

## Artificial neural network in prediction of the outcome of critically ill patients with perforative peritonitis

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### Introduction

Most scoring systems currently used in prediction of mortality in Surgical Intensive Care Units (SICU) are based on logistic

**Aim.** The aim of the present paper is to compare the use of Artificial Neural Network (ANN) to APACHE II, MOF, TISS-28 and MPI scoring system in prediction of peritonitis-related death in patients with perforative peritonitis. **Patients and methods.** A prospective study was performed of 145 patients with perforative peritonitis, treated in the Surgical Intensive Care Unit. The main outcome of this study was peritonitis-related death. The Levenberg-Marquardt method was used for training, and 16 variables for entrance into the Artificial Neural Network. Sensitivity and specificity of scoring systems are graphically shown for the different values of cut-off points with the receiver-operating characteristic curve (ROC) curve. **Results.** We tested 92 cases in a network and found that the APACHE II system predicted the lowest number of wrong assessments with a score of 12, with all the other scoring systems predicting 19 wrong assessments. The area under the curve for the first postoperative day was 0.87 for TISS-28 score, 0.86 for APACHE II score, 0.83 for MOF and 0.72 for MPI score. The highest rate of correlation between the observed and the expected mortality rate was in the APACHE II system. This demonstrated that TISS-28 and APACHE II are significantly better than other systems ( $P < 0.01$ ). In addition, this discriminatory ability was also retained on the third and seventh postoperative days. **Conclusion.** APACHE II is superior in the prediction of patient outcome to the Artificial Neural Network and other tested scoring systems.

**Key words:** Artificial neural network, Perforative peritonitis, APACHE II, Surgical intensive care unit.

regression. Although APACHE II (Acute Physiology and the severity of Chronic illness) system (1) was designed for severely ill medical patients, it has been validated in prediction of patient outcome in surgical pa-

tients with intra-abdominal infections and peritonitis (2, 3), but the usage of APACHE III system is not confirmed in these patients (4). There are scoring systems developed specifically for assessment of Multiple Organ Failure (MOF) (5), systems that reflect the amount of care and can provide useful information about severity of disease and prognosis (Therapeutic Intervention Scoring System – 28) (6) and a scoring system based on intra-operative data (Mannheim Peritonitis Index) (7). The Artificial Neural Network is an alternative technique in the prediction of mortality in SICU (8).

Artificial Neural Networks (ANN) are computer programs that simulate some of the higher level functions of the human brain. In the human brain, there are neurons and synapses, with various synaptic connection strengths, called weights, for each connected pair of neurons. There is a specific set of input and output neurons for each problem and each net corresponds to the inputs and outputs from a traditional computer program (9).

Despite the advancement of intensive care in medicine and the introduction of aggressive surgical techniques, the prognosis of peritonitis remains poor, especially if multiple organ failure has developed (10). About 80% of cases of secondary peritonitis in large hospitals are accounted for by perforative peritonitis, and 10 to 20% can be seen in patients after abdominal operations (11) Patients with peritonitis due to perforation of the hollow viscera are among the most complex cases encountered in surgical practice (12).

The evaluation of the therapeutic approach requires a precise assessment of the risk to the patient, as mortality remains high, in some instances reaching ~60% (3) With this in mind, we performed a prospective evaluation of several prognostic models with the Artificial Neural Network, in prediction of peritonitis-related death in patients with perforative peritonitis.

## Patients and methods

The prospective study involved 145 patients of both sexes with perforative peritonitis. Patients hospitalized in the SICU longer than 24 hours were included in the study. The inclusion criterion was perforative peritonitis, as determined by laparotomy. Exclusion criterion was post-traumatic peritonitis. Patients were tracked either to discharge or death.

The main outcome of this study was peritonitis-related death. APACHE II and Therapeutic Intervention Scoring System (TISS-28) scoring systems were calculated upon admission to the hospital (during the first 24 hours), and on the third and the seventh days after hospitalization. The MPI (Mannheim Peritonitis Index) scoring system was calculated during the first 24 hours after hospitalization or during laparotomy. Data were collected in a computer database made with the commercial program of Microsoft Access. Statistical analyses were performed using commercial software (SPSS 11.0).

Cut-off points were specified (26 points for APACHE II, 26 for MPI, 2 for MOF, 39 for TISS-28) and all values greater than the cut-off points were taken to predict death.

Sensitivity and specificity are graphically shown for the different values of cut-off points. They are presented by the ROC curve. The difference in the area under the ROC curve between scoring systems was tested statistically. The test of the difference between areas under the ROC curve was applied using the trapezoidal rule to approximate areas, conservative estimation for the standard deviation.

The Feed-Forward Artificial Neural Network had 4 hidden layers with 8 neurons in the layer. We used the Levenberg-Marquardt method for training, and 16 variables for the entrance into the network. One half of our data was taken by random selection for training, and the second half for testing

the neural network. The Artificial Neural Network was implemented in a Matlab software environment using the Neural Network Toolbox (Matlab 7.0).

## Results

The prospective study involved 145 patients of both sexes with perforative peritonitis. The mean age of all patients was  $58 \pm 18$ ; the ratio of men: women was 91/54, with no significant differences in the average age between the two genders. There were 92 patients that survived surgery (63.4%) while 53 patients died (36.6%).

### *Testing of scoring systems with Feed-Forward Artificial Neural Network (ANN)*

By testing 92 cases in a network, with a cut off point for all the neural networks of 0.5, and all the other networks specified values of the cut off score, APACHE II system predicted the lowest number of wrong assessments with a score of 12, while TISS-28 and MOF system predicted 15 and 20 wrong assessments, respectively, with all the other systems predicting 19 wrong assessments.

The introduced error is related to the number of wrong assessments. If we compare the given results, we can conclude that the neural network gave better results than the MOF scoring system. Cases in which the

neural network or the neural network and the APACHE II system, gave the right assessment, but not any of the other scoring systems, were recorded.

### *Discriminatory ability of prognostic systems*

The APACHE II and TISS-28 scoring systems showed the highest sensitivity and specificity during the first and the third postoperative days, while the sensitivity and specificity during the seventh postoperative day was good for all the scoring systems (Table1).

The ROC curve (receiver-operating characteristic curve) for the prognostic scoring systems used (relationship between sensitivity and the false positive rates [1-specificity] for different cut-off points) was given for the first, third and seventh postoperative days (Figures 1, 2, 3, 4). The APACHE II and TISS-28 curve demonstrated that their discriminatory ability was better than that of the MPI curve. The area under the curve for the first postoperative day was 0.87 for TISS-28 score, 0.86 for APACHE II score, 0.83 for MOF, and 0.72 for MPI score. This demonstrated that TISS-28 and APACHE II are significantly better than other systems in predicting patient outcome ( $P < 0.01$ ) (Figure 1 and 3). In addition, this discriminatory ability remained on the third and seventh postoperative day as well.

Table 1 Sensitivity and specificity of scoring systems.

Scoring systems	Sensitivity (%)			(Specificity %)			Positive predictive value (%)			Negative predictive value (%)		
	First day	Third day	Seventh day	First day	Third day	Seventh day	First day	Third day	Seventh day	First day	Third day	Seventh day
APACHE II	58.5	64.3	77.6	95.7	100.0	98.9	88.6	100.0	98.1	80.0	78.6	85.6
MOF	24.5	30.8	50.0	96.7	100.0	100.0	81.3	100.0	100.0	69.0	71.9	82.6
TISS-28	56.6	60.9	71.9	93.5	100.0	100.0	83.3	100.0	100.0	78.9	77.3	83.3
MPI	52.8	-	-	77.2	-	-	57.1	-	-	74.0	-	-

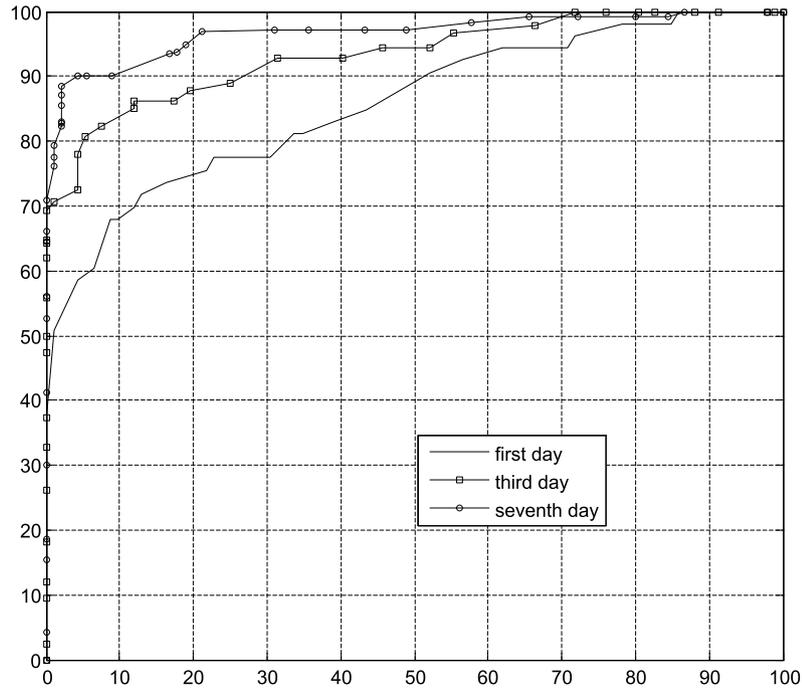


Figure 1 ROC curve (receiver–operating characteristic curve) for the APACHE II scoring system for the first, third and seventh postoperative days

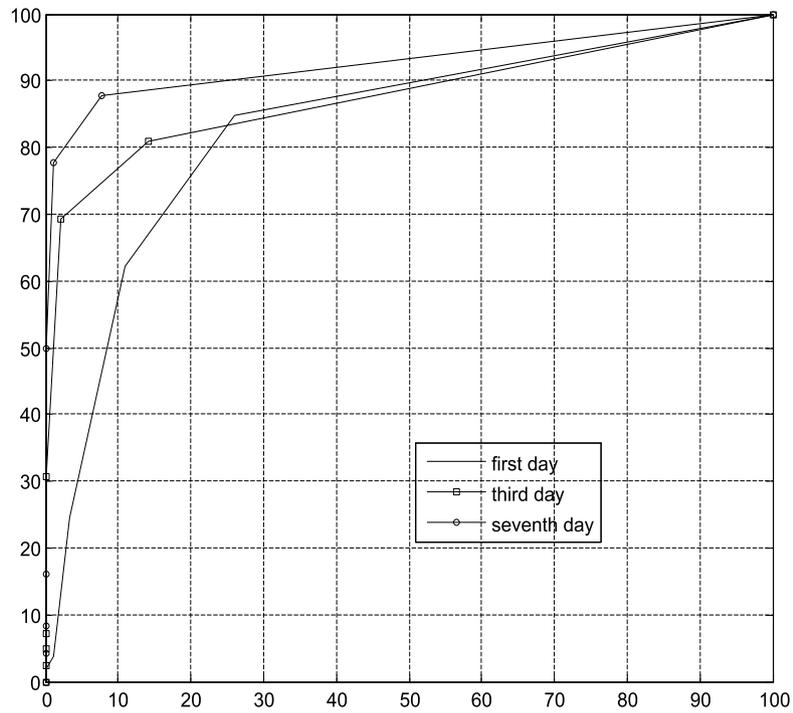


Figure 2 ROC curve (receiver–operating characteristic curve) for the MOF scoring system for the first, third and seventh postoperative days

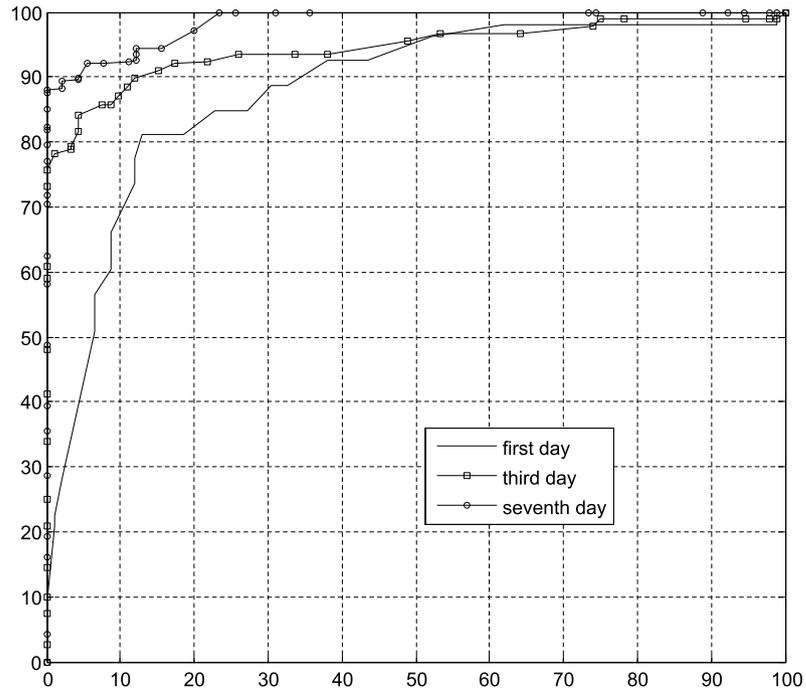


Figure 3 ROC curve (receiver–operating characteristic curve) for the TISS-28 scoring system for the first, third and seventh postoperative days

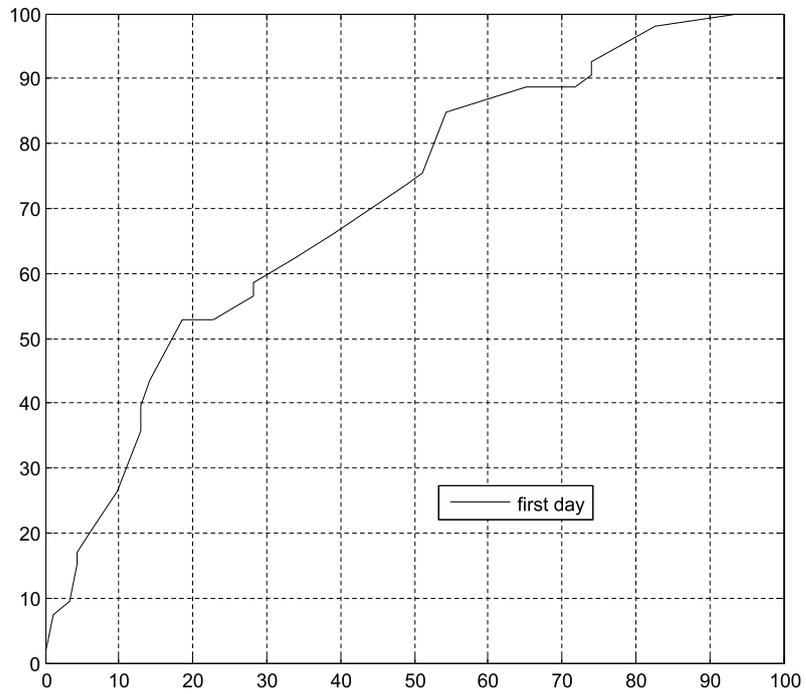


Figure 4 ROC curve (receiver–operating characteristic curve) for the MPI scoring system for the first day

## Discussion

We demonstrate here that the APACHE II scoring system gives the best prognosis of patient outcome, and that the neural network itself gives better results than the MOF scoring system. Although some studies have shown that neural networks are superior to logistic regression models (8), or that there is no significant difference between regression models and neural network (13), our data suggest that the APACHE II system is more accurate than other scoring systems. In univariate analysis, all tested scoring systems were relatively accurate in identification of patients with high risk of death from peritonitis. In multivariate analysis, only the APACHE II and TISS-28 systems independently contributed to prediction of outcome during all days of testing. Although we tested scoring systems on the first, third and seventh days, our study did not confirm the value of serial determination.

The APACHE II system is the best validated prognostic model which estimates general consequences of disease, taking into account age and previous diseases. It can be used in a defined population with the syndrome of systemic inflammatory response (2,3). All variables of the APACHE II system are a part of routine monitoring (14) which makes it easily applicable in everyday practice. APACHE II is extremely flexible, with good prediction capacity and without significant differences between elective and urgent surgery, in benign or malignant diseases, or in the prediction of complications (15).

Peritonitis generally responds promptly to surgical intervention and systemic antibiotics, but some patients continue to develop sepsis, organ failure and death. The seriousness of the disease and organ failure, but not recurrent infections, are the main reasons for lethal outcome in patients with peritonitis (16). Despite the advances in diagnostic techniques, the decision for re-operation

of critically ill patients depends on a medical assessment and it can be the source of a variety of conflicts caused by a broad spectrum of pressure concentrated on the surgeon (17).

Experienced doctors in the ICU are generally very good at predicting the probability of survival of their critically ill patients (18). However, it is sometimes very difficult to predict the probability of survival. In addition, doctors often disagree about the prognosis of survival of individual patients (19), and it could be said that the role of subjective assessment of a patient's outcome is a neglected issue, even though occasionally this subjective assessment could be the most powerful indicator of the outcome in comparison to the APACHE II system (20). This could be due to an experienced clinician's ability to evaluate certain factors which current scoring systems do not take into account. Therefore, it is necessary to undertake further studies in this direction. Scoring systems which give reliable prediction of patient outcome, with good agreement between the expected and the observed mortality rates, are useful tools for controlling the quality of treatment and assessment of care (21). The neural network is projected to use all possible data available. The advantage of the neural network, i.e. its applicability suitable of obtaining the assessment from available data, demands further testing of this prognostic model.

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