FUZZY ARTMAP NEURAL NETWORK PREDICTION OF HEART SURGERY MORTALITY

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A major national effort is underway to determine patterns of medical practice that most effectively result in favorable health outcomes. Databases arising from such effectiveness research may contain tens of thousands of cases and hundreds of variables intended to predict outcome status. Established statistical prediction algorithms may be suboptimal for such tasks because of obstacles arising from massive number of cases, missing data, variable selection, multicollinearity, specification of important interactions, and sensitivity to erroneous values.

To determine whether a self-organizing neural network based on adaptive resonance theory could accurately predict the mortality of coronary artery bypass grafting surgery (CABG), we evaluated 11,057 records of patients hospitalized at US Veterans Affairs Medical Centers over a 2-year period. We developed a supervised neural network that incorporates fuzzy set logic into adaptive resonance theory mapping (ARTMAP) to simultaneously predict outcome and define category patterns within outcomes. Multiple subnetworks resulting from random permutations of the learning set were created until a stable "voting" consensus (predictive score) was achieved.

Voting fuzzy ARTMAP was compared to the following 7 techniques performed by the Denver group: stepwise logistic regression (LOGIT; results confirmed by the Reno group), an additive model (ADDITIVE), Bayesian assignment (BAYES), cluster analysis (CLUSTER), classification and regression trees (CART), an expert panel-derived sickness score (EXPERT), and principal components analysis (PRCOMP). Because LOGIT with 6 of 33 total variables chosen by stepwise regression was found to be the best of the established methods, fuzzy ARTMAP was applied only to those 6 variables.

STATISTICAL TECHNIQUE	NUMBER OF FACTORS	LEARNING SET		TESTING SET	
		c index	Accuracy (@.5 cutoff)	c index	Accuracy (@.5 cutoff)
ARTMAP (15 votes)	6*	.985	.962	.806	.946
LOGIT	6*	.740	.918	.714	.918
ADDITIVE	23	.720	np	.712	np
BAYES	23	.706	np	.705	np
CLUSTER	6	.703	np	.705	np
CART	6	.681	np	.663	np
EXPERT	6	.636	np	.651	np
PRCOMP	4	.704	np	.636	np

* ARTMAP performed on same 6 variables selected by stepwise LOGIT, using all 5530 learning cases and 5527 testing cases without missing data on those 6 variables. np = not performed

The c index, a nonparametric estimator of the area under the receiver operating characteristic curve, was applied to the predictive scores of each algorithm in order to compare average accuracies in predicting post-operative mortality from CABG. The c index is independent of both the prior probability of each outcome and the threshold cutoff for categorization, and its computation requires only that the algorithm produce an ordinally-scaled relative predictive score, not a true probability. The c index estimates the average probability, over all possible pairs of patients with differing outcome, that an algorithm will assign a higher mortality score to those who died post-operatively compared to those who survived.

The fuzzy ARTMAP consensus of 30 parallel voting subnetworks outperformed all other predictive techniques (see Table) using only 6 of the 33 variables available to the established algorithms. Furthermore, each fuzzy ARTMAP voting subnetwork generated outcome-specific multivariate memory categories distinguished by simultaneous ranges within variables. We are presently exploring ways to interpret the multiple-vote partition of variable space and thereby define severity-of-illness and medical practice patterns associated with differing health outcomes.