basis for future discussions.

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