

Prediction of Oculocardiac Reflex in Strabismus Surgery Using Neural Networks

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Abstract

Successfully predicting an oculocardiac reflex (OCR) is difficult to achieve despite various proposed maneuvers. The aim of this study was to test the models built up by neural networks to predict the occurrence of OCR during strabismus surgery in children. Premedication was not given. Atropine 0.01 mg/kg was medicated just before induction. Induction was performed with fentanyl or ketorolac, followed by propofol. Atracurium or vecuronium was given for intubation. Anesthesia was maintained with O₂-N₂O with continuous propofol infusion. Chi-square test was performed for induction agents, gender, weight, muscle blockade, repaired muscle, number of repaired muscles, duration of operation to detect any association between the occurrence of OCR and to develop the model of neural networks. The multi-layer perceptron, radial basis function and Bayesian backpropagation network were tested. The occurrence of OCR was significantly associated with gender and repaired muscle ($p < 0.05$). Gender, repaired muscle and age were considered as input for the multi-layer perceptron, radial basis function and Bayesian backpropagation network. Three neural networks had predicted the same correction rate in the occurrence of OCR as being 87.5% overall among 16 patients' records tested. These models are conceptually different in predicting compared to conventional maneuvers, and have the advantage of testing individually and foretelling the propensity. By comparison neural networks use grouped experiential data and predict OCR by the learning rule. Neural networks require a relatively abundant number of experienced and homogenous patients' records to establish an accurate model. The multi-layer perceptron, radial basis function and Bayesian backpropagation modeling network may be an alternative way, and preferable to vagal tone maneuvers if the associated relationships to the occurrence of OCR are more clearly defined.

Key Words: Oculocardiac reflex, strabismus, neural networks

INTRODUCTION

Oculocardiac reflex (OCR) is a vagally, actually trigeminovagal, mediated bradycardia resulting from ocular or orbital manipulation. OCR, which was first described by Aschner and Dagnini in 1908, is still a potential danger in ophthalmic surgery, most commonly during pediatric strabismus surgery.^{1,2} The incidence of OCR varies widely up to 90% according to the evaluation criteria, anticholinergics, anaesthetic and surgical methods used, and individual variations among patients during strabismus surgery.³

Prediction of OCR still remains difficult despite different proposed interventions. Arnold et al. (1994) performed four vagotonic maneuvers (diving response, Valsalva maneuver, ocular compression and carotid sinus massage) based on the concept of a reproducible tendency toward OCR and concluded that carotid sinus massage might help predict low heart rates during eye surgery.⁴ Bedside maneuvers such as immersion in water and Valsalva or Müller maneuver were performed to determine the relative potency of the vagally-mediated reflex to demonstrate the effectiveness of its clinical use.⁵ Immersion in cold water proved to be effective at the bedside to augment vagal tone. All tests performed in adults have potential adverse effects and limit the predictive value of these tests. These investigations have focused on tests for OCR, which is a reproducible tendency, and oculocardiac propensity may be induced in connection with eye surgery.

Neural networks are a new way of analyzing methods to recognize underlying patterns of patients.⁶

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Neural networks have the ability to learn complex patterns and trends from the previous patients' results. Neural networks produce systems (models) based on the experience of interrelationships in resulting sources, and can make a decision or prediction about new, unseen data.

The purpose of this study was to verify the model established by neural networks which had the capability of predicting the occurrence of OCR during strabismus surgery in children without any adverse effects to patients.

MATERIALS AND METHODS

This study was approved by the bioethic subcommittee in the Department of Anesthesiology of Yonsei University Medical Center. Written consent was obtained from all parents. The anesthesiology records for 161 patients who had strabismus surgery at Severance Hospital were collected from January 1 to October 30, 1998. Children between the ages of 1 and 13 weighing between 8 and 54 kg (ASA grade I) and undergoing corrective surgery for strabismus, were studied. None was receiving any concurrent medication.

Premedication was not given. All patients received routine medication of atropine 0.01 mg/kg just before induction of anesthesia. Anesthesia was induced with fentanyl 2 mcg/kg or ketorolac 1 mg/kg, followed by propofol 2.6 mg/kg. Intubation was performed after administering atracurium or vecuronium. All patients routinely received ketorolac 1 mg/kg intravenously following intubation for preemptive analgesia. Anesthesia was maintained with O₂ 1 L/min, N₂O 2 L/min. with propofol infusion. Continuous propofol infusion was provided by a 3-staged method that infused 12 mg/kg/hr for the first 10 minutes, 9 mg/kg/hr for the second 10 minutes and 6 mg/kg/hr for the remaining time. EKG, pulse oximetry and a gas monitor were used, while non-invasive blood pressure and temperature were monitored. A warm air blanket was applied for maintaining appropriate body temperature.

OCR was defined as decreasing of the heart rate by more than 20% from the stable baseline values after starting an operation. It was planned that bradycardia occurring at any time during surgery and persisting for more than 20 s would be treated with

atropine 0.01 mg/kg or by requesting the surgeon to release the tension on the muscle, or both. All the operations were performed by the same surgeon. At end of surgery, neostigmine with atropine was administered to reverse the residual effects of muscular blockade.

Induction agents, gender, weight, muscle blockade, repaired muscle, number of repaired muscles, duration of operation, and occurrence of OCR were investigated in each patient's record to produce and to validate the modelling of the neural network.

Chi-square test was performed for detecting the association between the occurrence of OCR and remaining variables. A value of $p < 0.05$ was considered to be significant. Statistically significant variables including age were selected for developing the neural network model. All data were input as symbolic characters. Repaired muscles were categorized as the bilateral lateral rectus muscles, the bilateral medial rectus muscles, or others including combined repair. The multi-layer perceptron was chosen for modeling and forecasting. Eighty percent of collected data was separated for training the model, 10% was used to test the model and 10% was used to validate the model. The occurrence of OCR as the target variable was equalized for the normalization of data in a randomized manner. The multi-layer perceptron consisted of an input layer, 2 hidden layers and the output layer. The first hidden layer had 5 nodes and the second had 2 nodes, which adopted the hyperbolic tangent transfer function. The learning rule was a conjugated gradient algorithm. Training and validation was stopped at the 95% correction rate. Additionally, the radial basis function and Bayesian backpropagation network were tested. The radial basis function layer was processed as Euclidean error distance, Gaussian function, center 4. The Bayesian backpropagation network had one hidden layer posing 4 nodes and the most likely model in outlayer. SPSS 7.5.1 (SPSS Inc., Chicago, Illinois, USA) software was used for statistical analysis and Neural Connection 2.0 (SPSS Inc./Recognition System Inc., Chicago, Illinois, USA) was applied for the neural network.

RESULTS

No patients required intravenous atropine for profound bradycardia during operation and OCR dis-

Table 1. Prediction of the Occurrence of OCR in Three Neural Network Models

Real event	MLP		RBF		BBP	
	Yes	No	Yes	No	Yes	No
Yes	1	1	0	2	1	1
No	1	13	0	14	1	13

OCR, oculocardiac reflex; MLP, multi-perceptron neural network; RBF, radial basis function network; BBP, Bayesian backpropagation network. 16 patients' data were tested.

appeared within 20 s by releasing tension on the muscle. Incidence of OCR was 30.4% (49 cases) in 161 patients. There were slightly more boys than girls (55.3% vs. 44.7%). Mean (SD) age was 6.5 (± 2.9). There were slightly more patients aged over 5 than below that age (55.3% vs. 44.7%). Mean body weight was 22.7 (± 9.1) kg. Fentanyl was used more than ketorolac as an induction agent (50.6% vs. 48.8%). The bilateral lateral rectus muscles (91 cases) were most commonly operated on, followed by the bilateral medial rectus muscles (49 cases) and others including combined repair (21 cases). A total of 49 cases (30.4%) of OCR occurred. Among them, the bilateral medial rectus muscles were most commonly involved (46.9%), while combined repair was 33.3% and the bilateral lateral rectus muscle was 20.9%. The mean duration of anesthesia was 54.2 (± 10.3) minutes.

Chi-square test results showed that the occurrence of OCR was significantly associated with differences of gender and repaired muscle ($p < 0.05$). Other variables found no differences in the occurrence of OCR. Gender, repaired muscle and age were considered as input data for building the multi-layer perceptron, radial basis function and Bayesian backpropagation network. Three neural networks predicted the same correction rate in the occurrence of OCR as 87.5% overall among 16 patients' records tested (Table 1). These data had been excluded for building the model and validating it.

DISCUSSION

Previous studies have focused on individuals and adults only for testing vagal tone. Several have tested maneuvers, which had the potential hazard and limits

used on a clinical basis. Neural networks based on prediction were performed on the basis of historical records which were obtained from patients who had undergone strabismus surgery. The neural model is built up from these extracted data and recognizes the pattern of events and the occurrence of OCR. Therefore, if the same kinds of patients exist, it is possible to establish the neural network model without any hazard and limitations. Patients' ages need not be considered.

Neural networks process data much like a human brain and learn by training through input and output paths. Nodes which are joined and grouped into layers are interconnected and combine, usually by simple summation, the input values. These values are modified by the transfer function and passed to the output paths. A typical network consists of three layers; input, hidden, and output layer in sequence. Nodes in each layer connect with corresponding weights depending on the synaptic strength. The number of nodes in the hidden layer are added or subtracted empirically to improve the correction rate. Gender, repaired muscle and age were input to nodes in the input layer and the occurrence of OCR was loaded in the outlayer's nodes in the course of the learning process in three models.

In this study, gender and repaired muscle showed a significant causal relationship to the occurrence of OCR. Repaired muscle was a well-known factor which had been elucidated in other studies.^{7,8} However, gender was not clearly suspected of causing any differences in the occurrence of OCR. Compromised factors including induction agents, muscle blockade, and undefined differences of sensitivity in both sexes might be suspected to be the result. Though age was not statistically significant, it was considered as a potential and influential factor. According to the study of Hertle et al. and Arnold et al., younger patients were more likely to have a positive vaso-vagal response.^{9,10} Other variables showed no causal relationship to the differences of the occurrence of OCR.

Three neural network models are popular in predicting output value and the occurrence of OCR because unseen data depend upon their logic and learning. The multi-layer perceptron network is the most popular neural network, but it takes more time to develop over the radial basis function network, which produces results in a short time. The Bayesian

backpropagation network has an advantage in that it does not require validation data set for verifying a produced model.¹¹⁻¹⁶ As a result, less and limited data are required. These three models each have a different logic, nevertheless their correction rate was quite similar at 87.5%. If similar conditions are applied to strabismus surgery, these models can foresee a new patient's occurrence of OCR with up to 87.5% accuracy in clinical practice, making preoperative testing of vagal maneuvers needless. Neural network models look theoretical, but they work in a similar manner for an expert anesthesiologist who has learned from experience and has then formed knowledgeable opinions with the capability to make predictions. These models are basically different in concept to predicting vagal prone. Conventional maneuvers have the advantage of testing individually and can foretell propensity during operations. Neural networks use grouped experiential data and can discriminate the possibility of OCR by the learning rule. However, neural networks need quite a large amount of data and require a relatively homogenous data set to produce an accurate model. Further study is needed to elucidate the factors involved in the relationship of the occurrence of OCR to produce more accurate models. Precise models can be applied preoperatively in predicting events for individual patients and reducing the unnecessary use of oculocardiac blocking agents. Moreover, preoperative application of neural networks could be extended in foretelling and preventing intraoperative events.

In conclusion, applied neural networks for predicting the occurrence of OCR during strabismus surgery can be developed as a method of recognizing the pattern of OCR from patients' data, which is different from the conventional method of vagal maneuvers. These methods of modeling using neural networks may be preferable to vagal tone maneuvers considering age and adverse effects.

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REFERENCES

1. Aschner B. Uber einen bisher noch nicht beschriebenen Reflex von Auge auf Kreislauf und Atmung: Verschwinden des Radialspulses bei Druck auf das Auge. *Wien Klin Wchenschr* 1908;21:1529-30.
2. Dagnini G. Intorno ad un riflesso provocato in alcuni emiplegici collo stimolo della cornea e colla pressione sul bulbo oculare. *Boll Sci Med* 1908;8:380-1.
3. Blanc VF, Hardy JF, Milot J, Jacob JL. The oculocardiac reflex: a graphic and statistical analysis in infants and children. *Can Anaesth Soc J* 1983;30:360-9.
4. Arnold RW, Gould AB, Mackenzie R, Dryer JA, Low PL. Lack of global vagal propensity in patients with oculocardiac reflex. *Ophthalmology* 1994;101:1347-52.
5. Berk WA, Shea MJ, Crevey BJ. Bradycardia responses to vagally mediated bedside maneuver in healthy volunteers. *Am J Med* 1991;90:725-9.
6. Stern CS. New tools for analyzing data, making decisions, and forecasting trends. *Drug Benefit Trends* 1997;9:43-9.
7. Milot JA, Jacob JL, Blanc VF, Hardy JF. The oculocardiac reflex in strabismus surgery. *Can J Ophthalmol* 1983;18:314-7.
8. Loewinger J, Friedman-Neiger I, Cohen M, Levi E. Effects of atracurium and pancuronium on the oculocardiac reflex in children. *Anesth Analg* 1991;73:25-8.
9. Hertle RW, Granet DB, Zylan S. The intraoperative oculocardiac reflex as a predictor of postoperative vaso-vagal responses during adjustable suture surgery. *J Pediatr Ophthalmol Strabismus* 1993;30:306-11.
10. Arnold RW, Dyer JA, Gould AB. Sensitivity to vasovagal maneuvers in normal children and adults. *Mayo Clin Proc* 1991;66:797-804.
11. Farrell RM, Orr JA, Kuck K, Westensknow DR. Differential features for a neural network based anesthesia alarm system. *Biomed Sci Instrum* 1992;28:99-104.
12. Leon MA, Rasanen J. Neural network-based detection of esophageal intubation in anesthetized patients. *J Clin Monit* 1996;12:165-9.
13. Mobley BA, Leasure R, Davidson L. Artificial neural network prediction of lengths of stay on a post-coronary care unit. *Heart Lung* 1995;24:251-6.
14. Tu JV, Mazer CD. Can clinician predict ICU length of stay following cardiac surgery? *Can J Anaesth* 1996;43:789-94.
15. Buchman TG, Kubos KL, Seidler AJ, Siegforth MJ. A comparison of statistical and connectionist models for the prediction of chronicity in a surgical intensive care unit. *Crit Care Med* 1994;22:750-62.
16. Doyle HR, Dvorchik I, Mitchell S, Marino IR, Ebert FH, McMichael J, Fung JJ. Prediction outcomes after liver transplantation. A connectionist approach. *Ann Surg* 1994;219:408-15.