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RISK ANALYSIS OF QUARANTINE STATION PERFORMANCE: A CASE STUDY OF THE IMPORTATION OF EQUINE INFECTIOUS ANEMIA VIRUS INFECTED HORSES INTO CALIFORNIA

Carpenter T.E.[1], McBride M.D.[2], Hird D.W.[1]

L'objectif de cette étude visait à étudier et à examiner le risque à l'importation et de propagation accidentelle de l'anémie infectieuse des équidés (EIAV), par des chevaux infectés en Californie. Une simulation par ordinateur a été développée pour évaluer les stations de quarantaine actuelle et quelques alternatives. 150 répétitions ont été effectuées pour simuler 15 scénarios différents de 10.000 chevaux dans cette région sur une période de 14 ans. Les résultats de la simulation ont montré que, dans les conditions actuelles de faible prévalence de EIAV dans les pays examinés, une augmentation de la période de quarantaine ne diminue pas le nombre de chevaux infectés accidentellement par l'EIAV lors de la quarantaine. Ce modèle pourrait être appliqué à d'autres situations de quarantaine afin d'évaluer le risque à l'importation de l'EIAV, ainsi que pour d'autres maladies.

INTRODUCTION

Decision makers are frequently faced with difficult questions regarding quarantine of imported animals. For example, how long must an animal remain under quarantine before release with some degree of certainty that it is not infected with an exotic or reportable disease? Alternatively, what is the probability that an animal released at a given time is infected but has not yet begun to show clinical symptoms or has not seroconverted? Through the use of simulation modeling, these and other complex questions may be addressed.

Throughout the world, international animal movement is increasing. More than 9 million live, non-avian animals were imported into the United States between 1992-94. Nearly 1% of these imports were horses (Childs, 1992; Kahrs, 1994). GATT and NAFTA were designed to reduce and, and in some cases, eliminate international trade barriers. Among these barriers are "unjustified technical health standards" (Sheesley, 1994). Since, as Ahl stated, "...the condition of 'zero risk' is unattainable...", (Ahl, 1994) instead of eliminating all actions that involve a non-zero risk, scientists and decision makers must put risk in perspective. This may be done in a risk analysis approach.

Equine infectious anemia virus (EIAV) is a major concern for importation. It is the etiologic agent for EIA, a reportable disease in the United States (Crawford and Kittleson, 1987). EIA is characterized by an acute phase with fever, destruction of blood cells, anemia, unthriftiness and often edema. Most horses survive the first episode and recover as the horse produces specific neutralizing antibodies. Once infected with EIAV, a horse remains infected and seropositive for life (Issel and Coggins, 1979). However, many of the EIAV-seropositive horses are eventually destroyed (Issel and Cook, 1993), because their movement is restricted, thereby diminishing the economic value of these horses, many of which are used for breeding or racing.

Recently, the United States Department of Agriculture, Veterinary Services, requested an assessment of the current quarantine practices followed in California against EIA. In this paper we report a risk analysis of importation and detection of EIAV-infected horses into California. The purpose of this project was to evaluate current and alternative testing and quarantine procedures for horses entering California from abroad. Specifically, we were interested in determining the likelihood of an EIAV-infected horse entering a quarantine station and the probability of it being detected or avoiding detection.

MATERIALS AND METHODS

Records of horses from foreign countries imported into California were obtained from files in the California Area Office of the United States Department of Agriculture, Veterinary Services. Records were analyzed to determine the distribution, by country of origin, of horses imported into California between January 1992 and July 1995.

EIAV-seroprevalence information, from all countries that exported horses to California between January 1992 and June 1995, was obtained from the literature (Food and Agriculture Organization, 1993; Toma and Goret, 1973). Since the information was categorical, countries were classified, according to EIAV seroprevalence, as either low (0.0001% - 0.010%), medium (0.011% - 0.50%), or high (0.51% - 1.5%). Furthermore, within each of these categories, the minimum, mean and maximum values for were used in the analysis to reflect low, moderate and high prevalence estimates, respectively.

[1] Department of Medicine & Epidemiology, School of Veterinary Medicine, University of California, Davis, CA, 95616 USA.
[2] United States Department of Agriculture, Animal and Plant Health Inspection Service/ Veterinary Services, Sacramento, CA 95827 USA.

The agar gel immunodiffusion (AGID) test, developed by Coggins and Norcross (1970) is considered the international standard for diagnosis of EIA (Issel and Cook, 1993). Based on experimental inoculation trials and serologic surveys, the sensitivity and specificity of the AGID test are reportedly at least 99% (Coggins et al., 1972; Loftin et al, 1990; Pearson et al., 1970; Pearson and Gipson, 1988; Toma and Goret, 1973). However, the estimated sensitivity is based on the assumption that the individual horse was not recently (> 30 days) infected. Test sensitivity is very low within the first week post infection and increases rapidly throughout the first month (Coggins and Norcross, 1970; Coggins et al., 1972; Pearson et al, 1970). A similar relationship exists between time post infection and sensitivity of clinical symptoms (Pearson et al., 1970). Therefore in the model, it was necessary to estimate the time of EIAV infection prior to serologic testing and physical examination at a quarantine station.

Cumulative distribution functions (Evans et al., 1993), estimating sensitivity relative to days post EIAV infection, for the AGID test alone, clinical symptoms alone and AGID test and clinical symptoms combined, were selected based on statistical and biologic criteria. The statistical criterion was that the selected distributions were not significantly ($P > 0.05$) different from the empirical data. The χ^2 goodness of fit and Kolmogorov-Smirnov test statistics were examined, using the software program BestFit (Palisade Corporation, Newfield, NY). The biologic criterion was that the statistical distribution of the model fit our biologic knowledge of the immunologic and clinical process of the infection.

A simulation model was constructed using a spreadsheet program, EXCEL (Microsoft Corporation, Redmond, WA), to evaluate the risk of EIAV introduction by means of an infected horse imported through a quarantine station in California. Basically the simulation model worked as follows: A simulated horse was exported and, depending on the route of shipment, entered a quarantine station in California 1 or 18 days later. There, the horse was tested for antibodies to EIAV, using the AGID test. During the 3-day quarantine period, test results were read and the horse was observed for clinical symptoms of EIA. The horse was either declared EIA infected, and not released within the state, or EIA noninfected, and released. To simulate the expected outcome for a period of one year, 700 iterations were performed, representing the importation and testing of 700 horses. Multiple years were be evaluated by increasing the number of simulations.

The model was based on the following assumptions :

1. Recovered, infected horses remain infected and seropositive for at least 6 to 24 months and were considered candidates for importation into California (Stein et al, 1955).
2. EIAV-infected horses show either clinical symptoms or seroconvert by 45 days post infection (Coggins and Norcross, 1970; Coggins et al., 1972; Pearson et al., 1970).
3. Horses found to be clinically ill at pre-export veterinary inspection will not be shipped to California until signs have resolved.
4. Similarly, horses seropositive on the AGID test will not be shipped to California either because the veterinarian at the export country will not permit shipment of a test positive horse or one showing clinical signs of EIA, or the owner will voluntarily not ship the horse.
5. Although the number of days tested prior to importation is not known, it was believed that the vast majority of horses were tested for EIAV antibodies within 75 days of shipment
6. The greatest sensitivity value associated with either the AGID test, clinical symptoms, or the combination of the two, was used to classify a horse at the quarantine station as EIAV infected.
7. For horses shipped by air, one day was added to the time between initial physical examination and serologic testing at country of origin, and inspection on arrival in California. Eighteen days were added for horses shipped by sea.

RESULTS AND DISCUSSION

Three cumulative distribution functions and their respective parameters were selected to represent the sensitivity of detecting a EIAV-infected horse (Evans et al., 1993). For any given day post infection, the maximum sensitivity for an individual statistical distribution (AGID test or clinical symptoms) or combined was assumed to be the sensitivity for EIAV-infection while the horse was in quarantine.

The model predicted none or only a limited number of EIAV-infected horses entering the quarantine station, if the quarantine period were 3 days and the presumed prevalence estimates were low, moderate or high, respectively. The model also predicted that no more than 1 horse would not be detected while in a 3-day quarantine.

Results obtained from this analysis when moderate and high prevalence estimates were assumed agree with those observed in the United States. Five to 10 reactors are found annually among the approximately 10,000 horses per year at the National Veterinary Services Laboratory in Ames, Iowa for antibodies to EIAV over the past 3 years. The vast majority of these test-positive horses were imported from outside the United States (personal communication, A.D. Alstead, NVDLS, Ames, Iowa). In this case, it appears that United States equine imports are more likely from countries which have a distribution similar to that of our moderate and high prevalence estimates. Therefore, our findings for the extended quarantine analysis should be appropriate for the United States as a whole.

Examination of an extended (7 and 14 days) quarantine period is valuable for a number of reasons. First, due to a recent outbreak of Venezuelan equine encephalitis in Mexico, a 7-day quarantine period was in place from July 1993 through February 1995 for horses imported into California from Mexico. Although samples were collected from horses the day they entered quarantine, given horses were held an additional 4 days, (from 3 to 7), it would have been a reasonable alternative to sample these horses on the 5th rather than 1st day under quarantine. In this way an additional 4 days would be added to the number of days post infection, thereby increasing the sensitivity of the AGID test. Second, the benefit of extending quarantine period is a logical step in evaluating the risk/benefit of quarantine station performance.

The findings reported in this paper should not be interpreted to mean that because no horses have been detected as infected with EIAV, testing at quarantine should be discontinued. Rather it is more likely that test results warrant continued testing since it appears to be a successful method of reducing or even eliminating the threat of introducing EIAV-infected horses into California.

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