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Use of Veterinary Records To Teach Laboratory Thinking Skills in Biology

Christopher J. Woolverton

Recently, a draft recommendation regarding the teaching of a core laboratory curriculum was released by the American Society for Microbiology (1997). Written by a diverse group of microbiology educators who teach in community colleges, liberal arts colleges, comprehensive universities, and research universities, the document recommends essential techniques and content to standardize the microbiology learning experience through teaching of laboratory safety, laboratory skills and laboratory thinking skills (ASM 1997). While the recommendation is somewhat specific for microbiology, several important strategies were identified to develop strong cognitive, analytical, communication and interpersonal skills (ASM 1997) which are applicable across biology laboratory curricula.

The document recommends that laboratory curricula include:

1. Cognitive processing skills (including exercises that allow for forming a clear answerable question, developing a testable hypothesis, predicting results, and following an experimental protocol).
2. Analytical skills (collection and organization of data in a systematic fashion, presentation of data in appropriate forms, assessment of data validity [integrity and significance], and drawing appropriate conclusions).
3. Communication skills (presenting data in written and verbal forms).
4. Interpersonal skills (developed from effective collaborative work with task sharing [ASM 1997]).

I have designed a laboratory protocol using clinical, veterinary data which teaches the cognitive, analytical, communication and interpersonal skills suggested by the ASM recommendation.

Human physiological data are routinely used in the training of students preparing to enter clinical sciences and medicine. These data are presented as "case histories" assembled from actual patient records or obtained from the literature. In general, human clinical data are difficult to obtain outside the medical school training environment. Therefore, data from other animal species can be used to evaluate states of health and disease. Data from veterinary records can be readily obtained from zoos, universities, and the local veterinarian. The data can be evaluated in two different versions of the laboratory protocol, depending on pedagogical needs. First, the protocol can be designed to develop hypotheses regarding animal health status by predicting disease potential based on an individual’s or group’s deviation from normal values. Second, the data from distinct populations of animals can be compared to identify differences among species. Any species, or group of animals, can be studied, especially where a disease affects one member or species in the study group. The use of veterinary records reduces the need for primary data collection in the teaching laboratory, especially from endangered species. Metabolic disorders, infection, diseases of abuse, effects of malnutrition, and genetic abnormalities are a few of the health states that can be evaluated (Table 1). Exercises can be developed that allow the student to organize and analyze data, use computers and the computer programs that facilitate data analysis (e.g., database, statistics, graphics), draw conclusions and present results, all while working in collaborative groups.

Example

Marmosets (Genus Callithrix) and tamarins (Genus Saguinus) are members of the Callitrichidae, the primates family within the New World monkey group (Rylands 1993). Marmosets and tamarins are found in diverse habitats, live in organized social groups, have similar diets, and may interbreed (Kavanagh 1983). Both genera are small, squirrel-like monkeys having claws (rather than nails) on all digits except the big toe (Kavanagh 1983). The genera are distinguished on the basis of their teeth. Marmosets have "short-tusked" teeth with lower canines and incisors of the same size. Tamarins have "long-tusked" teeth with lower canines projecting above the incisors (Kavanagh 1983).

Callitrichid physiology is remarkably similar to that of humans (Kavanagh 1983). Callitrichids develop a spontaneously occurring colitis (often called marmoset wasting syndrome) and colonic adenocarcinoma which clinically resemble human ulcerative colitis and colorectal cancer (CRC), respectively. Marmoset wasting syndrome (MWS) is insidious and debilitating, characterized by vomiting, anorexia and chronic diarrhea progressing to intestinal inflammation that becomes ulcerative and obstructive (Clapp et al. 1993; King et al. 1993). Cotton-top tamarins (CTT, Saguinus oedipus) appear to contract MWS and CRC with greater frequency than other Callitrichids (Gozalo et al. 1994) and as such, are well studied. Interestingly, 48% of captive CTT in one colony appeared to exhibit acute colitis with 35.7% exhibiting chronic colitis (King 1993). In another study, acute colitis was associated with approximately 80% of the CRC cases in CTT (Tobi et al. 1993).

Human ulcerative colitis and MWS have no known etiology and are therefore labeled idiopathic. Similarity to
Table 1. Examples of clinical data significance in predicting disease.*

<table>
<thead>
<tr>
<th>Clinical Parameter</th>
<th>Possible Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Temperature</td>
<td>Infection, Inflammation, Hypothermia</td>
</tr>
<tr>
<td>Body Weight</td>
<td>Obesity, Metabolic Disorder</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>Cardiac Function</td>
</tr>
<tr>
<td>Red Blood Cell Counts/Hemoglobin</td>
<td>Anemia</td>
</tr>
<tr>
<td>White Blood Cell Counts/Differential</td>
<td>Infection, Inflammation, Allergy, Cancer</td>
</tr>
<tr>
<td>Serum Glucose</td>
<td>Diabetes</td>
</tr>
<tr>
<td>Serum Creatinine</td>
<td>Muscle Wasting</td>
</tr>
<tr>
<td>Serum Alkaline Phosphatase</td>
<td>Liver Damage, Cardiac Dysfunction</td>
</tr>
<tr>
<td>Serum Bilirubin</td>
<td>Hepatitis</td>
</tr>
<tr>
<td>Urinary Albumin</td>
<td>Kidney Damage, Diabetes</td>
</tr>
</tbody>
</table>

*Deviation from “normal” values may suggest a disease state.

bowel disorders of infectious origin and symptom subsidence with antimicrobial chemotherapy have suggested that MWS is an infectious disease, although no microbe has been cultured in the disease state that is not also found in healthy hosts. We have speculated that the idiopathic inflammation may result from inappropriate stimulation of immune cells in the colonic tissues, abnormal immune surveillance resulting from alterations in white blood cell (WBC) numbers and/or function, or both (Woolverton et al. 1994). It may be that similar WBC alterations result in the high frequency of colorectal cancer in C57. This study is designed to test the hypothesis that WBC phenotype and number are significantly different in cotton-top tamarins, which develop frequent and severe MWS and CRC, as compared with Callithrichids that do not demonstrate the frequency nor severity of MWS and CRC.

Materials

A desktop computer containing database or spreadsheet software and a statistical package are required for this exercise. The exercise is based upon access to clinical veterinary data that would be routinely collected by university or private practice veterinarians, zoos, or animal husbandry facilities. The students must decide on the types of animals and clinical data to be evaluated. Typically, veterinary records contain hematology, white blood cell differentials, serum chemistry and urinary enzyme data, as well as other physical parameters from which to choose. The data are entered into a computer database program such as dBase® (Borland International, Inc., CA), Microsoft Access® (Microsoft Corporation, Redmond, WA), or Quattro Pro® (Corel Corporation Limited, Ireland). Finally, a statistical software package such as GraphPad InStat® (GraphPad Software, Inc., San Diego, CA), PSI-Plot® (Poly Software International, Salt Lake City, UT) or SPSS® (SPSS, Inc., Chicago, IL) is needed to evaluate clinical data sets and make comparisons. Graphical or presentation software may be used to generate reports.

Methods

The first step of the exercise is to design the database. Assignment of the database fields is just as important as the analysis itself if one is to exploit the full capabilities of computer data analysis. The data should be entered into fields of the database that maximize the utilization of the available information. Even if all of the data will not be used for one set of analyses, they may be important at a later time. A possible database format to evaluate clinical values among species is presented in Table 2. With this approach, each student or student group can enter one part of the file. The students will then be able to sort the data by field. Once entered, the data in the database should be verified for accuracy. (This is an arduous task but one that is extremely important. The analyses are only as good as the integrity of the data.) Instructors can also code a field as “health status” in which any known disease state can be entered for evaluation of student success and feedback. We obtained a commercially available physiology database from Inter Species Information Systems (ISIS, Apple Valley, MN) and additional information from the Kent State University animal care facility. The ISIS database contains records of more than 750 different species from 80 different institutions.

Table 2. Example of a clinical record database template.

<table>
<thead>
<tr>
<th>Species</th>
<th>Source</th>
<th>Sample Date</th>
<th>Gender</th>
<th>DOB</th>
<th>Health Status</th>
<th>Clinical Parameter</th>
</tr>
</thead>
<tbody>
<tr>
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The second step of the exercise is to design the hypothesis. The obvious questions that arise from clinical data are of health and disease. Comparisons among and within species can be readily made by evaluating specific subsets of data. Histograms are then plotted to view the data subsets graphically and to evaluate the normality of the data (i.e. to determine which type of statistical test is appropriate for comparing the data).

The third step of the exercise is to export the numerical data into a statistical program. Descriptive statistics such as mean, standard deviation, 95% confidence intervals, etc. are calculated for each data subset. Paired comparisons can be used for normal data having known variance. For more complex data and multiple comparisons, an analysis of variance can be calculated to determine significant differences among groups. Post hoc tests would then be needed to determine significant differences among the means of each subset.

Finally, each student or student group can output the data via a graphical or presentation program (e.g. Microsoft's PowerPoint®) to complete oral and/or written assignments.

Example

The hematologic data from the veterinary records of 13 species of marmosets and tamarins were entered into Microsoft Access® using an IBM PS/2 with a Pentium 100 processor in a Windows® 95 environment. Database fields were assigned to contain data regarding species, source of data, date of specimen, date of birth (DOB), total WBC numbers, and numbers of respective WBC phenotypes (neutrophils, lymphocytes, monocytes, eosinophils and basophils). To test the hypothesis that CTT had WBC counts significantly different from other Callithrichids (possibly contributing to MWS and CRC), we sorted the database by species and white blood cell phenotype to rank the mean cell counts within each species. The data were next imported into SPSS® for statistical analysis. Descriptive statistics (mean and standard deviation) for total WBC counts, neutrophil, monocyte, basophil, eosinophil and lymphocyte counts were obtained. The data were evaluated by analysis of variance with significant differences among the means identified by the Bonferroni test (alpha level of 0.05).

Results

The flexibility of viewing data sets by gender, health status, or clinical parameter was quite useful when globally comparing species. Data integrity was a problem we encountered during key entry, however. We found several of the ISIS data sets containing values that varied by orders-of-magnitude from the remaining data. ISIS was aware of the problem and has since validated its data.

Descriptive statistics of the Callitrichid data suggest that total marmoset WBC counts are, in general, less than tamarin WBC counts (Table 3). The mean (+ standard deviation) for the total WBC counts for the six marmoset species evaluated is 7.86 ± 0.98 × 10^9 cells/μL of blood and the mean for the seven tamarin species is 12.25 ± 2.31. The difference between the WBC counts of the marmoset and tamarin data can be partially explained by the total neutrophil counts. Tamarins have a statistically greater number of neutrophils than do marmosets, 6.68 ± 1.31 × 10^9 cells/μL of blood compared with 4.53 ± 1.04, respectively (p < 0.05). Lymphocyte numbers for the two groups were not statistically different. (Data for monocytes, basophils and eosinophils are not presented here.)

Discussion

Clinical laboratory data are obtained by veterinarians during routine animal examinations, as well as times of sickness or accident. The data can be readily stripped of identifying features to provide an anonymous source of physical and physiological data. In the first laboratory session, I outline and discuss the exercise, allowing time for database design. I use several “How would you determine . . .?” questions to focus the students’ thinking on comparison studies. From a list of possible physical and physiological characteristics (Table 1, for example), I ask the students to formulate questions regarding a particular disease state,
References


NABT’s Annual Banquet Speaker

John “Jack” Horner is scheduled to speak at the NABT Annual Banquet Saturday, October 30. He is an NABT Distinguished Service Award recipient, and is Curator of Paleontology at the Museum of the Rockies; Adjunct Professor of Geology; and Adjunct Professor of Biology at Montana State University. He discovered the first dinosaur eggs in the Western Hemisphere.