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Mortality in Captive Baboons (*Papio spp*.): A 23 Year Study

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Abstract

Background—We report the causes of mortality for 4,350 captive baboons that died or were euthanized due to natural causes during a 23 year period at the Southwest National Primate Research Center.

Methods—Necropsy records were retrieved and reviewed to determine a primary cause of death or indication for euthanasia. Data was evaluated for morphological diagnosis, organ system and etiology.

Results—The 20 most common morphologic diagnoses accounted for 76% of the cases, including: stillborn (10.8%); colitis (8.6%); hemorrhage (8.4%); ulcer (5.2%); seizures (4.7%); pneumonia (4.2%); inanition (4.1%); dermatitis (3.8%); spondylosis (3.3%); and amyloidosis (3.0%). The digestive system was most frequently involved (21.3%), followed by the urogenital (20.3%), cardiovascular (12.2%), and multisystem disease (10.3%). An etiology was not identified in approximately one third of cases. The most common etiologies were trauma (14.8%), degenerative (9.5%), viral (8.7%), and neoplastic/proliferative (7.0%).

Conclusion—This information should be useful for individuals working with baboons.

Keywords

Nonhuman primate; Disease; Epidemiology; Cancer; Pathology; Spontaneous; Survey; Age at death; Lifespan; Morbidity

Introduction

The baboon is an increasingly important nonhuman primate model used in biomedical research. Accurate, extensive information about the natural pathology of the baboon is required for many aspects of biomedical research[83]. Baboons are currently studied for nutrition, fetal development and loss, endometriosis, infectious diseases, drug abuse,

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xenotransplantation, and epilepsy[9,18,72,73,75,80,82,83,85]. Veterinarians and researchers can use the frequency of different diseases to aid in diagnosis, make decisions on prognosis, foresee the possible interference with specific experimental procedures, and determine if the baboon is an appropriate model[22,25].

Numerous articles have published on individual diseases in baboons[83], but the spontaneously occurring causes of mortality in baboons are not generally available in the literature. To our knowledge, only three previous studies looked at the prevalence of disease in baboons; none specifically evaluated causes of mortality. Two of these studies were conducted over 35 years ago and had relatively few numbers of animals. One evaluated 100 baboons captured from the wild with no attempt to select for sick animals[46]. The focus of the study was to catalogue the range of lesions and parasites observed in free ranging baboons; it did not address mortality. We could only identify one similar study involving 105 baboons that died in captivity[36]. This study was conducted approximately 40 years ago in this same colony and reported the major causes of death in captive adult baboons as pneumonia, enteritis, and septicemia[36]. The most common lesions in stillborn and perinatal baboons were respiratory (pneumonia, aspiration, and hemorrhage) and birth injuries[36].

Recently, we documented all the spontaneous pathology observed in 4,297 captive baboons that died, or were euthanized, as a result of natural causes over a 20-year-period at the Southwest National Primate Research Center at the Texas Biomedical Research Institute (San Antonio, TX)[8]. We now report the specific causes of spontaneous mortality over a 23 year period in captive baboons from this same colony.

Materials and Methods

Animals

During the 23-year period covered in this manuscript (1988–2010), the approximate average baboon population was 3,300 animals, 63 % female (average age = 8.6 yr +/− SD 6.4) and 37% male (average age = 5.7 yr +/− SD 5.1). The colony was established in the late 1950s and is essentially self-sustaining, although baboons were occasionally added to the colony for genetic diversity and special projects. Baboons were housed in two open-top 6-acre metal and concrete corrals with dirt floors, gang cages with concrete floors, and in individual metal cages if special handling was required (i.e., for medical care). The commercial monkey chows fed over the years were supplemented with an enrichment fare of grains, fruits, and vegetables. The baboons were screened every 6 months for mycobacterium tuberculosis by intradermal intrapalpebral tuberculin skin testing. Several endemic diseases have been identified in the colony, including *Trypanosoma cruzi*[2,24], Simian T-Cell Leukemia Virus 1 (STLV-1)[32], Papiline herpesvirus 2 (Herpesvirus papio 2, HPV2)[45,76], *Histoplasmosis capsulatum* variety duboisii[10,31], Baboon Reovirus[37,39], Cytomegalovirus and a *Babesia microti*-like organism[41,59]. The baboons were usually members of the breeding colony and not used experimentally. If there was any question that the death could be related to experimental use of the animal, the animal was excluded. All animal care and procedures were approved by the Texas Biomedical Research Institute Animal Care and the Use Committee. The Texas Biomedical

Research Institute is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care, International.

Pathology

All baboons that died or were euthanized were necropsied, and tissues were collected for histologic evaluation as required for diagnosis. Tissues were fixed in 10% neutral buffered formalin, processed conventionally, embedded in paraffin, cut at 5 μM and stained with hematoxylin and eosin or other stains as needed for diagnosis. When indicated, individual tissues were frozen in liquid nitrogen and stored at −80°F, fixed in 2% glutaraldehyde for electron microscopy, placed in normal saline or transport medium for cytogenetic evaluation, cultured for bacteria and viruses, or frozen in Optimal Cutting Temperature Compound (Tissue-Tek®) compound for frozen sectioning. Further evaluation using immunohistochemistry was performed as required. The necropsy and histologic evaluation were performed by board certified veterinary pathologists. Conventional nomenclature was used for all lesions, and results were stored in an internal database (apath). Microscopic findings that were equivocal or otherwise challenging were reviewed by three to five other board-certified veterinary pathologists. If deemed necessary, cases were referred to the Armed Forces Institute of Pathology or other individual pathologists with expertise in the field.

Records Review

A computer search of the pathology database identified 4,753 baboons that spontaneously died or were euthanized due to natural causes during the 23 year period. Biopsy samples and animals on study were excluded. Stillbirths were considered separate animals with an age of zero. All original or computerized medical records, gross necropsy reports, histopathology reports and related laboratory results were retrieved. A primary cause of mortality (PCM: death or reason for euthanasia), system and organ affected, and etiology were determined for each baboon that died or was euthanized. A PCM could not be determined for 402 (8.5%) baboons due to either multi-factorial or undetermined causes. The remaining 4,350 baboons were included in the study.

In determining the PCM, we developed several criteria. Stillbirth was determined as the cause of death if the lungs did not show evidence of respiration (inflation). Many of the stillbirth cases also had various traumatic changes (hemorrhage, fracture, etc.) before they could be recovered from the group housing. Stillborn animals with lesions indicating a specific cause of death, such as fetal pneumonia, were listed as that specific cause. Deaths due to hemorrhage or infarction were included in the cardiovascular system regardless of organ involved. Deaths due to laceration were listed within the integumentary system, although most lacerations resulting in mortality extended into the subjacent tissues. Dystocia related deaths were listed in the urogenital system, with the organ recorded as uterus for the dam and multisystem for the fetus. Blindness of undetermined etiology was listed in the special senses system.

Data Analysis

The animal records reside in relational database maintained and managed with Microsoft SQL Server 2008 Enterprise Edition. The queries used to collect the data were developed within Microsoft Access. A Microsoft Office Excel (Microsoft, 2003) spreadsheet was generated from the database and sorted to generate worksheets organized by morphological diagnosis, organ systems, and cause of death or indications for euthanasia. The total incidence number, numbers of female, male, euthanized or died spontaneously, and the mean age (+/− SD) for female, male, and total baboons were identified for each morphologic diagnosis.

Animals were also divided into general age categories for determination of mortalities associated with varying life stages. The categories were defined as perinatal (less than or equal to 1 day old), infant (over 1 day to 6 months), juvenile (over 6 months to 5 years), adult (over 5 years to 15 years), aged (over 15 years to 26 years), and geriatric (over 26 years).

Mortality was also evaluated by gender. The Southwest National Primate Research Center maintains a baboon breeding program composed of harems containing one male and many females. Because young males are preferentially removed from the colony for research use, females are over represented in this study, especially within the older age groups. For example, the sex ratio of perinatal baboon necropsies is fairly close to 1 (females / males; . 91), while the overall sex ratio is approximately 3:2 (females / males; 1.47). We therefore chose to evaluate gender differences in mortality within each age group rather than within the overall colony.

The R programming language[58] was used for all analyses. The XLConnect package[49] was used to read the Microsoft Excel® spreadsheets that were generated during the initial data extraction. The test package[87] was used to test for internal consistency of the data. The xtable package[14] was used to generate the tables. The stringr package[86] was used to construct character variables used in table generation.

Fisher's exact test for two-by-two tables was used to test for independence of the animals' sex and their primary causes of death or reasons for euthanasia. Fisher's exact tests that could not produce $p < 0.05$ when the number of affected animals were arbitrarily set to either female or male were ignored, because of an insufficient number of affected animals. Rejection of the null hypothesis (no affect of sex) was indicated if the p-value was less than or equal to the Bonferroni corrected α (0.05 divided by the number of tests performed = corrected: 1:31 × 10-4). Since these tests are correlated, this is a conservative adjustment of α[28].

Results

Study population

4,350 baboons, 2,539 female (9.2 +/− 8.8 years) and 1,727 male (4.9 +/− 6.8 years), were included in the study. The age groupings of the 4,350 baboons in the study were perinatal (n = 800, female = 346, male = 385, unidentifiable = 69); infant (n = 710, female = 318, male =

377, unidentifiable = 15), juvenile (n = 816, female = 421, male = 395), adult (n = 1059, female = 717, male = 342), aged (n = 872, female = 649, male = 223), and geriatric (n = 93, female = 88, male = 5). Table 1 summarizes the number of animals in each age-group and the number of each sex by age-group.

Mortality

The causes of mortality are presented below. Total colony mortality is first presented by morphologic diagnosis, by system and organ, and by etiology. For each of the morphologic diagnosis, systems, and etiologies described below, information is presented based on the total animals from the colony, including the age group(s) most frequently presented, female to male ratio, frequency of euthanasia or death, and other general observations. References to the literature are included in the tabular results for the relevant organ and etiology. Key mortality findings for each age category and by gender are then presented. The most common diagnoses, systems and etiologies varied across the groups.

Morphologic Diagnoses

Table 2 presents the morphologic diagnoses resulting in mortality in order by frequency of occurrence (total number and percentage of deaths), and lists the number that died, number that were euthanized, numbers of female, male, and unidentifiable sex, and the mean age and standard deviation for female, male, and total baboons for each diagnosis. The 20 most common morphologic diagnoses accounted for 76.2% of the cases: stillborn (n = 468, 10.8%); colitis (n = 372, 8.6%); hemorrhage (n = 365, 8.4%); ulcer (n = 224, 5.1%); seizures (n = 205, 4.7%); pneumonia (n = 184, 4.2%); inanition (n = 179, 4.1%); dermatitis (n = 165, 3.8%); spondylosis (n = 142, 3.3%); amyloidosis (n = 130, 3.0%); fracture (n = 116, 2.7%); lymphosarcoma (n = 116, 2.7%); hypothermia (n = 101, 2.3%); laceration (n = 97, 2.2%); trichobezoar (n = 92, 2.1%); arthritis (n = 88, 2.0%); myocarditis (n = 81, 1.9%); endometriosis (n = 72, 1.7%); stricture (n = 60, 1.4%); and meningoencephalitis (n = 59, 1.4%).

Mortality arising from stillbirths (n = 468, all perinatal) occurred in slightly less females than males with 10.5% of undetermined sex. Most stillborns were of undetermined etiology (432, 92.3%); 129 (29.9%) of these were classified as in utero deaths, occurring some time prior to delivery. Only 36 (6.8%) of stillbirths had an identified etiology. Thirty two were due to physical causes, including dystocia (n = 28);,uterine rupture (n = 3), and ectopic pregnancy (n =1). There were two cases each of bacterial (both *Staphylococcus aureus*) and viral (both *Encephalomyocarditis virus*) etiology; all four of these were associated with male fetuses.

Mortality arising from colitis (n = 372) was most often seen in juvenile (220, 59.1%) baboons with an approximately 3:2 female to male ratio. Animals with colitis were more likely to have been euthanized (239, 64.3%) than to have died. The majority were of undetermined etiology (298, 80.1%). A bacterial etiology was cultured in 72 (19.35%); one (0.3%) case each of mycotic (*Zygomycetes* spp.) and parasitic (*Schistosoma* spp.) colitis was identified. The most frequent bacteria isolated were *Campylobacter* spp. (45, 62.5% of bacteria cultured), *Shigella* spp. (12, 16.7%) and *Salmonella* spp. (9, 12.5%).

Mortality arising from hemorrhage (n = 365) was almost exclusively seen in perinatal (190, 52.1%) and infant (132, 36.2%) baboons, associated with trauma (351, 96.2%), and had an equal female to male ratio. Animals with hemorrhage were much more likely to have died (324, 88.8%) than to have been euthanized. The most common organs affected were the head, brain and meninges (184, 50.4), followed by multisystem hemorrhage (104, 28.5%).

Mortality arising from ulcers (n = 224) was seen across all age groups, but the majority were seen in juvenile (76, 33.9%), infant (73, 32.6%) and adult (47, 21.0%) baboons, with an approximately 3:2 female to male ratio. Animals with ulcers were more likely to have been euthanized (135, 60.3%) than to have died. Ulcers were located in the digestive (124, 55.4%), integumentary (77, 34.4%), and urogenital (23, 10.3%) systems. Based on the presence of HPV2 in the colony and the lesion appearance, the majority of these (212, 94.7%) were considered to be sequela of HPV2 infection; laboratory confirmation was not performed for herpes virus. There was one additional sex skin ulcer that was attributed to a bacterial etiology (culture positive for *Escherichia coli* and *Klebsiella pneumoniae*). Eleven ulcers were of undetermined etiology. The organs affected by viral ulcers (n = 212) were the oral cavity (116, 51.8%), vulva (50, 22.3%), sex skin (23, 10.3%), and penis (23, 10.3%). Mortality patterns varied by ulcer location. Ulcers of the oral cavity affected infants and juveniles, with an approximately 2:3 female to male ratio, and was more likely to result in death (81, 69.8%). Ulcers involving the vulva and or sex skin in female baboons most often were seen in adult animals and were always associated with euthanasia. Ulcers of the penis in male baboons was most common in juveniles and nearly always associated with euthanasia.

Mortality arising from seizure (n = 205) was generally seen in adult (92, 44.9%) and juvenile (80, 39.0%) baboons with an approximately 1:1 female to male ratio. Animals with seizure were much more likely to have been euthanized (177, 86.3%) than to have died.

Mortality arising from pneumonia (n = 184) was most often seen in infant (74, 40.2%), juvenile (41, 22.3%), and adult (35, 19.0%) baboons, with an approximately 2:3 female to male ratio. Animals with pneumonia were much more likely to have died (125, 67.9%) than to have been euthanized. Nearly half (88, 47.8%) of the pneumonia cases were of undetermined etiology. Bacterial (57, 31.0%) and foreign body (32, 17.4%) were the most commonly identified etiologies. The most often recovered bacteria were *Streptococcus spp*. (17, 29.8%), *Staphylococcus spp*. (16, 28.1%), *Escherichia coli* (11, 19.3%), *Pasteurella multocida* (6, 10.5%), and *Klebsiella pneumoniae* (5, 8.8%); bacteria were identified histologically in seven baboons where lung culture was not performed. Foreign body pneumonia was predominantly due to aspiration (18 of 32, 56.3%) in animals of varied ages or poor clearance at birth (12, 37.5%) in neonates; the other two cases were neonates with aspiration of amniotic fluid. There were also four cases of mycotic pneumonia due to Coccidioides immitis and a single case of adenovirus pneumonia.

Mortality arising from inanition (n = 179) was almost exclusively seen in infant (124, 69.3%) baboons with an equal female to male ratio. Animals with inanition were much more likely to have died (165, 92.2%) than to have been euthanized.

Mortality arising from dermatitis (n = 165) was generally seen in adult (109, 66.1%) and juvenile (30, 18.2%) baboons with an approximately 3:1 female to male ratio. Animals with dermatitis were much more likely to have been euthanized (158, 95.8%) than to have died. The majority were of mycotic etiology (129, 78.2%); all were due to *Histoplasmosis capsulatum var. duboisii* with the exception of a single case of *Trichosporon beigelii*. Other common etiologies associated with dermatitis were trauma (10, 6.1%) and toxic (5, 3.0%); all five cases of toxic dermatitis were due to zinc toxicity. There were 18 dermatitis cases of undetermined etiology.

Mortality arising from spondylosis (n = 142) was almost exclusively seen in aged (117, 82.4%) and geriatric (21, 14.8%) baboons with an approximately 2:1 female to male ratio. All animals with spondylosis had been euthanized for the condition.

Mortality arising from amyloidosis (n = 130) was generally seen in adult (64, 49.2%) and aged (57, 43.9%) baboons with an approximately 3:1 female to male ratio. Animals with amyloidosis were much more likely to have been euthanized (112, 86.2%) than to have died. Amyloidosis related mortality was most often disseminated, involving multiple organs (82, 63.1%); this form had an approximately 2:1 female to male ratio. Amyloidosis of the pancreatic islets was the cause of mortality in 38 (29.2%), with 14 of these animals having a notation in the submission history that they were diabetic; this form had an approximately 12:1 female to male ratio. Other sites of amyloid deposition resulting in mortality were the kidney (8, 6.2%) and one case each involving the liver and spleen.

Mortality arising from fracture (n = 116) included 114 bone fractures and two adult male baboons euthanized for severe tooth fractures. Bone fractures most often involved the skull (65, 57.0%), radius (10, 8.8%), mandible (7, 6.1%), femur (6, 5.3%), and vertebrae (5, 4.4%). Skull fractures presented differently than fractures involving other bones. Skull fractures (n = 65) were almost always seen in infant (38, 58.5%) and perinatal (23, 35.4%) baboons with an equal female to male ratio. Animals with skull fractures were much more likely to have died (55, 84.6%) than to have been euthanized. Fractures involving other bones (n = 49) were generally seen in adult (14, 28.6%), juvenile (13, 26.6%) and infant (13, 26.5%) baboons with an approximately 2:1 female to male ratio. Animals with non-skull fractures were much more likely to have been euthanized (43, 87.8%) than to have died.

Mortality arising from lymphosarcoma (n = 116) was generally seen in adult (65, 56.0%) and aged (41, 35.3%) baboons with an approximately 7:3 female to male ratio. Animals with lymphosarcoma were much more likely to have been euthanized (103, 88.8%) than to have died. The overwhelming majority of lymphosarcoma cases were multisystem (105, 90.6%). The only single organ affected that was represented more than once was the lung (7, 6.0%).

Mortality arising from hypothermia (n = 101) was seen across perinatal to aged groups, but somewhat more often in infant (28, 27.7%) baboons with an approximately 3:1 female to male ratio. Animals with hypothermia were much more likely to have died (97, 96.0%) than to have been euthanized.

Mortality arising from lacerations (n = 97) was generally seen in adult (49, 50.5%) baboons with an approximately 3:2 female to male ratio. Animals with lacerations were more likely

to have been euthanized (60, 61.9%) than to have died. All lacerations were attributed to trauma. Lacerations almost always involved the integumentary system (93, 95.9%), most often the skin (84), followed by the scrotum (4), sex skin (3), ear (1) and eyelid (1). Three involved the digestive system: two lacerated tongues and one liver laceration. There was a single laceration of the penis, included within the urogenital system.

Mortality arising from trichobezoars (n = 92) was generally seen in adult (60, 65.2%) baboons with an approximately 3:1 female to male ratio. Animals with trichobezoars were slightly more likely to have been euthanized (52, 56.6%) than to have died. Trichobezoars resulting in mortality were predominantly found within the stomach (65, 70.7%). Other locations included the small intestine (12, 13.0%), esophagus (8, 8.7%), colon (4, 4.4%) and cecum (3, 3.3%).

Mortality arising from arthritis (n = 88) was generally seen in aged (60, 68.2%) and geriatric (18, 20.5%) baboons with a slightly less than 2:1 female to male ratio. All animals with arthritis were euthanized for the condition. The overwhelming majority of arthritis cases were degenerative (85, 96.6%). Seventeen (19.3%) animals had systemic arthritis affecting essentially all joints. The remaining 68 animals had a total of 99 joints affected (45 had a single joint affected; 23 had more than one). The most common joints affected in these 68 animals were the knee (65, 95.6%), hip (15, 22.1%), elbow (10, 14.7%), shoulder (6, 8.9%), and ankle (3, 4.4%). Three (3.4%) animals experienced mortality resulting from bacterial arthritis; two involving the elbow and knee joints, the other involving the knee joint only. *Pasteurella multocida*, *Staphylococcus aureus* and *Streptococcus pyogenes* were each cultured from one animal.

Mortality arising from myocarditis (n = 81) was seen across juvenile to aged groups, but somewhat more often in adult (31, 38.3%) baboons with an approximately 3:2 female to male ratio. Animals with myocarditis were much more likely to have died (73, 90.1%) than to have been euthanized. Mortality due to myocarditis was most often associated with Encephalomyocarditis virus (54, 66.7%), seen most often in juvenile and adult animals. There were 25 cases of undetermined etiology; more often in adult and aged animals. One case each of bacterial (*Staphylococcus aureus*) and parasitic (*Trypanosoma cruzi*) myocarditis were identified.

Mortality arising from endometriosis (n = 72) was almost exclusively seen in aged (59, 81.9%) baboons and only occurred in females. Animals with endometriosis were much more likely to have been euthanized (71, 98.6%) than to have died. Seventy one (98.6%) of the 72 cases of mortality due to endometriosis involved the peritoneal cavity. There was a single case of pulmonary endometriosis, with death secondary to rupture of the lesion and pneumothorax.

Mortality arising from strictures (n = 60) almost exclusively involved the vagina (57, 95.0%) and was generally seen in adult (34, 56.7%) and aged (22, 36.7%) female baboons. Based on the presence of HPV2 in the colony and the lesion appearance, the vaginal strictures were considered to be sequela of HPV2 infection; laboratory confirmation was not performed for herpes virus. Animals with strictures were much more likely to have been euthanized (57,

95.0%) than to have died. The other strictures were a congenital stricture of the umbilical cord, a colonic stricture of undetermined etiology, and a post-traumatic stricture of the nasal cavity in the only male baboon in the category.

Mortality arising from meningoencephalitis (n = 59) was generally seen in juvenile (21, 35.6%), aged (17, 28.8%) and adult (13, 22.0%) baboons with an approximately 2:3 female to male ratio. Animals with meningoencephalitis were more likely to have been euthanized (42, 71.2%) than to have died. Mortality arising from meningoencephalitis was predominantly related to Baboon Reovirus, accounting for 47 (79.7%) cases. Seven (11.9%) were of undetermined etiology. Five (8.5%) were of bacterial etiology; the organisms recovered were *Corynebacterium spp.* and *Escherichia coli* (dual infection), *Staphylococcus aureus*, alpha-hemolytic *Streptococcus* spp., *Streptococcus pneumoniae*, and *Streptococcus sanguis*.

Systems and Organs Affected

Table 3 presents the body systems and organs resulting in mortality in descending order of occurrence by body system and then organ, and lists the total number, percentage of overall and system mortalities, numbers of female, male, and unknown sex, mean age and standard deviation for female, male, and total baboons for each diagnosis, and selected references. The digestive system was most frequently involved (n = 925, 21.3%), followed by the urogenital (n = 883, 20.3%), cardiovascular (n = 532, 12.2%), multisystem disease (n = 448, 10.3%), musculoskeletal (n = 411, 9.5%), integumentary (n = 353, 8.1%), nervous (n = 318, 7.3%), respiratory (n = 259, 6.0%), hematopoietic/lymphatic (n = 123, 2.8%), endocrine (n = 53, 1.2%) and special senses (n = 44, 1.0%).

Digestive system—Mortality arising from digestive system lesions (n = 926) was generally seen in juvenile (350, 37.8%) and adult (236, 25.5%) baboons with an approximately 3:2 female to male ratio. Animals with digestive system related mortality were more likely to have been euthanized (535, 57.9%) than to have died. Within the digestive system, the most common causes of mortality were colitis (372, 40.2%), ulcer (124, 13.4%), trichobezoar (92, 10.0%), typhlitis (47, 5.1%), gastric dilatation (44, 4.8%), adenocarcinoma (36, 3.9%), intussusception (28, 3.0%), periodontal disease (22, 2.4%), peritonitis, (21, 2.3%), foreign body (20, 2.2%), rectal prolapse (19, 2.0%), esophagitis (14, 1.5%), enterocolitis (11, 1.2%), phytobezoar (11, 1.2%), and cholelithiasis/ cholangiohepatitis (n=11, 1.2%). The following descriptions by system do not include information from the morphologies fully covered above.

Ulcer associated mortality within the digestive system (n = 124) almost exclusively involved the oral cavity (116, 93.54%). These were considered Herpes papio virus 2 related and most commonly seen in infants (75, 60.5%) and juveniles (43, 34.7%), but not confirmed with laboratory tests. Animals with ulcer related mortality within the digestive system were more likely to have died (87, 70.2%) than to have been euthanized.

Typhlitis associated mortality (n = 47) was generally seen in aged (30, 63.8%) and adult (13, 27.7%) baboons with an approximately 2:1 female to male ratio. Animals with typhlitis related mortality were more likely to have been euthanized (31, 66.0%) than to have died.

The majority of cases (40, 85.1%) were of undetermined etiology. Seven (14.9%) were of bacterial etiology: *Campylobacter spp*. (3), *Salmonella enteritidis* (2), and one case each of *Alcaligenes faecalis*, *Escherichia coli*, and *Shigella spp*. were recovered from these animals.

Gastric dilatation associated mortality (n = 44) was generally seen in juvenile (18, 40.9%) baboons with an approximately 2:1 female to male ratio. Animals with gastric dilatation related mortality were much more likely to have died (43, 97.7%) than to have been euthanized.

Mortality resulting from adenocarcinoma (n = 36) was generally seen in aged (27, 75.0%) baboons with a 9:1 female to male ratio. Animals with adenocarcinoma related mortality were much more likely to have been euthanized (32, 88.9%) than to have died. Adenocarcinomas within the gastrointestinal system were predominantly seen near the ileo-cecal-colic junction. Specific locations were recorded as cecum (25, 69.4%), colon (5, 13.9%), and small intestine (4, 11.1%). One baboon each was euthanized for adenocarcinoma of the rectum and of the salivary gland.

Mortality resulting from intussusception (n = 28) was generally seen in adult (13, 46.4%) and juvenile (10, 35.7%) baboons with a 4:1 female to male ratio. Animals with intussusception related mortality were more likely to have been euthanized (18, 64.3%) than to have died. The distribution of intussusception resulting in mortality was: enterocolic (19, 67.9%; 10 ileo-colic and 9 ileo-cecal), colocolic (7, 25.0%; 4 colo-rectal and 3 ceco-colic), and enteroenteric (2, 7.1%; both jejuno-duodenal).

Mortality resulting from periodontal disease (n = 22) was almost exclusively seen in male (21, 95.5%) aged (17, 77.3%) baboons. All animals with periodontal disease related mortality were euthanized.

Mortality resulting from peritonitis (n = 21) was generally seen in aged (8, 38.1%) and adult (7, 33.3%) baboons with an approximately 3:2 female to male ratio. Animals with peritonitis related mortality were slightly more likely to have been euthanized (11, 52.4%) than to have died. Peritonitis was most often due to bacterial (9, 42.9%) or undetermined (9, 42.9%) etiology. The most common bacteria isolated were *Streptococcus spp*. (4) and *Escherichia coli* (3). Of the other three bacterial cases, two were secondary to gall bladder rupture and one was due to a perforation of the small intestine.

Mortality resulting from foreign body (n = 20) was generally seen in adult (11, 55.0%) baboons with an approximately 1:2 female to male ratio. Animals with foreign body related mortality were more likely to have been euthanized (13, 65.0%) than to have died. The most common sites for foreign bodies were the esophagus (10, 50.0%), stomach (5, 25.0%) and peritoneal cavity (2, 10.0%). The most common foreign body recovered was wire (13, 65.0%). Four of these resulted in fistulas between the esophagus and the aorta (2), coronary artery (1) or lung (1).

Mortality resulting from rectal prolapse (n = 19, 2.1%) was seen somewhat evenly across juvenile to and aged baboons with a 3:2 female to male ratio. Animals with rectal prolapse related mortality were more likely to have been euthanized (16, 84.2%) than to have died.

Mortality resulting from esophagitis (n = 14) was generally seen in juvenile (8 , 57.,1%) and adult (4, 28.8%) baboons with a 7:3 female to male ratio. Animals with esophagitis related mortality were more likely to have died (9, 64.3%) than to have been euthanized. Six of these were of mycotic etiology: five cases of *Candida spp*., and one of *Coccidioides immitis*. One case was considered related to gastroesophageal reflux. In seven an etiology was not identified.

Mortality resulting from enterocolitis (n = 11) was generally seen in juvenile (6, 54.6%) and infant (4, 36.4%) baboons with approximately equal female to male ratio. Animals with enterocolitis related mortality were more likely to have died (7, 63.6%) than to have been euthanized. Culture results were available from six cases with two cases each of *Salmonella enteritidis, Yersinia enterocolitica*, and *Campylobacter coli*.

Mortality resulting from phytobezoar (n = 11) was generally seen in adult (5, 45.5%) and aged (4, 36.4%) baboons involving 8 female and 3 male baboons. Animals with phytobezoar related mortality were more likely to have been euthanized (9, 81.8%) than to have died. Ten of the eleven phytobezoars were found in the stomach; the other was in the colon.

Mortality resulting from cholelithiasis and cholangiohepatitis (n = 11) was generally seen in aged (6, 54.6%) and adult (4, 36.4%) baboons with a generally even female to male ratio. Generally, cholangiohepatitis was seen in adult baboons and cholelithiasis in aged baboons. All animals with cholelithiasis and cholangiohepatitis related mortality were euthanized.

Urogenital system—Mortality arising from urogenital system lesions (n = 883) had a bimodal distribution. It was most often seen in perinatal (499, 56.6%) baboons, predominantly due to stillbirths (468, 53.0%). Excluding stillbirths, mortality from the remaining urogenital system lesions (n = 415) was generally seen in aged (160, 38.6%) and adult (157, 37.8%) baboons with an approximately 4:1 female to male ratio. Other than stillbirths, animals with urogenital system related mortality were much more likely to have been euthanized (339, 81.7%) than to have died. Within the urogenital system, the most common causes of mortality (n = 883) were stillborn (468, 53.0%), ulcer (73, 8.3%), endometriosis (71, 8.0%), stricture (58, 6.6%), dystocia (38, 4.3%), pyelonephritis (36, 4.1%), nephritis/glomerulonephritis (22, 2.5%), metritis (14, 1.6%), placentitis (12, 1.4%), adenomyosis (10, 1.1%), placenta abruptio (10, 1.1%) and cystitis (9, 1.0%). The following descriptions by system do not include information from the morphologies fully covered above.

Dystocia associated mortality (n = 38) was generally seen in adult (26, 68.4%) or aged (5, 13.2%) female baboons; one case of dystocia was seen in a juvenile baboon. There were six perinatal animals included in this category that died at, or shortly after, birth due to complications of dystocia; three were females, one was male, and 2 were of unknown gender. Animals with dystocia related mortality were slightly more likely to have died (20, 52.6%) than to have been euthanized.

Mortality resulting from pyelonephritis (n = 36) was generally seen in adult (19, 52.8%) and aged (15, 41.7%) baboons with a 3.5:1 female to male ratio. Animals with pyelonephritis

related mortality were more likely to have been euthanized (31, 86.1%) than to have died. Only three of these cases had culture results available, all three recovered *Escherichia coli*.

Mortality resulting from nephritis/glomerulonephritis (n = 22) was generally seen in aged (11, 50.0%) and adult (7, 31.8%) baboons with a 3:1 female to male ratio. Animals with nephritis/glomerulonephritis related mortality were more likely to have been euthanized (19, 86.4%) than to have died.

Mortality resulting from metritis (n = 14) was generally seen in adult (8, 57.1%) and aged (5, 35.7%) baboons; all were female. Animals with metritis related mortality were more likely to have been euthanized (10, 71.4%) than to have died. Bacterial and physical causes accounted for six (42.9%) cases each. Physical causes included four cases of retained fetus and two of retained placenta. Bacteria cultured included *Escherichia coli* (2), *Streptococcus spp*. (2), *Brucella spp*. (1), and *Morganella morganii* (1).

Mortality resulting from placentitis (n = 12) was only seen in perinatal baboons, with an equal female to male ratio. Animals with placentitis related mortality were much more likely to have died (11, 91.7%) than to have been euthanized. The majority (9, 75.0%) were of undetermined etiology. Bacteria were identified in the other three cases; the bacteria cultured were *Escherichia coli*, *Morganella morganii*, and a mixed infection of *Klebsiella pneumoniae* and *Aeromonas hydrophila*.

Mortality resulting from adenomyosis (n = 10) was only seen in aged (8, 80.0%) and geriatric (2, 20.0%) baboons; all were female. All animals with adenomyosis related mortality were euthanized.

Mortality resulting from placenta abruptio (n = 10) was only seen in perinatal baboons; five (50.0%) were male, two were female, and three were of undetermined gender. All 10 animals with placenta abruptio related mortality died.

Mortality resulting from cystitis (n = 9) was generally seen in adult (6, 66.7%) baboons with a 1:2 female to male ratio. Animals with cystitis related mortality were more likely to have died (6, 66.7%) than to have been euthanized.

Cardiovascular system—Mortality arising from cardiovascular system lesions (n = 532) was most often seen in perinatal (177, 33.3%) and infant (171, 33.3%) baboons with an approximately equal female to male ratio. Animals with cardiovascular system related mortality were more likely to have died (451, 84.8%) than to have been euthanized. Within the cardiovascular system, the most common causes of mortality were hemorrhage (365, 68.6%), myocarditis (81, 15.2%), septicemia (30, 5.6%), anomaly (12, 2.3%), fibrosis (11, 2.1%), endocardiosis (6, 1.1%), and infarct (6, 1.1%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from septicemia (n = 30) was seen somewhat evenly across perinatal, juvenile, adult and aged baboons with a 2:3 female to male ratio. Animals with septicemia related mortality were more likely to have died (20, 66.7%) than to have been euthanized. Twenty one (70.0%) were of confirmed bacterial origin. Fifteen were verified by culture and

bacteria were observed histologically in 6 others; seven cases had multiple organisms. The most common organisms cultured were *Staphylococcus aureus* (7), *Escherichia coli* (4), *Streptococcus spp*. (4), and *Pasteurella multocida* (2). Other organisms cultured once were *Enterococcus spp.*, *Klebsiella pneumoniae*, Methicillin-resistant *Staphylococcus aureus*, *Morganella morganii*, *Pseudomonas aeruginosa*, *Shigella spp*. and *Yersinia enterocolitica*.

Mortality resulting from cardiovascular anomaly (n = 12) was most often seen in infant (10, 83.3%) baboons with an equal female to male ratio. Animals with anomaly related mortality were more likely to have died (9, 75.0%) than to have been euthanized. The most common anomalies encountered were aortic aneurism rupture (5), atrial septal defect (2), and patent foramen ovale (2). Other anomalies seen once each were cardiac dysplasia, pulmonary artery stenosis, persistent ductus arteriosus, and tetrology of Fallot.

Mortality resulting from cardiac fibrosis (n = 11) was generally seen in aged (5, 45.5%) and adult (4, 36.4%) baboons with an equal female to male ratio. Animals with cardiac fibrosis related mortality were more likely to have died (8, 72.7%) than to have been euthanized.

Mortality resulting from endocardiosis (n = 6) was generally seen in aged (3, 50.0%) baboons with a 2:1 female to male ratio. Animals with endocardiosis related mortality were more likely to have been euthanized (4, 66.7%) than to have died.

Mortality resulting from infarct (n = 6) was most often seen in aged (3, 50.0%) and adult (2, 33.3%) baboons with a 2:1 female to male ratio. Animals with infarct related mortality were more likely to have been euthanized (4, 66.7%) than to have died. Three infarcts occurred within the cerebrum and one each within the cerebellum, jejunal mesentery, and placenta.

Multisystem Disease—Mortality arising from multisystem disease (n = 448) was seen more often in infant (163, 36.7%), adult (87, 19.4%), and juvenile (83, 18.5%) baboons with an approximately 3:2 female to male ratio. Animals with multisystem disease related mortality were more likely to have died (342, 76.3%) than to have been euthanized. The most common causes of mortality with multisystem disease were inanition (179, 40.0%), hypothermia (101, 22.5%), amyloidosis (82, 18.3%), entanglement (44, 9.8%), hyperthermia (15, 3.4%), anesthetic death (14, 3.1%), and emaciation (8, 1.8%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from entanglement (n = 44) was most often seen in juvenile (31, 70.5%) and infant (10, 22.4%) baboons with a 3:2 female to male ratio. All animals with entanglement related mortality died.

Mortality resulting from hyperthermia (n = 15) was most often seen in adult (7, 46.7%) baboons with a 2:1 female to male ratio. Animals with hyperthermia related mortality were much more likely to have died (13, 86.67%) than to have been euthanized.

Mortality resulting from anesthetic death (n = 14) was most often seen in adult (7, 50.0%) and aged (5, 35.7%) baboons with a 2.5:1 female to male ratio. Animals with anesthetic

death related mortality were much more likely to have died (12, 85.71%) than to have been euthanized.

Mortality resulting from emaciation (n = 8) was most often seen in aged (4, 50.0%) baboons with a 7:1 female to male ratio. All animals with emaciation related mortality were euthanized.

Musculoskeletal system—Mortality arising from musculoskeletal system lesions (n = 411) was seen most often in aged (200, 48.7%) baboons, mostly due to spondylosis and arthritis. It was also seen frequently in adults (54, 13.1%), associated with multiple causes, and in infant baboons (60, 14.6%), the majority due to fractures. Overall, animals with musculoskeletal system related mortality were seen in an approximately 3:2 female to male ratio and were much more likely to have been euthanized (338, 82.2%) than to have died. Within the musculoskeletal system, the most common causes of mortality were spondylosis (142, 34.6%), fracture (114, 27.7%), arthritis (88, 21.4%), hernia (10, 2.4%), abscess (8, 2.0%) and necrosis (5, 1.2%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from hernia (n = 10) was most often seen in adult (4, 40.0%) and aged (4, 40.0%) baboons with a 2:3 female to male ratio. Animals with hernia related mortality were more likely to have been euthanized (7, 70.0%) than to have died. The locations recorded for hernias were abdominal (3), diaphragmatic (3), inguinal (3) and umbilical (1).

Mortality resulting from abscess (n = 8) was most often seen in adult (4, 50.0%) and aged (3, 37.5%) baboons; there were five males and three females. Animals with abscess related mortality were more likely to have been euthanized (6, 75.0%) than to have died. Only 2 of these abscesses were cultured. One yielded *Pasteurella multocida*; the other yielded a mixed culture of *Escherichia coli*, *Pseudomonas aeruginosa* and Methicillin-resistant *Staphylococcus aureus*.

Mortality resulting from necrosis (n = 5) was most often seen in infant (3, 60.0%) baboons; there were three males and two females. Animals with necrosis related mortality were more likely to have died (3, 60.0%) than to have been euthanized. Three of these cases were attributed to trauma; the other two to frostbite.

Integumentary system—Mortality arising from integumentary system lesions (n = 353) was seen most often in adult (191, 54.1%) baboons with an approximately 3:1 female to male ratio. Animals with integumentary system related mortality were much more likely to have been euthanized (297, 84.1%) than to have died. The most common causes of mortality with integumentary system disease were dermatitis (165, 46.7%), laceration (93, 26.4%), ulcer (27, 7.7%), cellulitis (26, 7.4%), abscess (7, 2.0%), myxoma (6, 1.7%) and squamous cell carcinoma (6, 1.7%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from cellulitis (n = 26) was most often seen in adult (8, 30.8%) and aged (8, 30.8%) baboons in an approximately 3:1 female to male ratio. Animals with cellulitis related mortality were more likely to have been euthanized (20, 76.9%) than to have died.

Only 2 of these cases were cultured. One yielded betahemolytic *Streptoccocus spp*.; the other yielded a mixed culture of *Pasteurella multocida* and *Staphylococcus aureus*.

Mortality resulting from abscess (n = 7) was seen in adult (3, 42.9%), infant (2, 28.6%) and aged (2, 28.6%) baboons; there were four females and three males. Animals with abscess related mortality were more likely to have been euthanized (5, 71.4%) than to have died. Only 2 of these abscesses were cultured. One yielded *Staphylococcus aureus*; the other yielded a mixed culture of *Pasteurella multocida*, *Staphylococcus aureus* and *Streptococcus spp*.

Mortality resulting from myxoma (n = 6) was most often seen in aged (5, 83.3%) baboons; all six were females and all six neoplasms involved the sex skin. All animals with myxoma related mortality were euthanized. Specific diagnoses were: myxoma (2), myxosarcoma (2), myxofibroma (1), and angiomyxoma (1).

Mortality resulting from squamous cell carcinoma (n = 6) was most often seen in aged (5, 83.3%) baboons; all six were females. Animals with squamous cell carcinoma related mortality were much more likely to have been euthanized (5, 83.3%) than to have died.

Nervous system—Mortality arising from nervous system lesions (n = 318) was seen most often in adult (120, 37.7%) and juvenile (111, 34.9%) baboons with slightly less females than males. Animals with nervous system related mortality were more likely to have been euthanized (252, 79.3%) than to have died. Within the nervous system, the most common causes of mortality were seizures (205, 64.5%), meningoencephalitis (59, 18.6%), meningitis (16, 5.0%), encephalitis (9, 2.8%), hydrocephalus (7, 2.2%) and degeneration (6, 1.9%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from meningitis (n = 16) was most often seen in infant (6 37.5%), adult (5, 31.3%) and aged (4, 25.0%) baboons in an approximately 1:3 female to male ratio. Animals with meningitis related mortality were more likely to have died (9, 56.3%) than to have been euthanized. Seven of the sixteen were cultured; three isolated multiple organisms. The most common bacteria isolated was *Staphylococcus aureus* (4); there was one isolate each of *Enterococcus faecium, Lactobacillus acidophilus, Fusobacterium nucleatum, Gemella morbillorum, Pseudomonas aeruginosa* and *Streptococcus pneumoniae*.

Mortality resulting from encephalitis (n = 9) was most often seen in adult (3, 33.3%) and juvenile (3, 33.3%) baboons in an approximately equal female to male ratio. Animals with encephalitis related mortality were more likely to have been euthanized (6, 66.7%) than to have died. Five of the nine were cultured; one isolated multiple organisms. The most common bacteria isolated were *Staphylococcus aureus* (2) and *Streptococcus spp*. (2); there was one isolate each of *Escherichia coli* and *Micrococcus spp*.

Mortality resulting from hydrocephalus (n = 7) was seen in juvenile (4, 57.1%) and infant (3, 42.9%) baboons in an approximately equal female to male ratio. Animals with hydrocephalus related mortality were slightly more likely to have been euthanized (4, 57.1%) than to have died.

Mortality resulting from degeneration (n = 6) was most often due to spinal cord degeneration in aged male (5, 83.3%) baboons; there was a single case of degeneration of the brain in a infant female baboon. All animals with degeneration related mortality were euthanized.

Respiratory system—Mortality arising from respiratory system lesions (n = 259) was seen most often in infant (81, 31.3%), adult (57, 22.0%) and juvenile (53, 20.5%) baboons with an approximately 2:3 female to male ratio. Animals with respiratory system related mortality were more likely to have died (173, 66.8%) than to have been euthanized. Within the respiratory system, the most common causes of mortality were pneumonia (184, 71.0%), atelectasis (26, 10.0%), air sacculitis (18, 7.0%), edema (10, 3.9%) and asphyxiation (6, 2.3%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from atelectasis (n = 26) was seen in perinatal (19, 73.1%) and infant (7, 26.9%) baboons in an approximately 2:3 female to male ratio. Animals with atelectasis related mortality were much more likely to have died (25, 96.2%) than to have been euthanized.

Mortality resulting from air sacculitis (n = 18) was seen in adult (12, 66.7%) and aged (6, 33.3%) baboons. There were 17 males and only one female. Animals with air sacculitis related mortality were much more likely to have been euthanized (13, 72.2%) than to have died. Seven of the twenty six were cultured; five isolated multiple organisms. Two additional non-cultured cases had bacteria identified histologically. The most common bacteria isolated were *Streptococcus spp*. (6), *Escherichia coli* (2) and *Pasteurella multocida* (2); there was one isolate each of *Enterococcus spp*., *Fusobacterium spp*. and *Haemophilus spp*.

Mortality resulting from pulmonary edema (n = 10) was seen in similar numbers across juvenile to aged baboons in an equal female to male ratio. Animals with a edema related mortality were more likely to have died (6, 60.0%) than to have been euthanized.

Mortality resulting from asphyxiation was seen once in six (3 female, 3 male) juvenile baboons that crowded together in one corner of an enclosure.

Hematopoietic/lymphatic system—Mortality arising from hematopoietic/lymphatic system lesions (n = 123) was almost exclusively due to lymphosarcoma (116, 94.3%); other lesions were hyperplasia (2), lymphadenitis (2) and one case each of amyloidosis, anemia, and splenitis.

Endocrine system—Mortality arising from endocrine system lesions (n = 53) was seen most often in aged (36, 67.9%) baboons, with an approximately 8:1 female to male ratio. Animals with endocrine system related mortality were much more likely to have been euthanized (44, 83.0%) than to have died. Within the endocrine system, the most common causes of mortality were amyloidosis of the islets of Langerhans (38, 71.7%) and neoplasia

(13, 24.5%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality resulting from endocrine neoplasia (n = 13) was most often seen in aged (9, 69.23%) baboons in an approximately 5:1 female to male ratio. Animals with endocrine neoplasia related mortality were more likely to have been euthanized (11, 84.6%) than to have died. Specific endocrine neoplasias associated with mortality were carcinomas (5), adenomas (4) and neuroendocrine carcinomas (4). Three carcinomas involved the islets of Langerhans: a gastrinoma, malignant somatostatinoma and one that was not identified to cell product. There were two thyroid medullary carcinomas. There were three pituitary adenomas and one islet cell adenoma. One of the neuroendocrine carcinomas was within the liver, one involved the pericardium, and two were disseminated.

Special senses—Mortality arising from special senses lesions (n = 44) was seen most often in juvenile (22, 50.0%) and infant (10, 22.7%) baboons, with slightly more males than females. All animals with special senses related mortality were euthanized. Within the special senses, the most common causes of mortality were blindness (34, 77.3%) and cataract (5, 11.4%). The following descriptions by system do not include information from the morphologies fully covered above.

Mortality arising from blindness (n = 34) was seen most often in juvenile (20, 58.8%) and infant (10, 29.4%), in an approximately 3:4 female to male ratio. All were euthanized.

Mortality arising from cataract (n = 5) was seen most often in juvenile (2, 40.0%) and geriatric (2 of 5, 40.0%) baboons and involved four females and one male. All were euthanized.

Etiologic agents

Table 4 presents the etiologies resulting in mortality in order by frequency of occurrence (total number and percentage of deaths), numbers of female, male, and unknown sex, and the mean age and standard deviation for female, male, and total baboons for each diagnosis. An etiology was not identified in approximately one third of cases. The etiologies seen in descending order were trauma (n = 645, 14.83%), degenerative (n = 413, 9.49%), viral (n = 376, 8.64%), neoplastic/proliferative (n = 303, 6.97%), bacterial (n = 255, 5.89%), physical (n = 237, 5.45%), nutritional (n = 187, 4.30%), foreign body (n = 156, 3.59%), mycotic (n = 143, 3.26%), environmental (n = 118, 2.71%) and congenital (n = 52, 1.2%), iatrogenic (n = 32, 0.74%), toxic (n = 5, 0.11%) and parasitic (n = 3, 0.07%).

Trauma—Mortality resulting from traumatic etiology (n = 645) was most often seen in infant (236, 36.6%) and perinatal (202, 31.3%) baboons with slightly more females than males. Animals with trauma related mortality were more likely to have died (465, 72.1%) than to have been euthanized. The majority of trauma related mortality resulted from the cardiovascular (351, 54.4%), musculoskeletal (122, 18.9%) and, integumentary (117, 18.1%) systems. The most common morphologic diagnoses associated with trauma were hemorrhage (351 ,54.4%), fracture (116, 18.0%), laceration (97, 15.0%), entanglement (44,

6.8%), dermatitis (10, 1.6%) and cellulitis (8, 1.2%). Each of these morphologies has been fully covered above.

Degenerative—Mortality resulting from degenerative changes (n = 413) were most often seen in aged (267, 64.7%) baboons with a slightly less than 2:1 female to male ratio. Animals with degenerative related mortality were much more likely to have been euthanized (385, 93.2%) than to have died. Degenerative related mortality was seen in multiple systems. The musculoskeletal system (231, 55.9%), was most commonly involved, predominantly due to spondylosis and arthritis. Disseminated amyloidosis (82, 19.9%) and endocrine amyloidosis (islets of Langerhans, 38, 9.2%) were the next most frequent followed by the digestive (22; 5.3%), cardiovascular (18, 4.4%), urogenital (9, 2.2%), special senses (6, 1.5%), and nervous (spinal cord degeneration, 5, 1.2%) systems. Nineteen of the twenty two digestive system cases were due to periodontal disease. Degenerative cardiovascular changes included ten cardiac fibrosis and five endocardiosis cases. Eight of the nine urogenital cases were due to renal amyloidosis. Five of the six special senses cases were due to cataracts. The most common morphologic diagnoses overall were spondylosis (142, 34.4%), amyloidosis (130, 31.48%), arthritis (85, 20.6%), periodontal disease (19, 4.6%), cardiac fibrosis (10, 2.4%), unspecified degenerative change (8, 1.9%), endocardiosis (5, 1.2%), and cataract (5, 1.2%). Each of these has been fully covered above.

Viral—Mortality resulting from viral etiology (n = 376) was most often seen in juvenile (120, 29.0%) and adult (109, 29.0%) baboons in an approximately 3:2 female to male ratio. Animals with virus related mortality were more likely to have been euthanized (221, 58.8%) than to have died. Responsible viruses were presumed to be Papiline herpesvirus 2 (Herpesvirus papio 2, HPV2) (270, 71.8%), Encephalomyocarditis virus (58, 15.4%), Baboon Reovirus (47, 12.5%), and Adenovirus (1, 0.3%). HPV2 sequela responsible for mortality were ulcers of the oral cavity (116), vulva (50), penis (23) or sex skin (23), vaginal stricture (57) and cystitis (1). Encephalomyocarditis virus mortality resulted from myocarditis (54), stillbirth (2), cardiomyopathy (1) and porencephaly (1). There were 47 deaths from Reovirus meningoencephalitis and one from adenoviral pneumonia.

Neoplastic/proliferative—Mortality resulting from neoplastic/proliferative etiology (n = 303) was most often seen in aged (168, 55.5%) and adult (96, 31.7%) baboons in an approximately 5:1 female to male ratio. Animals with neoplastic/proliferative related mortality were much more likely to have been euthanized (276, 91.1%) than to have died. The most common neoplastic/proliferative causes of mortality were lymphosarcoma (116, 38.3%), endometriosis (72, 23.8%), adenocarcinoma (38, 12.5%), adenomyosis (10, 3.3%), carcinoma (10, 3.3%), squamous cell carcinoma (8, 2.6%), adenoma (7, 2.3%), myxoma (6, 2.0%), and neuroendocrine carcinoma (4, 1.3%). The gastrointestinal tract was primary site of adenocarcinomas, accounting for 36 of 38 (94.7%).

Bacterial—Mortality resulting from bacterial etiology (n = 255) was most often seen in adult (70, 27.5%), juvenile (70, 27.5%), infant (58, 22.8%) and aged (44, 17.8%) baboons in an approximately 4:5 female to male ratio. Animals with bacterial related mortality were more likely to have died (148, 58.0%) than to have been euthanized. The most frequent

systems affected were the digestive (97, 38.0%), respiratory (68, 26.7%), cardiovascular (23, 9.0%), nervous (19, 7.5%), and urogenital (19, 7.5%). The most frequent lesions associated with mortality arising from bacterial etiology were colitis (72, 28.2%), pneumonia (57, 22.4%), septicemia (21, 8.2%), abscesses (10, 3.9%), air sacculitis (9, 3.5%), peritonitis (9, 3.5%), meningitis (7, 2.8%), and typhlitis (7, 2.8%). These have been discussed above. Less frequent mortality due to bacterial etiology included enterocolitis (6, 2.4%), metritis (6, 2.4%), cellulitis (5, 2.0%), encephalitis (5, 2.0%), meningoencephalitis (5, 2.0%), pyelonephritis (4, 1.6%), arthritis (3, 1.2%), osteomyelitis (3, 1.2%), and placentitis (3, 1.2%).

Physical—Mortality resulting from physical etiology (n = 237) was most often seen in adult (71, 30.0%) and perinatal (68, 28.3%) baboons in an approximately 2:1 female to male ratio. Animals with physical related mortality were more likely to have died (156, 65.8%) than to have been euthanized. The systems affected were the digestive (105, 44.3%), urogenital (101, 42,6%), respiratory (26, 11.0%), and cardiovascular (5, 2.1%). The most frequent lesions associated with mortality arising from physical etiology were dilatation (44, 18.6%), dystocia (38, 16.0%), stillborn (32, 13.5%), intussusception (28, 11.8%), atelectasis (26, 11.0%), prolapse (22, 9.3%), and placenta abruptio (10, 4.2%).

Nutritional—Mortality resulting from nutritional etiology (n = 187) was most often seen in infant (125, 66.8%), perinatal (32, 17.1%) and juvenile (22, 12.0%) baboons in an approximately equal female to male ratio. Animals with nutritional related mortality were much more likely to have died (165, 88.2%) than to have been euthanized. These animals were all recorded as either inanition (179, 95.7%) or emaciation (8, 4.3%); animals coded as emaciation were generally older.

Foreign body—Mortality resulting from foreign body etiology (n = 156) was most often seen in adult (81, 51.9%), aged (31, 19.9%) and juvenile (27, 17.3%) baboons in an approximately 3:2 female to male ratio. Animals with foreign body related mortality were more likely to have died (86, 55.1%) than to have been euthanized. The systems affected were the digestive (124, 79.5%) and respiratory (32, 20.5%). The most frequent diagnoses associated with mortality arising from foreign body were trichobezoar (92, 59.0%), pneumonia (32, 20.5%), foreign body (21, 13.5%) and phytobezoar (11, 7.1%).

Mycotic—Mortality resulting from mycotic etiology (n = 143) was most often seen in adult (100, 70.0%) and juvenile (31, 21.7%) baboons in an approximately 3:1 female to male ratio. Animals with mycotic related mortality were much more likely to have been euthanized (135, 94.4%) than to have died. The vast majority of mycotic related deaths were animals euthanized for dermatitis due to *Histoplasmosis capsulatum var. duboisii* (128, 89.5%). *Coccidioides immitis* (7, 5.0%) was responsible for four cases of pneumonia and one case each of osteomyelitis, lymphadenitis, and esophagitis. *Candida spp*. (6, 4.2%) was seen in 5 cases of esophagitis and one case of gastritis. There was also a single case of dermatitis due to *Trichosporon beigelii* and colitis due to *Zygomycetes spp*.

Environmental—Mortality resulting from environmental etiology (n = 118) was most often seen in approximately equal numbers across perinatal to aged baboons in an slightly

less than 3:1 female to male ratio. Animals with environmental related mortality were much more likely to have died (111, 94.1%) than to have been euthanized. Three diagnoses accounted for all environmental related mortality: hypothermia (101, 85.6%), hyperthermia (15, 12.7%) and necrosis (frostbite, 2, 1.7%).

Congenital—Mortality resulting from congenital etiology (n = 52) was only seen in infant (26, 50.0%), juvenile (15, 28.9%) and perinatal (7, 13.5%) baboons in an equal female to male ratio. Animals with congenital related mortality were more likely to have been euthanized (33 63.5%) than to have died. The cardiovascular (13, 25.0%), musculoskeletal (11, 21.2%), special senses (8, 15.4%), nervous (7, 13.5%) and urogenital (7, 13.5%) systems were most often involved. The most frequent diagnoses associated with mortality arising from congenital lesions were anomaly (22, 42.3%), blind (8, 15.4%), hydrocephalus, (4, 7.7%), hypospadia (4, 7.7%), and arthrogryposis (4, 7.7). The majority of anomalies (n = 12) involved the heart and major vessels: aortic aneurism (5, 41.7%), atrial septal defect (2, 16.7%), patent foramen ovale (2, 16.7%), and one case each of pulmonary artery stenosis (concurrent with one of the atrial septal defects), persistent ductus arteriosus, tetrology of Fallot and unspecified dysplasia.

Iatrogenic—Mortality resulting from iatrogenic etiology (n = 32) was most often seen in aged (12, 37.5%), juvenile (10, 31.3%), and adult (9, 28.1%) baboons in an equal female to male ratio. Animals with iatrogenic related mortality were much more likely to have died (21, 65.6%) than to have been euthanized. The vast majority of iatrogenic related deaths were associated with anesthesia (16, 50.0%), capture (7, 21.9%) or surgery (7, 21.9%).

Toxic—Mortality resulting from toxic etiology (n = 5) presented as dermatitis resulting from zinc toxicity in three female and two male infant baboons. Three were euthanized and two died.

Parasitic—Three adult female baboons accounted for all the parasitic related mortality. One baboon died of myocarditis due to *Trypanosoma cruzi*, and one baboon each was euthanized due to colonic schistosomiasis and disseminated sparganosis.

Mortality by age groups

The morphologic diagnoses, systems, and etiologies resulting in mortality varied across age groups. Table 5 presents the ten most common diagnoses for each of the six age-groups. Table 6 presents the percentage of mortalities in each age group by system. Mortality of undetermined etiology was the most common finding in perinatal, juvenile, and adult baboons, second most common in infant and aged baboons and third most common in geriatric baboons. Table 7 presents the percentage of mortalities in each age group by confirmed etiology; mortality from undetermined etiology was excluded.

Perinatal Mortality—Perinatal mortality (n = 800) was predominantly due to stillbirth (468, 58.5%) and hemorrhage (173, 21.6%); the urogenital (499, 62.4%) and cardiovascular (177, 22.1%) systems were most often affected. Perinatal baboons with an identified

etiology (n = 348) generally died as a result of traumatic (202, 58.1%) or physical (68, 19.5%) causes.

Infant Mortality—The leading causes of infant mortality (n = 710) were hemorrhage (149, 21.0%) followed by inanition (124, 17.5%), ulcer (75, 10.6%), pneumonia (74, 10.4%), colitis (52, 7.3%), and fracture (51, 7.2%). Hemorrhage was almost exclusively related to trauma. Ulcers in infants were almost exclusively oral and presumed a sequela of HPV2. The cardiovascular (171,24.1%), multisystem (164, 23.1%), digestive (146, 20.6%), and respiratory (81, 11.4%) systems were most often affected. Infants with an identified etiology (n = 584) generally died as a result of traumatic (236, 40.4%), nutritional (125, 21.4%), or viral (77, 13.2%) causes.

Juvenile Mortality—The leading causes of juvenile mortality (n = 816) was colitis (220, 27.0%) followed by seizures (80, 9.8%), ulcer (76, 9.3%), and pneumonia (41, 5.0%). Ulcers leading to mortality in juveniles most often involved the oral cavity (42), penis (17) and vulva (15) and presumed a sequela of HPV2. The digestive (350, 42.9%), nervous (111, 13.6%), and multisystem (83, 10.2%) systems were most often affected. Juveniles with an identified etiology (n = 468) generally died as a result of viral (120, 25.6%), traumatic (80, 17.1%), or bacterial (70, 15.0%) etiologies.

Adult Mortality—Mortality in adult baboons (n = 1059) resulted from more varied causes. The leading cause of adult mortality was dermatitis (109, 10.29%) followed by seizures (92, 8.7%), colitis (76, 7.2%), lymphosarcoma (65, 6.1%), amyloidosis (64, 6.0%), trichobezoar (60, 5.7%), laceration (49, 4.6), and ulcer (47, 4.4%). The vast majority of dermatitis related mortality in adults (93 of 109, 85.3%) resulted from euthanasia secondary to infection with *Histoplasmosis capsulatum var. duboisii*. Amyloidosis in adult baboons was generally a systemic disease involving multiple organs. Ulcers leading to mortality in adults most often involved the vulva (n = 21), sex skin (n = 15) and penis (n = 6) and presumed a sequela of HPV2. The digestive (236, 22.3%), integumentary (191, 18.0%), urogenital (157, 14.8%), and nervous (120, 11.3%) systems were most often affected. Adults with an identified etiology (n = 754) generally died as a result of viral (109, 14.5%), traumatic (101, 13.4%), mycotic (99, 13.3%), neoplastic/proliferative (96, 12.7%), degenerative (86, 11.4%), or foreign body (81, 10.74%) etiologies.

Aged Mortality—The leading cause of mortality in aged baboons (n = 872) was spondylosis (117, 13.4%) followed by arthritis (60, 6.9%), endometriosis (59, 6.8%), amyloidosis (57, 6.5%), and lymphosarcoma (41, 4.7%). Amyloidosis in aged baboons was equally divided between a systemic disease involving multiple organs (27) and amyloidosis of the islets of Langerhans in the pancreas (26). The musculoskeletal (200, 22.9%), digestive (173, 19.8%), and urogenital (160, 18.4%) systems were most often affected. Aged animals with an identified etiology (n = 693) generally died as a result of degenerative (267, 38.5%) and neoplastic/proliferative (168, 24.2%) etiologies.

Geriatric Mortality—Geriatric mortality (n = 93) was predominantly due to spondylosis (21, 22.6%) and arthritis (18, 19.4%), both almost exclusively of degenerative etiology. Less common causes were adenocarcinoma (7, 7.5%), amyloidosis (5, 5.4%), and endometriosis

(4, 4.3%). Four of the five amyloidosis cases involved the islets of Langerhans in the pancreas; one was systemic. The musculoskeletal (40,43.0%), digestive (15, 16.1%), and urogenital (14, 15.0%) systems were most often affected. Geriatric animals with an identified etiology (n = 78) generally died as a result of degenerative (49, 62.8%) and neoplastic/proliferative (23, 29.5%) etiologies.

Mortality by Gender

After exclusion of the urogenital system as well as morphologies and organs that were gender specific (Table 9), there were few significant differences (Table 8) between female and male baboons within morphologic diagnoses, etiologies, or systems associated with mortality.

Adult male baboons were more likely to die or be euthanized as a result of lesions involving the respiratory system overall, and from airsacculitis and pneumonia, than adult females. Adult male baboons were also more likely to die or be euthanized as a result of bacterial etiologies than adult female baboons. Adult males had mortality related to the nervous system slightly more often. Adult male baboons also appeared to be overrepresented in mortality from meningitis/meningoencephalitis, abscess, and septicemia, however none of these reached statistical significance.

Aged male baboons were much more likely to die or be euthanized as a result of periodontal disease or degeneration than aged female baboons. Degeneration in aged male baboons most often involved the spinal cord (5), with one case each involving the eyelid (post-traumatic), eye (retinal degeneration), and heart.

Gender related mortality resulting from musculoskeletal system lesions varied by age group. In adult baboons, males were more likely to have mortality related to the musculoskeletal system; they appeared to have more fractures. In aged baboons, females were more likely to have mortality related to the musculoskeletal system; these cases appeared to predominantly due to spondylosis and arthritis. Aged female baboons also had significantly more mortality related to degenerative etiologies than aged males.

Discussion

We present the most comprehensive study of baboon mortality, documenting 4,350 baboons over a 23-year period analyzed by morphologic diagnosis, organ system, , and etiology. The most common morphologic diagnosis leading to mortality in descending order were stillborn, colitis, hemorrhage, ulcer, seizures, pneumonia inanition, dermatitis, spondylosis, amyloidosis, fracture, lymphosarcoma, hypothermia, laceration, trichobezoar, arthritis, myocarditis, endometriosis, stricture, and meningoencephalitis. The digestive system was most frequently involved, followed by the urogenital, cardiovascular, multisystem disease, musculoskeletal, integumentary, nervous, respiratory, hematopoietic/lymphatic, endocrine, and special senses. An etiology was not identified in approximately one third of cases. The most common etiologies in descending order were trauma, degenerative, viral, neoplastic/ proliferative, bacterial, physical, nutritional, foreign body, mycotic, environmental, and

congenital. Iatrogenic, toxic, and parasitic etiologies accounted for less than one percent each.

We could only identify one similar study to determine causes of mortality in 105 captive baboons conducted approximately 40 years ago in this same colony[36]. It is uncertain how many of those baboons were wild caught or captive born. The major causes of death in those captive adult baboons were pneumonia, enteritis, and septicemia[36]. While colitis and pneumonia were the 3rd and 9th, respectively, most common causes of mortality in our study, other conditions were more common. This likely is a result of improved husbandry and infection control practices over the last 40 years. Kim and Kalter[36] encountered 15 stillbirths in a total of 35 neonatal deaths and reported respiratory (pneumonia, aspiration, and hemorrhage) and birth injuries as the most common causes of perinatal baboon mortality. This is generally similar to our findings. Stillbirth of unknown etiology was by far the most frequent cause of perinatal mortality in our baboons. Trauma and physical etiologies were most frequent. Atelectasis and pneumonia were 5th and 7th, respectively, most common in our study. One difference was the frequency of inanition, the 3rd and 2nd most common causes of perinatal and infant mortality respectively in our animals. Inanition was not encountered in the prior study. It is unclear what would cause this difference, perhaps it reflects reduced mothering abilities within a captive population, where social stresses have been implicated in lactational incompetence in low-ranking, subordinate females[21].

We also saw differences when comparing these findings to our previous study documenting all the morphologic diagnoses recorded at necropsy for this baboon colony[8]. This is not surprising. A study listing all lesions seen includes many that would not be expected to result in mortality. Many common, but generally not fatal, diagnoses would be listed much less frequently in a mortality study, such as congestion, cyst, hyperplasia, edema, nephritis/glomerulonephritis, atrophy, emaciation, necrosis, hepatitis, gastritis, degeneration, and gingivitis. Less common, but more acute or severe, diagnoses would remain when evaluating mortality, and therefore be represented at higher percentages. Similar differences were observed comparing the frequency of systems involved. The cardiovascular, integumentary and nervous systems were represented more frequently in this review of mortality than the study listing of all lesions. While both sets of information are valuable for maintaining and managing a colony, we believe this present study to be generally more useful for clinical veterinarians providing colony care and the overall list of lesions[8] more valuable to pathologists and research scientists using these animals.

One of the benefits of this study is the documentation of the most common mortalities by age group in baboons. This should be of benefit to wildlife and zoo veterinarians and researchers caring for baboons. Perinatal mortality was predominantly due to stillbirth and trauma related hemorrhage (21.63%) generally of undetermined etiology and trauma, respectively. The leading causes of infant mortality were hemorrhage, inanition, and oral ulcers. Juvenile mortality was most often due to colitis, seizures, and orogenital ulcers. The leading causes of adult mortality were dermatitis resulting from *Histoplasmosis capsulatum var. duboisii*, seizures, colitis, lymphosarcoma, systemic amyloidosis, trichobezoar, laceration, and orogenital ulcers. The leading causes of mortality in aged baboons were

spondylosis, arthritis, endometriosis, amyloidosis (systemic and islet), and lymphosarcoma. Geriatric mortality was predominantly due to spondylosis and arthritis.

The causes of stillbirth remain largely unstudied; research and more intense diagnostic testing of stillborn baboons would help identify specific etiologies and provide strategies for management intervention. Perinatal and infant mortality due to trauma is another area of significant early mortality; modifications in housing arrangement and cage design that could reduce these losses would be worth investigating.

Ulcers in infants and juveniles were considered a result of HPV2 infection. Strategies to reduce the prevalence of HPV2 in the colony would presumably return significant improvements in infant, juvenile, and adult mortality. Recently, genital Alphapapillomaviruses in baboons were documented in association with cervical lesions[7] with speculation on potential to be involved in other lesions, specifically squamous cell carcinoma of the perineal area in female baboons. As the baboon colony in this report has not been tested for the presence of Alphapapillomaviruses, research to determine if some of the lesions attributed to HPV2 are due to Alphapapillomaviruses or a combination of both viruses is needed.

Although bacterial colitis due to known pathogenic bacteria was seen, many cases were of undetermined etiology. Research into colitis of undetermined etiology could provide significant reductions in juvenile and adult mortality. *Histoplasmosis capsulatum var. duboisii* is endemic in the colony. Although eradication efforts based on removal of infected individuals have been underway for a few years, the long incubation period and sporadic nature of the disease makes assessment of progress to date unclear. The majority of mortality in aged and geriatric animals is a result of degenerative and neoplastic/proliferative disease; continued research in the areas of arthritis, spondylosis, neoplasia and diabetes will not only benefit humans, but the care of the baboon population as well.

Although the skewed population of the overall colony and the individual age groups made statistical identification of gender differences in causes of mortality difficult, it was possible to identify some conditions influenced by gender. Adult males were more likely to have mortality due to air sacculitis and pneumonia; aged males were more likely to have mortality due to periodontal disease and spinal cord degeneration. It is not clear why mortality related to periodontal disease was significant in adult males in this study as gender has not previously been found to be significant in periodontal disease[48]. Adult males were also more likely to have mortality involving the respiratory or nervous systems, or arising from a bacterial etiology.

The findings of gender differences in mortality related to the musculoskeletal system in adult baboons and the more frequent mortality attributed to degenerative etiologies in aged females is interesting in light of a recent report describing sex differences in osteoarthritis prevalence and sex progression in baboons[42]. They reported that incidence and severity of osteoarthritis in younger animals (under 17 years old) was higher in males[42]. In baboons over 17 years of age, although the incidence is similar, female baboons have more severe lesions[42]. Although the separation in our study between adult and aged baboons was at 15

years of age, our findings are consistent with theirs. The difference in adult mortality in our study appears to be primarily a result of fractures, although of the nine adult animals euthanized for arthritis, six were male, consistent with earlier onset or severity in males. However in the aged baboons, there was a marked difference with female animals more likely to be euthanized for spondylosis and arthritis.

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Table 1

Total number of animals by age-group and sex (undetermined causes not included; n = 402).

Age group	Total	Female	Male	Unknown
Perinatal	800	346	385	69
Infant	710	318	377	15
Juvenile	816	421	395	0
Adult	1059	717	342	0
Aged	872	649	223	0
Geriatric	93	88	5	0
All	4350	2539	1727	84

Table 2

Causes of mortality in all baboons by sex and age (undetermined causes not included; n = 402).

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Stillborn	468	10.76	468	0	199	220	49	0.00	0.00	0.00	0.00	0.00	0.00
Colitis	372	8.55	133	239	224	148	0	5.26	5.79	2.56	4.22	4.19	5.38
Hemorrhage	365	8.39	324	41	177	176	12	1.36	3.70	0.60	2.68	0.95	3.20
Ulcer	224	5.15	89	135	129	95	0	7.82	7.47	1.51	2.06	5.14	6.60
Seizures	205	4.71	28	177	98	107	0	7.92	5.97	5.34	4.14	6.57	5.24
Pneumonia	184	4.23	125	59	72	111	1	4.39	6.63	4.23	6.20	4.27	6.34
Inanition	179	4.11	165	14	85	89	5	0.86	2.76	0.19	0.54	0.50	1.96
Dermatitis	165	3.79	7	158	126	39	0	8.87	5.46	6.51	4.73	8.32	5.38
Spondylosis	142	3.26	0	142	92	50	0	23.24	4.01	20.21	3.75	22.17	4.17
Amyloidosis	130	2.99	18	112	99	31	0	15.49	5.79	13.43	5.46	15.00	5.76
Fracture	116	2.67	61	55	65	50	1	3.63	6.54	2.33	4.29	3.04	5.67
Lymphosarcoma	116	2.67	13	103	81	35	0	12.87	6.43	11.62	5.31	12.49	6.11
Hypothermia	101	2.32	97	4	73	26	2	7.49	8.66	2.66	6.44	6.10	8.35
Laceration	97	2.23	37	60	57	38	2	7.91	6.49	4.24	3.84	6.32	5.85
Trichobezoar	92	2.11	40	52	70	22	0	10.53	5.58	7.47	3.60	9.80	5.32
Arthritis	88	2.02	0	88	56	32	0	23.15	5.77	18.72	4.69	21.54	5.78
Myocarditis	81	1.86	73	8	48	33	0	11.23	8.15	7.29	6.69	9.62	7.79
Endometriosis	72	1.66	1	71	72	0	0	18.99	4.49	N/A	N/A	18.99	4.49
Stricture	60	1.38	3	57	59	1	0	12.29	5.14	5.75	N/A	12.18	5.17
Meningoencephalitis	59	1.36	17	42	25	34	0	9.76	8.09	6.97	7.98	8.15	8.08
Typhlitis	47	1.08	16	31	32	15	0	18.07	5.21	12.21	6.65	16.20	6.27
Dilitation	44	1.01	43	1	30	14	0	8.38	8.23	4.73	7.00	7.22	7.97
Entanglement	44	1.01	44	0	27	17	0	1.87	2.20	2.22	2.04	2.01	2.13
Adenocarcinoma	38	0.87	4	34	35	3	0	22.06	4.95	20.33	0.55	21.92	4.77
Dystocia	38	0.87	20	18	35	1	2	10.69	5.29	0.00	N/A	9.84	5.85
Pyelonephritis	36	0.83	5	31	28	8	0	15.28	6.30	10.50	5.36	14.22	6.36
Blind	34	0.78	0	34	15	19	0	3.54	7.26	1.79	4.05	2.56	5.66

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Septicemia	30	0.69	20	10	12	17	1	11.38	9.03	4.28	4.88	6.99	7.61
Intussusception	28	0.64	10	18	22	6	0	8.14	6.25	8.28	6.97	8.17	6.27
Atelectasis	26	0.60	25	1	9	14	3	0.00	0.00	0.03	0.07	0.02	0.05
Cellulitis	26	0.60	6	20	20	6	0	13.43	9.34	6.20	7.28	11.76	9.30
Anomaly	22	0.51	13	9	9	13	0	0.53	1.03	0.28	0.30	0.38	0.69
Nephritis / Glomerulonephritis	22	0.51	3	19	17	5	0	17.72	8.06	12.10	5.00	16.44	7.75
Periodontal disease	22	0.51	0	22	1	21	0	11.83	N/A	17.71	5.43	17.44	5.45
Peritonitis	22	0.51	10	12	12	9	1	13.79	8.11	11.25	8.18	12.12	8.30
Prolapse	22	0.51	4	18	15	7	0	11.06	7.11	6.18	6.14	9.50	7.06
Abscess	21	0.48	10	11	12	9	0	11.55	9.53	8.28	4.60	10.15	7.82
Foreign body	20	0.46	7	13	8	12	0	12.90	9.23	9.86	4.66	11.07	6.80
Air sacculitis	18	0.41	5	13	1	17	0	6.42	N/A	13.44	5.28	13.05	5.38
Meningitis	16	0.37	9	7	4	12	0	8.98	9.66	7.37	6.91	7.77	7.36
Hyperthermia	15	0.34	13	2	10	5	0	9.72	8.34	8.67	4.48	9.37	7.12
Anesthetic death	14	0.32	12	2	10	4	0	10.77	6.65	12.77	6.99	11.34	6.54
Esophagitis	14	0.32	9	5	10	4	0	5.08	4.89	3.77	6.45	4.71	5.15
Metritis	14	0.32	4	10	14	0	0	12.66	4.45	N/A	N/A	12.66	4.45
Fibrosis	13	0.30	8	5	7	6	0	12.26	7.95	14.87	6.57	13.46	7.17
Hyperplasia	12	0.28	2	10	8	4	0	12.49	7.05	7.71	2.25	10.90	6.21
Necrosis	12	0.28	7	5	6	6	0	11.25	7.52	1.46	2.93	6.36	7.46
Placentitis	12	0.28	11	1	5	5	2	0.00	0.00	0.00	0.00	0.00	0.00
Enterocolitis	11	0.25	7	4	5	6	0	2.32	2.53	0.63	0.57	1.40	1.87
Phytobezoar	11	0.25	2	9	8	3	0	12.76	7.11	11.14	6.72	12.32	6.70
Adenomyosis	10	0.23	0	10	10	0	0	22.26	4.36	N/A	N/A	22.26	4.36
Carcinoma	10	0.23	2	8	10	0	0	19.16	7.85	N/A	N/A	19.16	7.85
Degeneration	10	0.23	1	9	2	8	0	13.13	18.45	17.98	2.81	17.01	6.94
Edema	10	0.23	6	4	5	5	0	11.83	9.26	5.75	4.53	8.79	7.58
Hernia	10	0.23	3	7	4	6	0	11.04	9.28	11.17	7.48	11.12	7.73
Placenta abruptio	10	0.23	10	0	2	5	3	0.00	0.00	0.00	0.00	0.00	0.00
Cystitis	9	0.21	6	3	3	6	0	13.64	3.83	9.13	4.61	10.63	4.70

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Encephalitis	9	0.21	3	6	4	5	0	14.25	10.60	6.59	6.79	10.00	9.03
Emaciation	8	0.18	0	8	7	1	0	12.73	10.24	4.83	N/A	11.74	9.88
Squamous Cell Carcinoma	8	0.18	1	7	8	0	0	20.06	8.15	N/A	N/A	20.06	8.15
Adenoma	7	0.16	0	7	4	3	0	26.21	2.24	16.08	3.95	21.87	6.08
Hydrocephalus	7	0.16	3	4	3	4	0	0.70	1.13	2.91	2.03	1.96	1.97
Asphyxiation	6	0.14	6	0	3	3	0	1.67	1.09	0.72	0.18	1.20	0.87
Cholelithiasis	6	0.14	0	6	4	2	0	18.25	2.80	14.54	3.24	17.01	3.24
Endocardiosis	6	0.14	2	4	4	2	0	15.23	10.52	7.88	10.90	12.78	10.22
Infarct	6	0.14	2	4	4	2	0	17.75	7.23	7.79	11.02	14.43	9.06
Myxoma	6	0.14	0	6	6	0	0	17.99	5.86	N/A	N/A	17.99	5.86
Amputation	5	0.11	1	4	3	2	0	0.59	0.54	3.88	5.48	1.90	3.30
Cardiomyopathy	5	0.11	3	2	0	5	0	N/A	N/A	13.65	6.24	13.65	6.24
Cataract	5	0.11	0	5	4	1	0	18.42	14.86	1.92	N/A	15.12	14.84
Cholangiohepatitis	5	0.11	0	5	2	3	0	17.21	10.08	5.61	5.28	10.25	8.92
Enteritis	5	0.11	3	2	3	2	0	9.89	6.90	0.75	0.95	6.23	7.01
Hepatitis	5	0.11	3	2	5	0	0	15.41	10.24	N/A	N/A	15.41	10.24
Nephrosis	5	0.11	2	3	5	0	0	13.52	5.52	N/A	N/A	13.52	5.52
Torsion	5	0.11	4	1	3	2	0	9.39	13.35	3.75	0.24	7.13	9.93
Arthrogryposis	4	0.09	0	4	2	2	0	0.06	0.03	0.14	0.16	0.10	0.10
Hypospadia	4	0.09	0	4	0	4	0	N/A	N/A	2.65	2.35	2.65	2.35
Impaction	4	0.09	1	3	4	0	0	16.29	7.56	N/A	N/A	16.29	7.56
Kyphosis	4	0.09	0	4	4	0	0	9.13	10.26	N/A	N/A	9.13	10.26
Neuroendocrine carcinoma	4	0.09	1	3	4	0	0	20.27	6.93	N/A	N/A	20.27	6.93
Obstruction	4	0.09	2	2	0	4	0	N/A	N/A	5.19	5.28	5.19	5.28
Osteomyelitis	4	0.09	0	4	2	2	0	15.59	5.07	5.46	6.42	10.52	7.52
Cyst	3	0.07	0	3	3	0	0	14.58	5.21	N/A	N/A	14.58	5.21
Fibrosarcoma	3	0.07	0	3	0	3	0	N/A	N/A	11.14	1.31	11.14	1.31
Fistula	3	0.07	0	3	1	2	0	17.83	N/A	19.63	0.29	19.03	1.06
Glioblastoma multiforme	3	0.07	1	2	1	2	0	24.42	N/A	11.46	1.12	15.78	7.52
Malignant neoplasm	3	0.07	2	1	1	2	0	14.67	N/A	9.54	12.43	11.25	9.28

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Orchitis	3	0.07	1	2	0	3	0	N/A	N/A	7.61	3.48	7.61	3.48
Osteosarcoma	3	0.07	0	3	3	0	0	10.08	3.57	N/A	N/A	10.08	3.57
Pancreatitis	3	0.07	2	1	2	1	0	9.38	0.53	16.58	N/A	11.78	4.18
Sarcoma	3	0.07	0	3	0	3	0	N/A	N/A	6.67	3.98	6.67	3.98
Thrombus	3	0.07	1	2	2	1	0	16.71	7.37	8.75	N/A	14.06	6.95
Adhesions	2	0.05	0	2	1	1	0	4.33	N/A	20.00	N/A	12.17	11.08
Burn	2	0.05	1	1	1	1	0	7.92	N/A	0.02	N/A	3.97	5.59
Ectopic pregnancy	2	0.05	0	2	2	0	0	11.50	4.48	N/A	N/A	11.50	4.48
Endocarditis	2	0.05	1	1	1	1	0	2.00	N/A	18.00	N/A	10.00	11.31
Gastritis	2	0.05	0	2	2	0	0	12.71	1.24	N/A	N/A	12.71	1.24
Granulosa cell tumor	2	0.05	0	2	2	0	0	19.29	4.54	N/A	N/A	19.29	4.54
Hypoplasia	2	0.05	0	2	2	0	0	9.33	3.54	N/A	N/A	9.33	3.54
Lipoma	2	0.05	0	2	2	0	0	17.04	13.49	N/A	N/A	17.04	13.49
Lymphadenitis	2	0.05	0	2	2	0	0	15.29	7.37	N/A	N/A	15.29	7.37
Mastitis	2	0.05	0	2	2	0	0	19.25	0.11	N/A	N/A	19.25	0.11
Megacolon	2	0.05	0	2	2	0	0	23.17	1.53	N/A	N/A	23.17	1.53
Myositis	2	0.05	1	1	2	0	0	17.84	1.18	N/A	N/A	17.84	1.18
Nephroblastoma	2	0.05	0	2	1	1	0	0.83	N/A	0.17	N/A	0.50	0.47
Omphalitis	2	0.05	2	0	1	1	0	0.00	N/A	0.01	N/A	0.01	0.01
Otitis Externa	2	0.05	0	2	0	2	0	N/A	N/A	14.07	4.50	14.07	4.50
Pericarditis	2	0.05	2	0	1	1	0	8.58	N/A	0.25	N/A	4.42	5.89
Polyp	2	0.05	0	2	2	0	0	29.33	3.54	N/A	N/A	29.33	3.54
Porencephaly	2	0.05	1	1	1	1	0	1.33	N/A	0.17	N/A	0.75	0.82
Retention	2	0.05	1	1	2	0	0	15.69	4.57	N/A	N/A	15.69	4.57
Rhinitis	2	0.05	0	2	2	0	0	17.42	9.55	N/A	N/A	17.42	9.55
Sperm granuloma	2	0.05	0	2	0	2	0	N/A	N/A	16.88	1.59	16.88	1.59
Tetanus	2	0.05	0	2	2	0	0	9.88	4.77	N/A	N/A	9.88	4.77
Vaginitis	2	0.05	0	2	2	0	0	21.00	1.77	N/A	N/A	21.00	1.77
Alopecia	1	0.02	0	1	1	0	0	7.50	N/A	N/A	N/A	7.50	N/A
Anemia	1	0.02	0	1	1	0	0	21.33	N/A	N/A	N/A	21.33	N/A

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Arteritis	1	0.02	0	1	0	1	0	N/A	N/A	11.42	N/A	11.42	N/A
Atony	1	0.02	0	1	0	1	0	N/A	N/A	3.67	N/A	3.67	N/A
Atrophy	1	0.02	0	1	1	0	0	18.08	N/A	N/A	N/A	18.08	N/A
Bronchioalveolar Carcinoma	1	0.02	1	0	1	0	0	13.00	N/A	N/A	N/A	13.00	N/A
Cardiomegaly	1	0.02	0	1	0	1	0	N/A	N/A	24.50	N/A	24.50	N/A
Cholangiocellular carcinoma	1	0.02	0	1	1	0	0	23.83	N/A	N/A	N/A	23.83	N/A
Congestion	1	0.02	1	0	1	0	0	20.58	N/A	N/A	N/A	20.58	N/A
Conjunctivitis	1	0.02	0	1	0	1	0	N/A	N/A	8.92	N/A	8.92	N/A
Dehydration	1	0.02	1	0	1	0	0	3.50	N/A	N/A	N/A	3.50	N/A
Dislocation	1	0.02	0	1	0	1	0	N/A	N/A	0.08	N/A	0.08	N/A
Dysgerminoma	1	0.02	0	1	1	0	0	22.92	N/A	N/A	N/A	22.92	N/A
Electrocution	1	0.02	1	0	1	0	0	3.42	N/A	N/A	N/A	3.42	N/A
Emphysema	1	0.02	0	1	0	1	0	N/A	N/A	18.08	N/A	18.08	N/A
Eosinophilic granulomas	1	0.02	0	1	1	0	0	17.58	N/A	N/A	N/A	17.58	N/A
Fibrous osseous proliferation	1	0.02	0	1	0	1	0	N/A	N/A	7.83	N/A	7.83	N/A
Gangrene	1	0.02	0	1	1	0	0	7.17	N/A	N/A	N/A	7.17	N/A
Glossitis	1	0.02	0	1	1	0	0	12.67	N/A	N/A	N/A	12.67	N/A
Granulation tissue	1	0.02	0	1	1	0	0	1.08	N/A	N/A	N/A	1.08	N/A
Granulomas	1	0.02	0	1	1	0	0	12.17	N/A	N/A	N/A	12.17	N/A
Hydroureter	1	0.02	0	1	1	0	0	5.75	N/A	N/A	N/A	5.75	N/A
Leiomyoma	1	0.02	0	1	1	0	0	23.75	N/A	N/A	N/A	23.75	N/A
Leukodystrophy	1	0.02	1	0	1	0	0	0.08	N/A	N/A	N/A	0.08	N/A
Lymphoid Hyperplasia	1	0.02	0	1	0	1	0	N/A	N/A	9.42	N/A	9.42	N/A
Megaesophagus	1	0.02	0	1	1	0	0	20.83	N/A	N/A	N/A	20.83	N/A
Meningioma	1	0.02	0	1	1	0	0	6.83	N/A	N/A	N/A	6.83	N/A
Mesothelioma	1	0.02	1	0	1	0	0	5.42	N/A	N/A	N/A	5.42	N/A
Myelitis	1	0.02	0	1	0	1	0	N/A	N/A	16.00	N/A	16.00	N/A
Myelopathy	1	0.02	0	1	0	1	0	N/A	N/A	8.33	N/A	8.33	N/A
Myopathy	1	0.02	0	1	0	1	0	N/A	N/A	3.17	N/A	3.17	N/A
Neuritis	1	0.02	0	1	1	0	0	18.42	N/A	N/A	N/A	18.42	N/A

	Total							Age, Female		Age, Male		Age, All	
Morphologic Diagnosis	**(n)**	**(%)**	**Died**	**Euthanized**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Neurofibroma	1	0.02	0	1	1	0	0	2.67	N/A	N/A	N/A	2.67	N/A
Ophthalmitis	1	0.02	0	1	1	0	0	25.58	N/A	N/A	N/A	25.58	N/A
Osteoma	1	0.02	0	1	1	0	0	14.42	N/A	N/A	N/A	14.42	N/A
Osteoporosis	1	0.02	0	1	1	0	0	27.00	N/A	N/A	N/A	27.00	N/A
Otitis interna	1	0.02	0	1	1	0	0	17.17	N/A	N/A	N/A	17.17	N/A
Pericholangitis	1	0.02	0	1	1	0	0	28.08	N/A	N/A	N/A	28.08	N/A
Proctitis	1	0.02	1	0	1	0	0	17.00	N/A	N/A	N/A	17.00	N/A
Pyometra	1	0.02	0	1	1	0	0	19.42	N/A	N/A	N/A	19.42	N/A
Rupture	1	0.02	1	0	0	1	0	N/A	N/A	0.25	N/A	0.25	N/A
Scoliosis	1	0.02	0	1	1	0	0	21.90	N/A	N/A	N/A	21.90	N/A
Splenitis	1	0.02	0	1	0	1	0	N/A	N/A	1.08	N/A	1.08	N/A
Spondylitis	1	0.02	0	1	0	1	0	N/A	N/A	14.25	N/A	14.25	N/A
Subinvolution	1	0.02	0	1	1	0	0	13.58	N/A	N/A	N/A	13.58	N/A
Subluxation	1	0.02	1	0	0	1	0	N/A	N/A	3.75	N/A	3.75	N/A
Teratoma	1	0.02	0	1	1	0	0	23.50	N/A	N/A	N/A	23.50	N/A
Tracheitis	1	0.02	0	1	1	0	0	12.50	N/A	N/A	N/A	12.50	N/A
Total	4350	100.00	2118	2232	2539	1727	84	9.22	8.81	4.85	6.79	7.31	8.32

Table 3

Mortality in all baboons by system and organ (undetermined causes not included; n = 402).

	Total						Age, Female		Age, Male		Age, All		
System / Organ	**(n)**	**(%)**	**% System**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**References**
Digestive (Total)	925	21.26	100.00	560	364	1	8.77	8.05	4.87	6.45	7.23	7.70	[8]
Colon	389	8.94	42.05	239	150	0	5.94	6.45	2.60	4.22	4.65	5.92	[3, 13, 15, 47, 60, 64, 67–69]
Stomach	136	3.13	14.70	94	42	0	10.01	6.88	6.77	5.88	9.01	6.74	[47, 62, 63, 70]
Oral cavity	116	2.67	12.54	47	69	0	1.33	2.60	0.70	0.61	0.96	1.74	[45, 47, 48]
Cecum	105	2.41	11.35	81	24	0	16.39	7.30	12.63	6.86	15.53	7.34	[12, 47, 67]
Esophagus	37	0.85	4.00	26	11	0	8.09	6.49	4.92	4.20	7.15	6.02	[22, 47, 61, 65, 66]
Small intestine	27	0.62	2.92	17	10	0	12.73	8.35	5.43	4.55	10.03	7.94	[12, 47]
Peritoneal cavity	25	0.57	2.70	13	11	1	13.06	8.20	11.30	7.18	11.77	7.87	[3, 12, 15, 33]
Rectum	23	0.53	2.49	14	9	0	12.03	7.87	4.82	5.96	9.21	7.90	[12, 60]
Gingiva	22	0.51	2.38	1	21	0	11.83	N/A	17.71	5.43	17.44	5.45	
Liver	14	0.32	1.51	10	4	0	17.30	9.17	4.21	5.14	13.56	10.10	[1, 62]
Intestine	11	0.25	1.19	5	6	0	2.32	2.53	0.63	0.57	1.40	1.87	
Gall bladder	8	0.18	0.86	6	2	0	15.56	7.97	14.54	3.24	15.31	6.86	[77]
Pancreas	4	0.09	0.43	3	1	0	6.92	4.27	16.58	N/A	9.33	5.96	[12, 25, 26, 34]
Tongue	3	0.07	0.32	2	1	0	11.09	2.24	15.75	N/A	12.64	3.13	[45]
Salivary gland	2	0.05	0.22	2	0	0	32.13	7.60	N/A	N/A	32.13	7.60	
Tooth	2	0.05	0.22	0	2	0	N/A	N/A	8.71	1.71	8.71	1.71	
Epiglottis	1	0.02	0.11	0	1	0	N/A	N/A	0.67	N/A	0.67	N/A	
Urogenital (Total)	883	20.30	100.00	534	293	56	9.06	8.94	1.51	3.86	5.98	8.24	[8]
Multisystem	474	10.90	53.68	202	221	51	0.00	0.00	0.00	0.00	0.00	0.00	
Kidney	76	1.75	8.61	59	17	0	15.75	7.24	11.46	5.79	14.79	7.14	[12, 23, 84]
Peritoneal cavity	73	1.68	8.27	73	0	0	18.92	4.53	N/A	N/A	18.92	4.53	
Vagina	64	1.47	7.25	64	0	0	12.80	4.84	N/A	N/A	12.80	4.84	[12, 45, 75]
Uterus	60	1.38	6.80	60	0	0	14.65	6.41	N/A	N/A	14.65	6.41	[4, 6, 9, 12, 15, 24, 73, 74]
Vulva	51	1.17	5.78	51	0	0	11.33	7.22	N/A	N/A	11.33	7.22	[76]
Penis	30	0.69	3.40	0	30	0	N/A	N/A	3.86	2.82	3.86	2.82	[84]
Placenta	25	0.57	2.83	10	10	5	4.50	7.42	0.00	0.00	1.80	5.07	[33, 71]

	Total						Age, Female		Age, Male		Age, All		
System / Organ	**(n)**	**(%)**	**% System**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**References**
Urinary Bladder	9	0.21	1.02	3	6	0	13.64	3.83	9.13	4.61	10.63	4.70	[15, 84]
Ovary	6	0.14	0.68	6	0	0	16.51	8.82	N/A	N/A	16.51	8.82	[12, 15, 51, 52]
Urethra	4	0.09	0.45	0	4	0	N/A	N/A	5.19	5.28	5.19	5.28	[84]
Testicle	3	0.07	0.34	0	3	0	N/A	N/A	7.61	3.48	7.61	3.48	[12, 84]
Entire female tract	2	0.05	0.23	2	0	0	9.33	3.54	N/A	N/A	9.33	3.54	
Epididymis	2	0.05	0.23	0	2	0	N/A	N/A	16.88	1.59	16.88	1.59	
Fallopian tube	2	0.05	0.23	2	0	0	24.80	0.18	N/A	N/A	24.80	0.18	[15]
Umbilical cord	2	0.05	0.23	2	0	0	0.00	0.00	N/A	N/A	0.00	0.00	
Cardiovascular (Total)	532	12.23	100.00	265	254	13	4.58	7.34	2.73	5.59	3.58	6.55	[8]
Heart	120	2.76	22.56	66	54	0	11.03	8.35	8.82	7.69	10.04	8.10	[2, 33, 50, 88]
Multisystem	104	2.39	19.55	51	49	4	1.43	3.42	0.04	0.10	0.72	2.48	
Brain	76	1.75	14.29	38	37	1	1.91	5.88	0.61	2.69	1.26	4.58	
Meninges	57	1.31	10.71	30	24	3	0.05	0.14	0.08	0.18	0.06	0.15	
Head	53	1.22	9.96	26	24	3	1.21	3.15	1.17	3.28	1.12	3.10	
Blood	31	0.71	5.83	13	17	1	10.77	8.91	4.28	4.88	6.87	7.51	
Lung	21	0.48	3.95	6	15	0	2.07	3.18	0.05	0.11	0.63	1.85	
Peritoneal cavity	12	0.28	2.26	5	7	0	0.05	0.11	0.05	0.09	0.05	0.10	
Subcutis	10	0.23	1.88	6	4	0	0.20	0.43	0.00	0.00	0.12	0.34	
Skin	8	0.18	1.50	7	1	0	5.42	4.66	0.17	N/A	4.76	4.70	
Aorta	7	0.16	1.32	3	4	0	0.33	0.09	3.11	5.54	1.92	4.19	
Skeletal Muscle	6	0.14	1.13	2	4	0	7.80	10.78	5.82	9.92	6.48	9.13	
Uterus	4	0.09	0.75	4	0	0	16.13	4.58	N/A	N/A	16.13	4.58	
Liver	3	0.07	0.56	0	3	0	N/A	N/A	0.03	0.04	0.03	0.04	
Thoracic cavity	3	0.07	0.56	2	1	0	0.17	0.12	0.01	N/A	0.11	0.12	
Umbilicus	3	0.07	0.56	1	1	1	0.00	N/A	0.00	N/A	0.03	0.05	
Artery, femoral	2	0.05	0.38	1	1	0	11.50	N/A	8.75	N/A	10.13	1.94	
Leg	2	0.05	0.38	1	1	0	0.33	N/A	2.08	N/A	1.21	1.24	
Skull	2	0.05	0.38	1	1	0	0.00	N/A	0.33	N/A	0.17	0.23	
Spinal cord	2	0.05	0.38	1	1	0	0.08	N/A	1.17	N/A	0.63	0.77	
Vein	2	0.05	0.38	1	1	0	21.92	N/A	17.25	N/A	19.59	3.30	

	Total						Age, Female		Age, Male		Age, All		
System / Organ	**(n)**	**(%)**	**% System**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**References**
Eye	1	0.02	0.19	0	1	0	N/A	N/A	0.58	N/A	0.58	N/A	
Gall bladder	1	0.02	0.19	0	1	0	N/A	N/A	5.75	N/A	5.75	N/A	
Jejunum	1	0.02	0.19	0	1	0	N/A	N/A	15.58	N/A	15.58	N/A	
Placenta	1	0.02	0.19	0	1	0	N/A	N/A	0.00	N/A	0.00	N/A	
Multisystem (Total)	448	10.30	100.00	271	170	7	6.52	7.72	3.28	5.79	5.19	7.18	[8, 53]
Musculoskeletal (Total)	411	9.45	100.00	247	163	1	16.38	10.49	11.79	9.24	14.52	10.26	[8]
Bone	281	6.46	68.37	171	109	1	14.96	10.82	10.82	9.66	13.30	10.57	[12, 29, 50, 55]
Joint	93	2.14	22.63	58	35	0	22.35	7.08	17.23	6.68	20.43	7.34	[42]
Skeletal Muscle	28	0.64	6.81	12	16	0	13.43	8.20	7.93	6.31	10.29	7.56	[12]
Arm	3	0.07	0.73	2	1	0	9.38	12.31	12.17	N/A	10.31	8.85	
Leg	3	0.07	0.73	2	1	0	0.17	0.23	0.01	N/A	0.12	0.18	
Peritoneal cavity	1	0.02	0.24	1	0	0	10.00	N/A	N/A	N/A	10.00	N/A	
Shoulder	1	0.02	0.24	0	1	0	N/A	N/A	0.08	N/A	0.08	N/A	
Tail	1	0.02	0.24	1	0	0	1.08	N/A	N/A	N/A	1.08	N/A	
Integumentary (Total)	353	8.11	100.00	262	89	2	10.24	7.00	5.84	5.16	9.07	6.86	[8]
Skin	258	5.93	73.09	186	70	2	8.85	6.10	5.16	4.46	7.78	5.94	[12, 20, 27, 30, 31, 43, 54]
Subcutis	40	0.92	11.33	29	11	0	12.80	9.14	7.88	7.11	11.44	8.83	
Sex skin	39	0.90	11.05	39	0	0	14.47	6.47	N/A	N/A	14.47	6.47	
Mammary Gland	5	0.11	1.42	5	0	0	19.67	2.71	N/A	N/A	19.67	2.71	[12, 40]
Scrotum	5	0.11	1.42	0	5	0	N/A	N/A	9.50	5.83	9.50	5.83	
Eyelid	3	0.07	0.85	2	1	0	2.21	2.88	18.17	N/A	7.53	9.44	
Umbilicus	2	0.05	0.57	1	1	0	0.00	N/A	0.01	N/A	0.01	0.01	
Ear	1	0.02	0.28	0	1	0	N/A	N/A	5.92	N/A	5.92	N/A	
Nervous (Total)	318	7.31	100.00	144	174	0	8.39	6.83	6.17	5.69	7.17	6.32	[8]
Brain	291	6.69	91.51	137	154	0	8.24	6.76	5.70	5.33	6.89	6.16	[12, 37, 39, 57, 79–81]
Meninges	17	0.39	5.35	5	12	0	8.55	8.42	7.37	6.91	7.71	7.13	[37, 39]
Spinal cord	8	0.18	2.52	0	8	0	N/A	N/A	13.44	6.11	13.44	6.11	[37, 39]
Ear	1	0.02	0.31	1	0	0	17.17	N/A	N/A	N/A	17.17	N/A	
Nerve	1	0.02	0.31	1	0	0	18.42	N/A	N/A	N/A	18.42	N/A	
Respiratory (Total)	259	5.95	100.00	102	153	4	5.36	7.40	5.00	6.61	5.06	6.90	[8]

	Total						Age, Female		Age, Male		Age, All		
System / Organ	**(n)**	**(%)**	**% System**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**References**
Lung	226	5.20	87.26	90	132	4	4.84	7.04	4.00	6.06	4.26	6.44	[5, 11, 12, 16, 32, 35, 44]
Air sac	18	0.41	6.95	1	17	0	6.42	N/A	13.44	5.28	13.05	5.38	[38]
Multisystem	6	0.14	2.32	3	3	0	1.67	1.09	0.72	0.18	1.20	0.87	
Nasal cavity	4	0.09	1.54	3	1	0	20.20	8.29	5.75	N/A	16.59	9.90	[12]
Thoracic cavity	3	0.07	1.16	3	0	0	2.86	2.27	N/A	N/A	2.86	2.27	
Trachea	2	0.05	0.77	2	0	0	15.25	3.89	N/A	N/A	15.25	3.89	
Hematopoetic/Lymphatic (Total)	123	2.83	100.00	86	37	0	12.94	6.46	11.22	5.48	12.43	6.21	[8]
Multisystem	105	2.41	85.37	75	30	0	12.78	6.23	12.09	5.21	12.58	5.94	
Lung	7	0.16	5.69	4	3	0	8.63	4.56	8.94	7.92	8.76	5.60	
Lymph node	4	0.09	3.25	3	1	0	15.47	5.22	7.42	N/A	13.46	5.86	[3, 13, 32, 44]
Spleen	2	0.05	1.63	1	1	0	3.00	N/A	1.08	N/A	2.04	1.36	[12, 32]
Blood	1	0.02	0.81	1	0	0	21.33	N/A	N/A	N/A	21.33	N/A	[20]
Cecum	1	0.02	0.81	1	0	0	27.17	N/A	N/A	N/A	27.17	N/A	
Colon	1	0.02	0.81	1	0	0	22.33	N/A	N/A	N/A	22.33	N/A	
Kidney	1	0.02	0.81	0	1	0	N/A	N/A	8.50	N/A	8.50	N/A	
Skin	1	0.02	0.81	0	1	0	N/A	N/A	8.67	N/A	8.67	N/A	
Endocrine (Total)	53	1.22	100.00	48	5	0	19.36	5.53	19.16	3.14	19.34	5.33	[8, 12, 26, 52]
Islets of Langerhans	43	0.99	81.13	40	3	0	18.85	5.52	20.25	2.45	18.95	5.36	[12, 25, 34]
Pituitary gland	3	0.07	5.66	1	2	0	22.92	N/A	17.54	4.30	19.33	4.35	[12]
Thyroid	3	0.07	5.66	3	0	0	23.75	3.05	N/A	N/A	23.75	3.05	[12]
Multisystem	2	0.05	3.77	2	0	0	15.72	5.72	N/A	N/A	15.72	5.72	
Liver	1	0.02	1.89	1	0	0	28.58	N/A	N/A	N/A	28.58	N/A	
Peritoneal cavity	1	0.02	1.89	0	1	0	N/A	N/A	21.17	N/A	21.17	N/A	
Thoracic cavity	1	0.02	1.89	1	0	0	21.08	N/A	N/A	N/A	21.08	N/A	
Special Senses (Total)	44	1.01	100.00	20	24	0	7.62	11.33	4.04	6.72	5.67	9.17	[8]
Eye	42	0.97	95.45	20	22	0	7.62	11.33	3.13	6.17	5.27	9.17	
Ear	2	0.05	4.55	0	2	0	N/A	N/A	14.07	4.50	14.07	4.50	

Table 4

Causes of mortality in all baboons by etiology (undetermined causes not included; n = 402).

	Total					Age, Female		Age, Male		Age, All		
Etiology	**(n)**	**(%)**	**Female**	**Male**	**Unknown**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**References**
Undetermined	1425	32.76	754	621	50	6.97	8.10	3.69	5.52	5.30	7.18	
Trauma	645	14.83	344	286	15	3.32	5.67	1.55	3.50	2.46	4.84	
Degenerative	413	9.49	263	150	0	19.89	6.73	17.73	5.43	19.10	6.37	[25, 34, 42, 56, 78]
Viral	376	8.64	234	142	0	9.20	7.10	3.32	5.16	6.98	7.04	[11, 17, 33, 38, 39, 45, 76]
Neoplastic/Proliferative	303	6.97	251	52	0	17.48	6.94	11.76	5.74	16.50	7.08	[1, 6, 12, 16, 23, 27, 32, 40, 57, 60, 69]
Bacterial	255	5.86	113	140	2	8.68	8.10	4.89	5.86	6.52	7.18	[38]
Physical	237	5.45	149	78	10	9.15	7.41	3.01	5.46	6.74	7.37	[22, 71]
Nutritional	187	4.30	92	90	5	1.76	4.89	0.24	0.72	0.98	3.54	
Foreign body	156	3.59	97	59	0	10.14	6.55	6.78	5.65	8.87	6.42	[47]
Mycotic	143	3.29	110	33	0	8.11	4.33	7.39	4.45	7.95	4.35	[10, 31]
Environmental	118	2.71	84	32	2	7.67	8.59	3.52	6.43	6.42	8.21	
Congenital	52	1.20	26	26	0	1.47	2.86	0.83	1.40	1.15	2.25	[19, 29, 50, 52]
Iatrogenic	32	0.74	16	16	0	8.41	6.46	11.13	8.00	9.77	7.29	
Toxic	5	0.11	3	2	0	0.42	0.08	0.50	0.00	0.45	0.07	[20, 43, 54]
Parasitic	3	0.07	3	0	0	11.97	1.46	N/A	N/A	11.97	1.46	[2, 5, 24, 53, 88]
Total	4350	100.00	2539	1727	84	9.22	8.81	4.85	6.79	7.31	8.32	

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Table 5

The ten most common morphologic diagnoses by age group.

Perinatal			**Infant**			**Juvenile**		
Morphologic Diagnosis	**(n)**	**(%)**	**Morphologic Diagnosis**	**(n)**	**(%)**	**Morphologic Diagnosis**	**(n)**	**(%)**
Stillborn	468	58.50	Hemorrhage	149	20.99	Colitis	220	26.96
Hemorrhage	173	21.63	Inanition	124	17.46	Seizures	80	9.80
Inanition	32	4.00	Ulcer	75	10.56	Ulcer	76	9.31
Fracture	23	2.88	Pneumonia	74	10.42	Pneumonia	41	5.02
Atelectasis	19	2.38	Colitis	52	7.32	Entanglement	31	3.80
Hypothermia	17	2.13	Fracture	51	7.18	Dermatitis	30	3.68
Pneumonia	16	2.00	Hypothermia	28	3.94	Myocarditis	29	3.55
Placentitis	12	1.50	Laceration	22	3.10	Meningoencephalitis	21	2.57
Placenta abruptio	10	1.25	Seizures	15	2.11	Blind	20	2.45
Dystocia	6	0.75	Anomaly	14	1.97	Hypothermia	20	2.45
Total	800	100.00	Total	710	100.00	Total	816	100.00
Adult			**Aged**			**Geriatric**		
Morphologic Diagnosis	**(n)**	**(%)**	**Morphologic Diagnosis**	**(n)**	**(%)**	**Morphologic Diagnosis**	**(n)**	**(%)**
Dermatitis	109	10.29	Spondylosis	117	13.42	Spondylosis	21	22.58
Seizures	92	8.69	Arthritis	60	6.88	Arthritis	18	19.35
Colitis	76	7.18	Endometriosis	59	6.77	Adenocarcinoma	7	7.53
Lymphosarcoma	65	6.14	Amyloidosis	57	6.54	Amyloidosis	5	5.38
Amyloidosis	64	6.04	Lymphosarcoma	41	4.70	Endometriosis	4	4.30
Trichobezoar	60	5.67	Typhlitis	30	3.44	Adenoma	3	3.23
Laceration	49	4.63	Adenocarcinoma	29	3.33	Dermatitis	3	3.23
Ulcer	47	4.44	Ulcer	24	2.75	Adenomyosis	2	2.15
Pneumonia	35	3.31	Stricture	22	2.52	Cataract	2	2.15
Stricture	34	3.21	Colitis	21	2.41	Cellulitis	2	2.15
Total	1059	100.00	Total	872	100.00	Total	93	100.00

Table 6

Percentage of mortalities in each age group by system (undetermined causes not included; n = 402).

System	Perinatal	Infant	Juvenile	Adult	Aged	Geriatric
Cardiovascular	22.13	24.08	7.11	7.27	5.28	3.23
Digestive	0.63	20.56	42.89	22.29	19.84	16.13
Endocrine	0.00	0.00	0.12	0.94	4.13	6.45
Foreign Body	0.00	0.00	0.00	0.00	0.11	0.00
Hematopoetic/Lymphatic	0.00	0.00	1.23	6.33	5.05	2.15
Integumentary	0.75	5.21	6.00	18.04	7.22	7.53
Musculoskeletal	3.38	8.87	3.31	5.10	22.94	43.01
Nervous	0.00	5.21	13.60	11.33	5.62	1.08
Respiratory	4.38	11.41	6.50	5.38	3.67	1.08
Special Senses	0.13	1.41	2.70	0.28	0.69	2.15
Urogenital	62.38	0.14	6.37	14.83	18.35	15.05
Multisystem	6.25	23.10	10.17	8.22	7.11	2.15
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 7

Percentage of mortalities in each age group by etiology (undetermined causes (n = 402) and undetermined etiology (n = 1425) not included).

Etiology	Perinatal	Infant	Juvenile	Adult	Aged	Geriatric
Bacterial	3.45	9.93	14.96	9.42	6.35	1.28
Congenital	2.01	4.45	3.21	0.53	0	0
Degenerative	0	0.17	2.14	11.41	38.53	62.82
Environmental	4.89	5.31	5.13	2.92	3.32	1.28
Foreign body	2.30	1.54	5.77	10.74	4.47	0.00
Iatrogenic	0.00	0.17	2.14	1.19	1.73	0.00
Mycotic	0.00	0.00	6.62	13.13	1.73	0.00
Neoplastic/Proliferative	0.00	0.17	3.21	12.73	24.24	29.49
Nutritional	9.20	21.40	4.70	0.27	0.87	0.00
Parasitic	0.00	0.00	0.00	0.40	0.00	0.00
Physical	19.54	2.40	9.40	9.42	5.48	2.56
Toxic	0.00	0.86	0.00	0.00	0.00	0.00
Trauma	58.05	40.41	17.09	13.40	3.61	1.28
Viral	0.57	13.18	25.64	14.46	9.67	1.28
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 8

Morphologic diagnoses, systems and organs excluded from evaluation for association with sex.

Morphologic Diagnosis
Adenomyosis
Dysgerminoma
Dystocia
Ectopic pregnancy
Endometriosis
Granulosa cell tumor
Hydroureter
Hypospadia
Mastitis
Metritis
Orchitis
Pyometra
Retention
Sperm granuloma
Stricture
Subinvolution
Vaginitis
System
Urogenital
Organ
Entire female tract
Epididymis
Fallopian tube
Ovary
Penis
Scrotum
Sex skin
Testicle
Uterus
Uterus
Vagina
Vulva

Table 9

Morphologic diagnoses, etiologies, and systems that have a significant association with sex.

Males	Age group	p value	risk	(n)
Morphologic Diagnosis				
Degeneration	Aged	1.66E-05	Infinite	8
Periodontal disease	Aged	5.36E-11	Infinite	17
Air sacculitis	Adult	3.04E-05	11	12
Pneumonia	Adult	9.28E-06	2.18	35
System				
Respiratory	Adult	1.95E-09	2.35	57
Musculoskeletal	Adult	8.80E-06	1.57	54
Nervous	Adult	1.04E-05	1.03	120
Etiology				
Bacterial	Adult	2.29E-06	1.45	71
Females	**Age group**	**p value**	**risk**	**n**
System				
Musculoskeletal	Aged	1.96E-05	0.6	200
Etiology				
Degenerative	Aged	7.50E-13	0.72	267