VALIDATION OF LOGISTIC REGRESSION MODELS USED IN THE CLINICAL ASSESSMENT OF EQUINE COLIC PATIENTS

REEVES, M.J., CURTIS, C.R., SALMAN, M.D., STASHAK, T.S., REIF, J.

Several authors have utilized multivariable statistical methods to evaluate prognosis in equine colic patients (Parry et al., 1983; Orsini et al., 1988; Reeves et al., 1989). However, none of these models have undergone independent prospective validation. Based on data collected from a study of 1,965 colic cases, two multivariable models have been developed to evaluate both prognosis and the need for surgery of equine colic patients (Reeves et al, 1990; Reeves et al, 1991). The objective of this present study was to perform an independent prospective validation in order to evaluate the true predictive performance of these models.

MATERIALS AND METHODS

Five university veterinary hospitals, 5 private equine referral hospitals and 10 equine ambulatory practices were selected for the study. None of these 20 institutions were involved in the initial study which generated the models. The initial target was to collect 1000 cases over a 15 month period; 67 cases from each hospital and 33 from each ambulatory practice. A questionnaire was used to record the necessary information.

The death (prognosis) outcome was defined: (0) alive or (1) died or euthanized at day 3 (medical cases) or day 14 (surgical cases). Cases that were euthanized for primarily financial considerations were excluded. The need for surgery outcome was defined: (0) medical cases (horses that received routine medical treatment only) or (1) surgical cases (horses that had definitive gastrointestinal lesions identified during exploratory laparotomy or post mortem examination). Cases of gross peritoneal rupture and anterior enteritis were excluded.

Calculation of post-test probabilities

For each horse the likelihood ratios (LR) for prognosis and the need for surgery were calculated by utilizing the regression co-efficients from the appropriate logistic regression equation. (Albert, 1982):

$$LR = e^{(INT + \Sigma B_k * X_k)} \qquad (1)$$

where: int= adjusted intercept; B_k= logistic regression coefficients for each variable X_1, X_2, ... X_n; X_k= value of each variable X_1, X_2...X_n for the particular horse.

From the College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523.

The intercept term was adjusted for unequal proportions of cases and controls by adding log(q/p) to the estimated intercept, where p is the proportion of cases in the data used to generate the model (Albert, 1982). The LR expresses the odds of death or need for surgery for a particular horse, given its particular covariate pattern. By application of Bayes' theorem, the probability of either death or need for surgery for each horse was calculated:

$$\text{Pre-test odds} \times \text{Test odds} = \text{Post-test odds} \qquad (2)$$

The pre-test odds were estimated for each outcome by using either the case-fatality rate or the prevalence of surgery (proportion of colic cases which required surgical treatment) at each institution. The test odds is equivalent to the likelihood ratio (LR) generated from equation 1. Thus:

$$\frac{\text{Case-fatality rate}}{1 - \text{case-fatality rate}} \times \text{LR} = \text{Post-test odds for death} \qquad (3)$$

$$\frac{\text{Proportion surgical cases}}{1 - \text{proportion surgical cases}} \times \text{LR} = \text{Post-test odds for need for surgery} \qquad (3)$$

The above equations (3) serve to adjust the LR of each horse for the underlying case-fatality rate or prevalence of the need for surgery at the particular institution the horse was observed at (Sackett et al, 1985). Finally, the post-test odds are converted to the more intuitive post-test probability:

$$\text{Post-test probability} = \frac{\text{Post-test odds}}{1 + \text{post-test odds}} \qquad (4)$$

Evaluation of goodness-of-fit

For each outcome, Hosmer-Lemeshow Goodness-of-Fit Chi square statistics (GOFCS) were generated using equal sized deciles of post-test probabilities (Hosmer et al, 1989).

RESULTS AND DISCUSSION

A total of 730 cases were collected by the end of the study period. Four private ambulatory practices collected less than 10 total cases and were eliminated from further analysis. A total of 712 cases from 16 different institutions were used in the analysis.

Sixty seven cases were euthanized for primarily economic reasons and were therefore excluded, leaving 645 cases for the evaluation of the prognosis outcome. The GOFCS was 11.19 (10 degrees of freedom; $0.3 < p < 0.4$), thus the model fitted the validation data set well and appears to provide an accurate estimate of the probability of death.

Thirty seven cases were excluded from the evaluation of the need for surgery model leaving a total of 675 cases. For every decile the expected number of surgical cases was slightly greater than the observed number. The GOFCS was 39.01 (10 degrees of

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freedom; $p < 0.001$) indicating a poor fit. However, despite this over-estimation we feel that the model should provide useful clinical information. There may be several reasons for the over-estimation of the need for surgery. Firstly, the rectal examination findings are coded simply as normal or abnormal. Thus relatively mild derangements which may not be associated with the need for surgical intervention will tend to over-inflate the LR estimate. Secondly, the evaluation of the need for surgery outcome involves the assessment of variables which tend to be dynamic in nature (e.g., rectal findings, frequency of abdominal pain). These variables can undergo relatively rapid changes during the time course of the colic episode which would invalidate any previous assessment and hence add to the overall inaccuracy.

The Bayes' Theorem approach which utilizes the LR in generating post-test probabilities has several advantages: i) compared to sensitivity and specificity the LR is more robust to changes in the underlying prevalence of disease in the population being tested, ii) it provides a simple method to adjust the test result (LR) for the underlying prevalence of disease in the population being tested and iii) the LR preserves the degree of abnormality of the test result (Sackett et al., 1985).

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