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THE RELATIONSHIP OF THE INTERNATIONAL PROSTATE SYMPTOM SCORE AND OBJECTIVE PARAMETERS FOR DIAGNOSING BLADDER OUTLET OBSTRUCTION. PART II: THE POTENTIAL USEFULNESS OF ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Purpose: The International Prostate Symptom Score (I-PSS) is used exclusively for evaluating patients with a prostate condition and following various treatment modalities. As previously demonstrated, there is poor or no correlation of bladder outlet obstruction diagnosed by pressure flow study with the symptoms projected by the I-PSS. Thus, we applied an artificial neural network model to assess patients with lower urinary tract symptoms.

Materials and Methods: Data on 460 patients enrolled in part 1 of our study were entered into a multilayer feed forward, back propagation network.

Results: In the training set of 305 patients the model predicted obstruction in 94% with 94% sensitivity and 68% specificity. In the test set of 155 patients it predicted obstruction in 87% with 87% sensitivity and 44% specificity.

Conclusions: The accuracy of the model for diagnosing obstruction based on the I-PSS is acceptable, considering that statistical models failed to demonstrate a correlation of symptoms with objective obstruction.

KEY WORDS: bladder, computer simulation, urination disorders, neural networks (computer), bladder neck obstruction

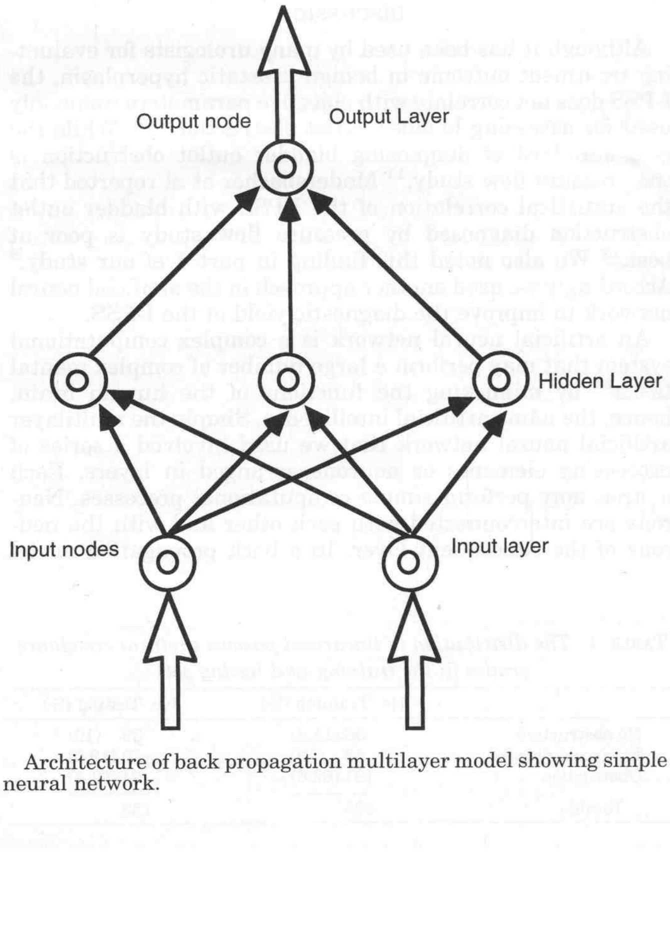
Based on our previous results and those of others indicating no correlation of symptom scores with objective bladder outlet obstruction measurements,[1,2] we explored the potential use of an artificial neural network. Statistical classification models require a known distribution of variables. This distribution should ideally be normal but this situation does not always occur in medicine. In addition, statistical prediction models nullify the role of nonlinear relationships among variables, which are usually described as statistically insignificant relations,[3] and they cannot form a nonlinear decision boundary.

Artificial neural network models have many advantages over logistic regression models, including less statistical training and the detection of complex nonlinear relationships as well as all possible interactions among predictor variables.[4] However, disadvantages include its black box nature, the requirement of more sophisticated computational processes, the empirical nature of model development and the risk of over fitting data, such that over training an artificial neural network model to 1 set of variables may jeopardize its ability to form general predictions.

PATIENTS AND METHODS

Included in part 2 of our study were the same patients and data previously reported, including symptom scores and urodynamic measurements.[5] The pressure flow pattern was interpreted using the linear passive urethral resistance relation, as described by Schäfer.[6] For simplicity the results of pressure flow studies were classified into categories of 0 and 1—nonobstructed, 2—equivocal and 3 to 6—obstructed.

These data were entered into an especially designed artificial neural network that was constructed using commercially available computer software. The foundation of this network is a feed forward, back propagation architecture (see figure). The network comprises 3 layers, including an input layer of 8 neurons into which the scores of the 8 I-PSS



Architecture of back propagation multilayer model showing simple neural network.

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questions were entered, a hidden layer of 25 neurons in which computation and differential weighing were done and an output layer of 3 neurons in which pressure flow study results were entered as obstructed, nonobstructed or equivocal.

Initially unsupervised learning was done using fuzzy logic principles. Fuzzy logic is currently used in neural networks for developing decision making systems.[7,8] In our model we applied fuzzy logic in the form of fuzzy C-means for clustering symptom scores in preparation for training, followed by supervised learning using back propagation. The target was to achieve a sum of squared error of 0.01. For this goal 662,000 iterations or epochs were needed. The training set consisted of the records of 305 patients. After the network was trained accordingly it was used to predict the pressure flow pattern in a further 155 patients who comprised the testing set. In the training set we entered into the network the scores of patients for whom pressure flow readings were known to the network. In the testing set we entered only the scores into the network. The network was blinded to the output, that is the pressure flow results in patients in the testing set were unknown to the network. We then evaluated the sensitivity and specificity of training as well as the testing sets using a confusion matrix.

RESULTS

Table 1 shows the distribution of cases among the training and testing sets in regard to pressure flow study results. Notably patient distribution was similar in each category. In the training set model sensitivity and specificity were 94% and 68% for predicting obstruction, 68% and 85% for predicting no obstruction, and 56% and 86% for predicting equivocal cases, respectively. The model had 86.5% overall accuracy (table 2). In the testing set model sensitivity and specificity were 87% and 44% for predicting obstruction, 60% and 82% for predicting no obstruction, and 49% and 19% for predicting equivocal cases, respectively. Test set overall accuracy was 73% (table 3).

DISCUSSION

Although it has been used by many urologists for evaluating treatment outcome in benign prostatic hyperplasia, the I-PSS does not correlate with objective parameters commonly used for assessing bladder outlet obstruction.[9,10] While the gold standard of diagnosing bladder outlet obstruction is the pressure flow study,[11] Madersbacher et al reported that the statistical correlation of the I-PSS with bladder outlet obstruction diagnosed by pressure flow study is poor at best.[12] We also noted this finding in part 1 of our study.[5] Accordingly we used another approach in the artificial neural network to improve the diagnostic yield of the I-PSS.

An artificial neural network is a complex computational system that may perform a large number of complex mental tasks[13] by mimicking the functions of the human brain, hence, the name artificial intelligence. Simply the multilayer artificial neural network that we used involved a series of processing elements or neurons arranged in layers. Each neuron may perform simple computational processes. Neurons are interconnected with each other and with the neurons of the subsequent layer. In a back propagation model connections are assigned a weight and the learning process changes these weights to achieve a minimal output error. This process is repeated many times (epochs or iterations) to attain the desired output.[13]

Artificial neural networks have been exclusively used for decision making and classification systems in various fields.[13,14] In urology artificial neural networks have been applied for diagnosing and prognosticating prostatic adenocarcinoma.[15–17] Based on our results we believe that the artificial neural network model that we used is far better than simple symptom scoring. Overall accuracy was 73% with 87% model sensitivity for obstruction. In contrast, when the I-PSS was tested by Spearman's correlation coefficient in part 1 of our study, we noted no correlation with the objective parameters used to diagnose bladder outlet obstruction.[5] The lowest sensitivity was observed in patients with equivocal disease, who represented 19% of our study population. In such circumstances a pressure flow study should be performed.

TABLE 1. *The distribution of linearized passive urethral resistance grades in the training and testing sets*

	No. Training (%)	No. Testing (%)
No obstruction	56 (18.4)	29 (19)
Equivocal disease	58 (19)	30 (19.6)
Obstruction	191 (62.6)	94 (61.4)
Totals	305	153

TABLE 2. *Confusion matrix results in training set*

Network	No. Urodynamics (%)			
	No Obstruction	Equivocal Disease	Obstruction	Totals
No obstruction	38 (67.8)	7 (12.1)	4 (23)	49
Equivocal disease	5 (9)	33 (5.8)	8 (4.3)	46
Obstruction	13 (23.2)	18 (31.1)	179 (93.7)	210
Total No.	56	58	191	305

TABLE 3. *Confusion matrix results in testing set*

Network	No. Urodynamics (%)			
	No Obstruction	Equivocal Disease	Obstruction	Totals
No obstruction	17 (58.6)	4 (14)	4 (4.2)	25
Equivocal disease	6 (20.7)	15 (49)	8 (8.6)	29
Obstruction	6 (20.7)	11 (37)	82 (8.2)	99
Total No.	29	30	94	153

CONCLUSIONS

The artificial neural network model is a helpful tool for objectifying nonnominal symptom scores. The ability of the artificial neural network to form decision boundaries from nonlinear data makes possible the evolution of a fairly reliable diagnostic tool based on symptoms.

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