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Reference Values for Serum Proteins of Common Laboratory Rodent Strains

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Protein electrophoresis is a common proven technique to determine the protein components of plasma or serum in human, veterinary, and laboratory animal medicine. Changes in albumin and globulin protein levels can provide early and valuable diagnostic and prognostic information. Here we describe a preliminary analysis of the distribution of serum protein fractions in adult BALB/c, C57BL/6, and CD1 mice and Sprague-Dawley rats and describe the changes in protein values from birth to maturity in BALB/c mice and Sprague-Dawley rats. Quantifiable changes in the electrophoretic profile were apparent in mice with chronic-active dermatitis.

Protein electrophoresis is a common tool to determine the protein components of plasma or serum. This technique involves overlaying plasma or serum on a thin agarose gel. Electric current applied to the gel causes the proteins to migrate according to the charge and size of the proteins, intensity of the electric field, and characteristics of the support medium through which the protein particles migrate. The movement of the proteins creates bands in the gel which can be quantified. The gel is fixed and stained, and the protein bands are analyzed and quantified by using laser tracings from a densitometer.[12] Specific proteins within these bands can be identified through immunologic staining; however, in many animal species, such identification is limited by the availability of species-specific sera. Historically, several substrates (for example, cellulose acetate, starch gel, polyacrylamide gel, and paper) have been used for protein electrophoresis, thus complicating comparison of results because protein migration is related to the substrate medium. More modern techniques (for example, agarose gel electrophoresis and capillary electrophoresis) using commercial electrophoretic systems provide increased resolution and precision.

Serum protein bands or peaks visualized by electrophoresis include albumin and α1, α2, β, and γ globulins. Collectively, the proteins in these bands or fractions serve various functions, including maintaining colloid osmotic pressure and acting as enzymes, hormones, and antibodies. Albumin is the primary and most homogenous fraction, comprising 35% to 50% of total serum protein in animals.[12] A key metabolic function of albumin is its role as a general binding and transport protein. Among the globulins, α1 and α2 globulins include many of the diagnostically important acute-phase proteins (for example, α2 macroglobulin, haptoglobin), whereas β globulins include other acute-phase proteins in addition to complement and various proteins important in coagulation. The γ globulins include the immunoglobulins (IgA, IgM, IgE, and IgG), but some immunoglobulins migrate in the β region. Protein fractions can change with factors such as age, nutritional status, stress, and disease state. Albumin is a negative acute-phase protein (that is, its quantity decreases during the acute-phase response), whereas α, β, and γ globulins are positive acute-phase proteins and increase in quantity during the acute-phase response.[12]

Protein electrophoresis has been a proven diagnostic technique to examine proteins in plasma or serum in human, veterinary, and laboratory animal medicine for more than 40 y.[8,12-15] In domestic species, diseases such as multiple myeloma and Aleutian's disease in ferrets are characterized by a gammaglobulinopathy. In mice, protein electrophoresis was used as a tool to investigate protein changes in tumor-bearing compared with normal animals,[2] and increases in β and γ globulins were noted in mice carrying transplantable plasma cell leukemias.[3] Another study[4] used protein electrophoresis to compare the serum proteins of female mice in different stages of estrus and pregnancy.

The aims of the current study study were to (1) perform a preliminary analysis of serum protein fractions in common strains of laboratory mice and rats by using a commercially available agarose gel electrophoresis system, (2) monitor age-associated changes in protein fractions, and (3) document that this technique could be used to define protein changes in B6.129P2-*Apoe*^{tm1Unc}/Crl (apoE) mice with dermatitis. These results will help lay the foundations for the use of protein electrophoresis as a diagnostic and prognostic tool for use in health monitoring of small laboratory animals including *Mus musculus* and *Rattus norvegicus*.

Materials and Methods

Animals and housing. All animals were maintained in accordance with recommendations regarding housing, temperature, and humidity in the *Guide for the Care and Use of Laboratory Animals*[10] at AAALAC-accredited facilities. All experimental procedures were approved by the University of Miami Animal Care and Use Committee. Sprague–Dawley rats (Crl:SD, Charles River Laboratories, Wilmington, MA) and mice [BALB/cAnNCrl, C57BL/6NCrl, and Crl:CD1(ICR); Charles River Laboratories] of various ages were housed conventionally in standard polycarbonate cages (Ancare, Bellmore, NY) with shredded aspen bedding (Harlan Teklad, Madison, WI) and microisolation lids. Room conditions included a 12:12-h light:dark cycle, temperature range of 20.6 to 23.3 °C (69 to 74 °F), and 30% to 70% humidity. The rats and mice were provided ad libitum access to

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rodent chow (diet 5001, Purina, St Louis, MO) and municipal water by bottle. A group of 11 female B6.129P2-*Apoe*^{tm1Unc}/Crl (apoE) mice (age, 10 wk) that were housed similarly and had moderate chronic-active dermatitis were sampled as part of a diagnostic workup for an investigator.

Rodent colony health was monitored by using a sentinel system. Sentinel mice maintained on dirty bedding were screened quarterly for the following agents: mouse hepatitis virus, Sendai virus, *Mycoplasma pulmonis*, pneumonia virus of mice, minute virus of mice, Thieler murine encephalomyelitis virus, mouse parvovirus, mouse rotavirus, lymphocytic choriomeningitis virus, and parasitic infections. Once each year, the panel was extended to include the following agents: mouse norovirus, *Ectromelia* virus, K virus, *Encephalitozoon cuniculi*, polyoma virus, mouse adenovirus, reovirus, murine cytomegalovirus, Hantaan virus, mouse thymic virus, *Clostridium piliforme*, and cilia-associated respiratory bacillus. During this study, all samples were negative for the tested agents.

Blood was collected from the submandibular vein or by cardiocentesis under anesthesia (isoflorane by mask) from rats and mice of various ages (and approximately equal numbers of both sexes). No animal underwent multiple sampling to avoid possible interference from repeated handling and technique stimulation. Blood was collected into tubes without anticoagulant, allowed to clot, and centrifuged, and serum was separated and frozen (–20 °C) before analysis. The sample sizes for each age and time point are presented in the tables.

Protein electrophoresis. Serum samples were analyzed by using an agarose gel electrophoresis system (Paragon SPEP-II, Beckman, Fullerton, CA). Briefly, a 2-µL sample of serum was diluted 1:4 in running buffer and applied to the gel, which was exposed to 100 V for 37 min. After a wash in water, the gel was fixed, dried, and stained (Beckman Blue Stain, Beckman). Bands were scanned and quantified by densitometer at 600 µm (Figure 1). Percentages and absolute values (g/dL) for the protein fractions were determined on the basis of the total protein concentration obtained by refractometry. The albumin:globulin ratio was calculated as albumin/(α1 + α2 + β + γ globulins).

Statistical analyses. All data were checked for normality and statistical analyses performed (Sigma Stat, version 3.11, SYSTAT, Chicago, IL). If data were normally distributed, 1-way ANOVA and *t* tests were used. If data were not normally distributed, Kruskal–Wallis 1-way ANOVA or Mann–Whitney *U* tests were used.

Results

In mice (Table 1), both albumin and total protein values increased dramatically within the first several weeks of neonatal life. Albumin comprised between 46% and 58% of total serum protein. The albumin:globulin ratio increased with age in mice. In addition, α1 globulins comprised approximately 6% to 10% of serum proteins, increased with age, and appeared to reach stable adult levels by 6 wk of age. In comparison, α2 globulins comprised approximately 12% to 17% of serum proteins, appeared to increase more rapidly than α1 globulins, and maintained increases at 6 wk. In mice, β globulins comprised approximately 16% to 28% of serum protein. These globulins were increased at 2 wk of age but then decreased as the mice neared adulthood. In contrast, γ globulins remained at low concentration, approximately 2% to 3% of total serum protein.

In rats (Table 2), both albumin and total protein values increased dramatically within the first several weeks of neonatal life. Albumin comprised between 47% and 57% of serum proteins throughout the neonatal period. Albumin absolute values

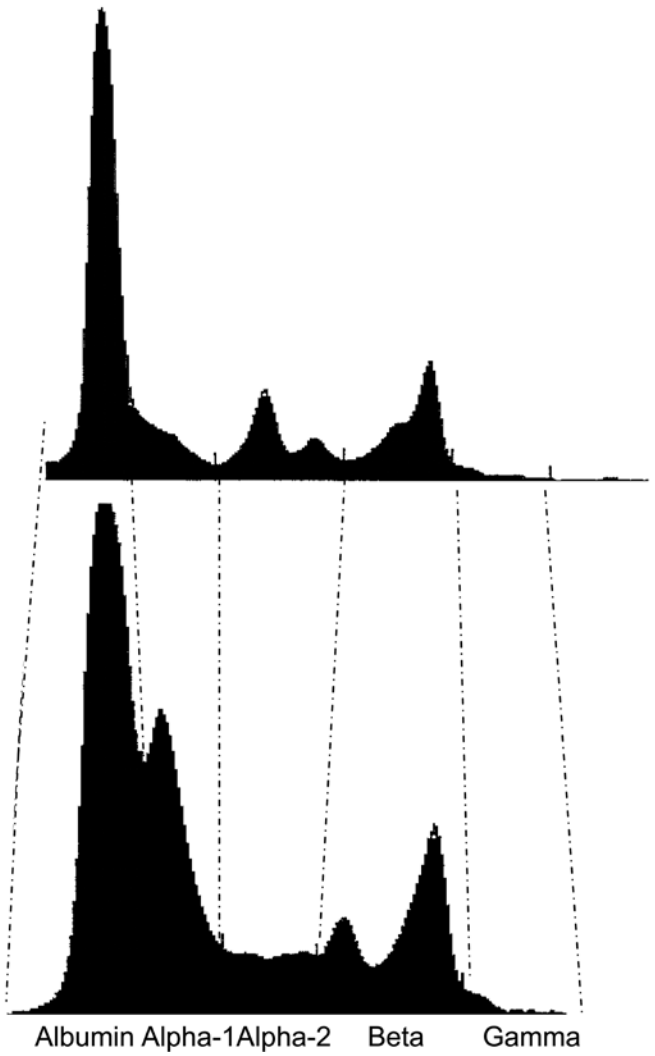

Figure 1. Representative typical electrophoretograms for a clinically healthy (A) adult BALB/c mouse and (B) adult Sprague–Dawley rat.

increased, whereas the albumin percentage decreased as the total protein increased. The albumin:globulin ratio decreased with age in rats, apparently plateauing at about 45 d of age. Quantities of α1 (8% to 20% of serum protein) and α2 (7% to 9%) globulins increased steadily and reached adult values at 45 d of age. Whereas β globulins comprised between 19% and 27% of the total protein and increased in concentration into adulthood, γ globulins comprised only 2% to 5.5% of serum proteins in rats, and their absolute value and percentage was variable over the time period examined.

We compared the results of serum protein electrophoresis for 2 commonly used laboratory inbred strains, BALB/c and C57BL/6, and 1 outbred stock (CD1; Table 3). All data were from mice 8 to 10 wk of age. Differences in protein values were apparent. C57BL/6 and CD1 mice had higher concentrations of total protein, albumin, α2 globulins, and γ globulins than did BALB/c mice. Compared with CD1 mice, C57BL/6 mice had lower albumin values and higher γ globulin values.

Relative to that of an average healthy adult C57BL/6 mouse, the electrophoretograms of samples from B6.129P2-*Apoe*^{tm1Unc}/Crl mice with clinical chronic–active dermatitis demonstrated significant increases in total protein (apoE mice, 5.7 ± 0.16 g/dL; C57 mice, 5.0 ± 0.06 g/dL; Mann–Whitney test: T = 67, P = 0.003), α2 globulins (apoE, 1.45 ± 0.06 g/dL; C57, 0.82 ± 0.02 g/

Table 1. Electrophoretic reference values for BALB/c mice

	7 d (n = 6)	14 d (n = 11)	21 d (n = 6)	28 d (n = 6)	42 d (n = 15)	56 d (n = 8)
Total protein (g/dL)*	2.5 ± 0.20[a,b]	4.0 ± 0.10[b]	3.8 ± 0.07[c]	4.0 ± 0.10	4.7 ± 0.10[a,c]	4.0 ± 0.10
Albumin (g/dL)*	1.2 ± 0.08[a,b]	2.0 ± 0.1	2.1 ± 0.08	2.3 ± 0.05[b]	2.7 ± 0.10[a,c]	2.0 ± 0.10[c]
Albumin (%)*	46.1 ± 0.5[a,b]	49.8 ± 0.6[c,d]	52.7 ± 2.4	57.8 ± 0.5[a,c]	57.0 ± 1.4[b,d]	50.7 ± 2.5
α1 Globulin (g/dL)*	0.22 ± 0.03[a,b]	0.28 ± 0.02[c]	0.30 ± 0.02	0.23 ± 0.03[d,e]	0.45 ± 0.03[a,c,d]	0.41 + 0.03[b,e]
α1 Globulin (%)*	8.4 ± 0.4	6.8 ± 0.5[a,b]	7.8 ± 0.5	5.7 ± 0.6[c,d]	9.5 ± 0.6[a,c]	10.3 ± 0.3[b,d]
α2 Globulin (g/dL)*	0.35 ± 0.03[a,c,d]	0.50 ± 0.02[b]	0.63 ± 0.05[c]	0.57 ± 0.02	0.71 ± 0.03[a,b]	0.62 + 0.03[d]
α2 Globulin (%)*	14.0 ± 0.4[a]	11.9 ± 0.3[ab,c,d,e]	16.7 ± 1.2[a,b]	14.2 ± 0.4[c]	15.1 ± 0.5[d]	15.7 ± 0.5[e]
β Globulin (g/dL)*	0.67 ± 0.09[a]	1.21 ± 0.07[a,b,c]	0.81 ± 0.02	0.80 ± 0.03	0.75 ± 0.04[b]	0.84 + 0.13[c]
β Globulin (%)*	25.9 ± 1.7[a]	28.8 ± 0.8[b]	21.4 ± 0.6	19.8 ± 1.0	16.1 ± 1.0[a,b]	20.6 ± 2.3
γ Globulin (g/dL)*	0.08 ± 0.01	0.11 ± 0.01	0.08 ± 0.01[a]	0.10 ± 0.02	0.12 ± 0.01[a]	0.11 + 0.01
γ Globulin (%)	3.1 ± 0.4	2.7 ± 0.1	2.0 ± 0.2	2.6 ± 0.4	2.5 ± 0.2	2.9 ± 0.3
Albumin:globulin ratio*	0.90 ± 0.05[a,b]	1.0 ± 0.02[c,d]	1.1 ± 0.09	1.4 ± 0.03[a,c]	1.4 ± 0.08[b,d]	1.1 ± 0.10

Data are presented as mean ± 1 SE. Asterisks indicate significant (Kruskal–Wallis 1-way ANOVA, $P < 0.05$) differences with age. For each parameter, values indicated with the same superscript letters are significantly different (Dunn pairwise multiple comparisons, $P < 0.05$).

Table 2. Electrophoretic reference values (g/dl and %) for Spraque Dawley rats

	7 d (n = 10)	14 d (n = 10)	21 d (n = 10)	28 d (n = 9)	45 d (n = 8)	53 d (n = 18)	60 d (n = 11)
Total protein (g/dL)*	3.0 ± 0[a,e,h]	4.1 ± 0.04[b,f,i]	4.1 ± 0.06[c,g,j]	4.6 ± 0.07[d]	5.5 ± 0.20[e,f,g]	5.4 ± 0.10[h,i,j]	6.5 ± 0.20[a,b,c,d]
Albumin (g/dL)*	1.6 ± 0.03[a,b,c,d]	2.2 ± 0.03[e]	2.2 ± 0.05[f]	2.6 ± 0.04[a]	2.6 ± 0.10[b]	2.6 ± 0.0[c]	3.0 ± 0.10[d,e,f]
Albumin (%)*	52.2 ± 1.0[a,b,c,j]	54.7 ± 0.6[d,e,f]	53.4 ± 1.2[g,h,i]	56.9 ± 0.5[j,k,l,m]	46.6 ± 0.9[a,d,g,k]	48.6 ± 0.8[b,e,h,l]	47.0 ± 0.9[c,f,i, m]
α1 Globulin (g/dL)*	0.31 ± 0.01[a,b,c]	0.38 ± 0.01[d,e,f]	0.35 ± 0.02[g,h,i]	0.71 ± 0.02	1.10 ± 0.05[a,d,g]	1.1 ± 0.04[b,e,h]	1.01 ± 0.08[c,f,i]
α1 Globulin (%)*	10.2 ± 0.4[a,d]	9.4 ± 0.3[b,e,i]	8.4 ± 0.5[c,f,j]	15.5 ± 0.4	19.8 ± 0.5[a,b,c]	20.4 ± 0.4[d,e,f]	16.6 ± 1.4[i,j]
α2 Globulin (g/dL)*	0.24 ± 0.004[a,b,c]	0.32 ± 0.01[d,e,f]	0.31 ± 0.01[h,i,j]	0.30 ± 0.02[k,l,m]	0.50 ± 0.02[a,d,h,k]	0.50 ± 0.02[b,e,i,l]	0.51 ± 0.03 [c,f,j,m]
α2 Globulin (%)*	8.1 ± 0.1[a]	7.9 ± 0.3[d]	7.4 ± 0.2[b,c]	6.6 ± 0.4[a,e,f]	9.1 ± 0.3[b,e,g]	9.0 ± 0.2[c,d,f]	7.8 ± 0.3[g]
β Globulin (g/dL)*	0.72 ± 0.02[a,b,c,d]	0.97 ± 0.02[e]	1.10 ± 0.04[a]	0.89 ± 0.05[f]	1.20 ± 0.04[b]	1.10 ± 0.03[c,g]	1.65 ± 0.11[c,e,f,g]
β Globulin (%)	24.1 ± 0.6[a,b]	23.8 ± 0.5[c]	26.5 ± 0.6[d,e,f]	19.3 ± 1.0[a,d,h]	21.4 ± 0.8[e]	19.9 ± 0.3[b,c,f,i]	25.3 ± 1.1[h,i]
γ Globulin (g/dL)*	0.17 ± 0.01[a]	0.22 ± 0.02[b,d]	0.18 ± 0.02[c]	0.08 ± 0.01[a,b,c,e]	0.20 ± 0.04	0.10 ± 0.01[d,f]	0.25 ± 0.03[e,f]
γ Globulin (%)*	5.5 ± 0.3[a,b]	5.3 ± 0.3[c,d]	4.4 ± 0.4[e,f]	1.7 ± 0.1[a,c,e,h]	3.2 ± 0.7	2.1 ± 0.1[b,d,f]	3.8 ± 0.4[h]
Albumin: globulin ratio*	1.1 ± 0.04[a,b,c,d]	1.2 ± 0.03[e,f,g,h]	1.2 ± 0.06[i,j,k,l]	1.3 ± 0.03[a,e,i,m,n,o]	0.90 ± 0.03[b,f,j,m]	1.0 ± 0.03[c,g,k,n]	0.88 ± 0.03[d,h,l,o]

Data are presented as mean ± 1 SE. Asterisks indicate significant (Kruskal–Wallis 1-way ANOVA, $P < 0.05$) differences with age. For each parameter, values indicated with the same superscript letters are significantly different (Dunn pairwise multiple comparisons, $P < 0.05$).

dL; Mann–Whitney test: T = 55, $P < 0.001$), and β globulins (apoE, 1.51 ± 0.06 g/dL; C57, 0.81 ± 0.03 g/dL; Mann–Whitney test: T = 55, $P < 0.001$) and a significant decrease in the albumin:globulin ratio (apoE, 0.52 ± 0.03; C57, 1.18 ± 0.04; t test: t = –14.03, df = 19, $P < 0.001$).

Discussion

This study is the first to document the baseline electrophoretic pattern and preliminary reference values of albumin and α1, α2, β, and γ globulin proteins from birth to 60 d of age in BALB/c mice and Sprague–Dawley rats. These values reflect the developing profile of proteins integral in maintenance of homeostasis and metabolism in typical healthy mice and rats. The globulins comprise the positive acute-phase proteins involved in the response to injury, inflammation, and stress. Significant changes in the absolute value of the globulin fractions occur with growth to maturity. Neonatal mice and rats show the typical pattern of hypoalbuminemia seen in mammals.[12] Adult levels of albumin are attained by 4 wk of age.

Previously published electrophoretograms, regardless of medium, clearly identify albumin and α1, α2, β, and γ globulin fractions in rodents.[8,12] By using paper-based electrophoretic separation with samples from white Swiss mice, 1 study[2] documented percentages of albumin and β and γ globulins that were lower than those of the outbred stock in the present study and α1 and α2 globulin percentages that were higher than those we found. Similar findings were noted in other strains of Swiss mice in which the protein electrophoresis was run by using cellulose acetate as the substrate.[14] In the current study, we document differences between the outbred CD1 stock and inbred BALB/c and C57BL/6 strains as visualized by using a commercial agarose gel electrophoresis system. Because these mice are used widely in laboratory animal research, the availability of specific reference values for the protein fractions (like strain-specific reference values for hematologic and biochemical parameters) provides an additional level of diagnostic capability.

Dermatitis is a common clinical problem in C57BL/6 strains.[1] In apoE knockout mice with dermatitis, α2 and β globulin fractions were increased relative to those in normal control C57BL/6 mice, suggesting that an acute-phase response was activated in apoE mice. With appropriate treatment of and subsequent recovery from dermatitis, the acute-phase response in mice

Table 3. Comparison of electrophoretic reference values of various strains of laboratory mice

	Total protein	Albumin	α1 Globulin	α2 Globulin	β Globulin	γ Globulin	Albumin:globulin rato
BALB/C (n = 8)							
g/dL	3.98 ± 0.14[a,c]	2.0 ± 0.07[a,c]	0.41 ± 0.02	0.62 ± 0.02[a,c]	0.84 ± 0.13	0.11 ± 0.01[a,c]	1.06 ± 0.1
%	not applicable	50.7 ± 2.5	10.3 ± 0.3[c]	15.7 ± 0.5	20.6 ± 2.3	2.9 ± 0.3	
C57BL/6 (n = 10)							
g/dL	5.0 ± 0.06[a]	2.7 ± 0.04[a,b]	0.38 ± 0.02	0.82 ± 0.02 [a]	0.81 ± 0.03	0.30 ± 0.02[a,b]	1.18 ± 0.04
%	not applicable	54.0 ± 0.8	7.5 ± 0.4	16.3 ± 0.3	16.1 ± 0.6	6.1 ± 0.4[b]	
CD1 (n = 6)							
g/dL	5.1 ± 0.07[c]	2.9 ± 0.07[b,c]	0.34 ± 0.04	0.84 ± 0.02[c]	0.85 ± 0.03	0.20 ± 0.01[b,c]	1.30 ± 0.07
%	not applicable	56.4 ± 1.3	6.5 ± 0.7[c]	16.5 ± 0.6	16.7 ± 0.6	4.0 ± 0.3[b,c]	

Data are presented as mean ± 1 SE. Values with the same superscript letters are significantly different ($P < 0.05$) between the strains indicated.

should diminish and be visible by serum protein electrophoresis as decreases in the α2 and β globulin fractions. These readily apparent changes in globulin levels and electrophoretic pattern can be used to identify and monitor progress of inflammatory (and other) processes. An alternative explanation is that the differences are due in part to the mixed genetic background of ApoE mice (for example, C57BL6 and 129 backgrounds). Further studies are underway in our lab to evaluate the use of serum protein electrophoresis in common rodent inflammatory or pathologic conditions.

The benefits of using serum protein electrophoresis as an ancillary diagnostic and prognostic tool have been described previously for companion animals, large animals, birds, and exotic species.[5,6,8,9,12,19] In birds, serum protein electrophoresis is a documented technique in the diagnosis of aspergillosis and sarcocystosis.[6,7,11] Monitoring of acute-phase proteins has become a more prominent tool recently in farm animal herd health management.[8,14,17,18] This technique would be most valuable for use in small species or subjects from which only a small amount of blood (that is, yielding <10 µL of serum) can be obtained safely. In addition, the small volumes of blood necessary render serial serum protein electrophoresis feasible and humane. A recent study[8] has begun to apply capillary electrophoresis methodology to animals.

Increases in the levels of serum cytokines and acute-phase proteins occur early in disease processes, often preceding clinically observable behavioral and physiologic changes in animals.[16] These biochemical changes are correlated with more subjective assessments of pain and distress.[16] Numerous acute-phase proteins migrate in the α, β, and γ fractions generated on agarose gels.[12] Therefore progressive changes in albumin and globulin levels (and the albumin:globulin ratio) may provide early and valuable diagnostic and prognostic information when managing clinical conditions in animals. Characterization of the serum protein profile in select populations of laboratory animals may greatly benefit toxicologic studies. In addition, these parameters may also be sensitive in defining humane endpoints for experimental studies, an area of marked concern in laboratory animal medicine.[16] Further studies addressing the utility of serum protein electrophoresis as a diagnostic and prognostic tool and as an objective marker of pain and distress are ongoing in our laboratory.

References

1. **Brayton C.** 2007. Spontaneous diseases in commonly used mouse strains. In: Fox JG, Davisson MT, Quimby FW, Barthold SW, Newcomer CE, Smith AL, editors. The mouse in biomedical research, 2nd ed. Amsterdam (Netherlands): Academic Press.
2. **Brenneman M, Rigby P.** 1968. Protein electrophoretic patterns of serum and peritoneal fluid in normal, tumor-bearing and immune mice. Cancer Res **28:**1138–1142.
3. **Clausen J, Heremans J, Heremans M, Rask-Nielsen R.** 1959. Immunoelectrophoretic studies of serums from mice carrying two transplantable plasma cell leukemias. J Natl Cancer Inst **22:**57–81.
4. **Cons JM, Glass LE.** 1963. Electrophoresis of serum proteins and selected enzymes in males, non-pregnant, pregnant, and lactating female mice. Proc Soc Exp Biol Med **113:**893–897.
5. **Cray C, Rodríguez M, Zaias J.** 2007. Protein electrophoresis of psittacine plasma. Vet Clin Pathol **36:**64–72.
6. **Cray C, Tatum LM.** 1998. Application of protein electrophoresis in avian diagnostics. J Avian Med Surg **12:**4–10.
7. **Cray C, Zielzienzki-Roberts K, Bonda M, Stevenson R, Ness R, Clubb S, Marsh A.** 2005. Serologic diagnosis of sarcocystosis in psittacine birds: 16 cases. J Avian Med Surg **19:**208–215.
8. **Crivellente F, Bonato M, Cristofori P.** 2008. Analysis of mouse, rat, dog, marmoset, and human serum proteins by capillary electrophoresis: comparison with agarose gel electrophoresis. Vet Clin Pathol **37:**73–78.
9. **Ganheim C, Alenius S, Waller KP.** 2007. Acute phase proteins as indicators of calf herd health. Vet J **173:**645–651.
10. **Institute of Laboratory Animal Resources.** 1996. Guide for the care and use of laboratory animals. Washington (DC): National Academy Press.
11. **Ivey ES.** 2000. Serological and plasma protein electrophoresis findings in 7 psittacine birds with aspergillosis. J Avian Med Surg **14:**103–106.
12. **Kaneko JJ.** 1997. Serum proteins and the dysproteinemias. In: Kaneko JJ, editor. Clinical biochemistry of domestic animals. San Diego (CA): Academic Press. p 117-138
13. **Kozma CK, Pelas A, Salvador RA.** 1967. Electrophoretic determination of serum proteins of laboratory animals. J Am Vet Med Assoc **151:**865–869.
14. **Murata H, Shimada N, Yoshioka M.** 2004. Current research on acute phase proteins in veterinary diagnosis: an overview. Vet J **168:**28–40.
15. **Ngure RM, Eckersall PD, Jennings FW, Mburu J, Burke J, Mungatana N, Murray M.** 2008. Acute phase response in mice experimentally infected with *Trypanosoma congolense*: a molecular gauge of parasite host interaction. Vet Parasitol **151:**14–20.
16. **Olfert ED, Godson DL.** 2000. Humane endpoints for infectious disease animal models. ILAR J **41:** 99-104.
17. **Orro T, Jacobsen S, LePage JP, Niewold T, Alasuutari S, Soveri T.** 2008. Temporal changes in serum concentrations of acute phase proteins in newborn dairy calves. Vet J **176:**182–187.
18. **Petersen HH, Nielsen JP, Heegaard PMH.** 2004. Application of acute phase protein measurements in veterinary clinical chemistry. Vet Res **35:**163–187.
19. **Zaias J, Cray C.** 2002. Protein electrophoresis: a tool for the reptilian and amphibian practitioner. Journal of Herpetological Medicine and Surgery **12:**30–32.