UC Davis
UC Davis Previously Published Works

Title

Equine abortion and stillbirth in California: a review of 1,774 cases received at a diagnostic laboratory, 1990-2022.

Permalink

https://escholarship.org/uc/item/4m16q7v4

Journal

Journal of Veterinary Diagnostic Investigation, 35(2)

Authors

Cantón, Germán
Navarro, Mauricio
Asin, Javier
et al.

Publication Date

2023-03-01

DOI

10.1177/10406387231152788

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Full Scientific Report

Journal of Veterinary Diagnostic Investigation
2023, Vol. 35(2) 153–162
© 2023 The Author(s)
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/10406387231152788
jvdi.sagepub.com

Equine abortion and stillbirth in California: a review of 1,774 cases received at a diagnostic laboratory, 1990–2022

Germán J. Cantón, Mauricio A. Navarro, Javier Asin, Peter Chu, Eileen E. Henderson, Asli Mete, Francisco A. Uzal[1]

Abstract. Reproductive failure represents an important cause of economic loss for the equine industry. We reviewed the cases of equine abortion and stillbirth submitted to the California Animal Health and Food Safety Laboratory System, University of California–Davis from 1990 to 2022. A total of 1,774 cases were reviewed. A confirmed cause of abortion was determined in 29.2% of the cases. Abortion or stillbirth was attributed to infectious agents in 18.7% of the cases, with *Streptococcus* spp., equine herpesvirus 1, and *Leptospira* spp. being the most prevalent. Noninfectious causes of abortion were established in 10.5% of the cases, with umbilical cord torsion being the most common. In 70.8% of the cases, a definitive cause of abortion could not be established. Our study demonstrated the difficulties in establishing an etiologic diagnosis, even when following a standard diagnostic work-up. New diagnostic approaches are needed to improve the likelihood of reaching a final diagnosis in cases of equine abortion and stillbirth.

Keywords: abortion; equine; horses; pathology; stillbirth.

Abortion is an important cause of economic loss for the equine industry given the costs associated with diagnosis, treatment, and loss of animals. Additionally, several infectious agents known to cause reproductive losses in horses are zoonotic and/or have a major impact on international trade.[15]

Studies have shown that up to 40% of mares may suffer pregnancy failure (from fertilization to parturition).[12,14,17,21,22] These reproductive losses are associated with infectious or noninfectious causes. Among the infectious causes are equine herpesvirus 1 (EHV1; *Equid alphaherpesvirus 1*), *Streptococcus* spp., *Salmonella* spp., and *Leptospira* spp.[2,14,15,18] According to one study, the prevalence of noninfectious causes of equine abortions, such as torsion of the umbilical cord, has increased since 2018, surpassing the occurrence of infectious causes of abortion.[2]

Surveillance of abortigenic conditions is critical to determine the most prevalent causes of abortion and to establish preventive measures.[2,18] Also, increasing awareness of the presence of specific infectious causes of abortion in a particular geographic area is useful for local practitioners when assessing equine health.[18] The reported frequency of these causes varies over time as a result of changes in the capabilities of diagnostic laboratories, and changes in husbandry practices or climatic conditions of at-risk equine populations.[13,14,22] Furthermore, correctly defining abortions, stillbirth, and perinatal mortality is also important, especially late in gestation.[1,22]

Our objectives were: 1) to identify the most common causes of equine abortion and stillbirth in cases submitted to the California Animal Health and Food Safety Laboratory System, University of California–Davis (CAHFS) laboratories between 1990 and 2022; 2) to establish which submitted specimens were most useful in establishing a cause of abortion or stillbirth; and 3) to characterize the main findings in cases of equine abortion or stillbirth.

Materials and methods

Case selection

We performed a retrospective analysis of equine abortions and stillbirth (fetuses and fetal membranes) submitted to the Davis, Tulare, and San Bernardino laboratories of CAHFS from January 1, 1990, to April 12, 2022. Abortion was defined as fetal loss before the 10th month of gestation. Stillbirth was defined as the delivery of a dead foal after the 10th month of gestation; stillbirths were foals considered to be capable of survival if they had been born alive.[18,24] A case

National Institute of Agricultural Technology, Balcarce, Argentina (Cantón); Instituto de Patología Animal, Facultad de Ciencias Veterinarias, Universidad Austral de Chile, Valdivia, Chile (Navarro); California Animal Health and Food Safety Laboratory System, San Bernardino (Asin, Henderson, Uzal) and Davis (Chu, Mete) Laboratories, School of Veterinary Medicine, University of California–Davis, CA, USA.

[1]Corresponding author: Francisco A. Uzal, California Animal Health and Food Safety Laboratory System, UC Davis, 105 W Central Ave, San Bernardino, CA 92408, USA. fauzal@ucdavis.edu

was defined as one or more fetuses, fetal tissues, or fetal membranes submitted at the same time. Cases consisting of intact fetuses or tissues from autopsies conducted in the field were included only if fresh and fixed heart, lung, liver, kidney, and intestine were available for evaluation.

For each case, the following information was incorporated into a spreadsheet: CAHFS laboratory branch (Davis, San Bernardino, or Tulare), accession number, login date, breed, age, sex (male, female, not recorded), state of postmortem preservation (good, moderate, or poor as interpreted by the pathologist in charge, or not recorded), placenta submission (yes or no), gross lesions, histologic lesions, final diagnosis, and etiology.

Criteria for inclusion and diagnostic testing

The gestational age of aborted fetuses or stillborn foals was determined using crown-rump length measurement, weight, and presence of hair in different locations over the body and/or incisor teeth eruption at the time of autopsy.[28] The aborted fetuses were clustered into 3 gestational age groups: 0–4 mo (first), 5–8 mo (second), and 9–10 mo (third). When available, umbilical cord length and placental weight were recorded.

All ancillary tests described below were performed following CAHFS standard operating procedures. Histologic examination was performed on H&E-stained sections of available tissues, including, in most cases, lung, liver, kidney, spleen, adrenal gland, thymus, lymph nodes, heart, skeletal muscle, stomach, intestine, brain, amnion, umbilical cord, and allantochorion.

Selected sections were also stained with Grocott–Gomori methenamine silver, Steiner, or periodic acid–Schiff stains, and immunohistochemistry (IHC) for *Leptospira* spp. (*Leptospira* multivalent rabbit antibody conjugate; National Veterinary Services Laboratories [NVSL], Ames, IA, USA) and EHV1/4 (mouse monoclonal cocktail anti-EHV1 [13B2, 16C2] and EHV4 [20F3, 21C5]; University of Kentucky, Lexington, KY, USA).

Bacteriologic tests included some or all of the following: selective culture for *Campylobacter* spp. and *Salmonella* spp. on stomach content and placenta; aerobic culture of stomach content, lung, liver, and placenta. The presence of *Leptospira* spp. and *Salmonella* spp. nucleic acids was tested by PCR on kidney and liver samples, respectively. A direct fluorescent antibody test (FAT) was performed on kidney and/or placenta for *Leptospira* spp. (multivalent rabbit conjugate; NVSL). Fungal cultures on placenta were performed in selected cases when considered necessary by the pathologist.

Virology testing included some or all of the following: FAT on frozen sections of liver and lung for EHV1 (monoclonal conjugated; VMRD); virus isolation and EHV1 PCR, with and without the neuropathogenic marker, on placenta, liver, and lung. When compatible lesions were present, PCR, viral isolation, or IHC for equine arteritis virus (EAV; *Alphaarterivirus equid*) was performed in a few selected cases.

Serologic testing was performed on fetal fluids for IgG, and for EHV1, EAV, and *Leptospira* spp. When available, serum from dams was also tested for EHV1, EAV, and *Leptospira* spp. antibodies. IgG was measured by a commercial ELISA (Triple J Farms). EHV1 and EAV serology were performed by virus neutralization. *Leptospira* spp. serology was performed by the microagglutination technique. Heavy metals (arsenic, manganese, molybdenum, lead, zinc, mercury, iron, copper), selenium, and vitamin E concentrations were measured in fetal liver of some cases.

The cause of abortion in each case was classified as confirmed, presumptive, or undetermined. Cases with a confirmed cause of abortion were those in which there were compatible gross and/or microscopic lesions coupled with detection of the cause of abortion in placenta and/or fetal samples by the corresponding ancillary testing. Mineral deficiencies (e.g., selenium values below RIs and associated with lesions) were included in this category. Dystocia was considered to be the cause of abortion in cases in which there were circulatory disturbances in the head and neck, rib fractures, intrathoracic hemorrhage, and/or ruptured liver, in conjunction with the absence of inflammatory microscopic changes and/or detection of significant pathogens. Umbilical cord torsion was considered to be the cause of abortion if the umbilical cord was >80 cm long and had more than 5 twists, coupled with circulatory disturbances, including ischemia, congestion with varicose dilation of umbilical vessels, hemorrhage, and/or edema.

The category of presumptive cause of abortion included cases in which gross and/or microscopic lesions in the placenta and/or fetal tissues were compatible with a particular entity but the agent was not detected. Cases with nonspecific or no detectable gross or microscopic findings and no detection of a significant agent were included in the category of undetermined cause of abortion; several congenital defects and mummified fetuses were included in this category.

Statistical analysis

We prepared contingency tables to study the association of variables among the cases of equine abortion. Pearson chi-square or Fisher exact tests were used in determining any statistically significant differences in the establishment of a final diagnosis (confirmed, presumptive, undetermined) and the following analyzed categories: period of gestation (first, second, third), state of postmortem preservation (good, fair, poor) and submission of placenta (yes, no). Likewise, the Pearson chi-square test was used to determine statistically significant differences between the period of gestation (first, second, third) and the most prevalent causes of abortion or stillbirth (*Streptococcus* spp., *Leptospira* spp., EHV1, fungi). Statistical analyses were performed using R for Mac (v.3.2.6;

https://cran.r-project.org/bin/macosx/). A p-value ≤ 0.05 was regarded as statistically significant.

Results

Case selection

We included 1,774 cases of equine abortion and stillbirth submitted to CAHFS between January 1990 and May 2022. An average of 55 (±21) cases were received each year. A seasonal pattern was observed; most cases were received between September and April each year ($n = 1,596$; 90.0%) with a peak between November and February. The most prevalent equine breeds were Thoroughbred ($n = 505$; 28.5%) and Quarter Horse ($n = 355$; 20.0%), followed by Miniature Horse ($n = 133$; 7.5%), Arabian ($n = 126$; 7.1%), Paint ($n = 73$; 4.1%), and others ($n = 582$: 32.8%). Others included the following breeds: crossbred, Friesian, Andalusian, Warmblood Horse, Appaloosa, Morgan, Hanoverian, Standardbred, Warmblood, Tennessee Walking Horse, Peruvian Paso, Dutch Warmblood, Oldenburg, Saddlebred, Percheron, Missouri Fox Trotting Horse, Clydesdale, Holsteiner, Mustang, Gypsy Vanner, Przewalski, Welsh Pony and Cob, Icelandic, Norwegian Fjord, Paso Fino, pony, Belgian, Hackney, Lipizzaner, Pony of the Americas, Shetland pony, Swedish Warmblood, Trakehner, and Westphalian. The gestational age of the submitted cases was estimated to be mostly in the second ($n = 694$; 39.1%) and third ($n = 763$; 43.0%) terms, with a small number of cases ($n = 78$; 4.4%) in the first gestational period. In 239 (13.5%) cases, the gestational age was not recorded. Abortions (fetuses of <10-mo gestation) represented 1,036 of the 1,774 (58.4%) submissions; 499 submissions (28.1%) were considered stillbirths (≥10-mo gestation).

A total of 830 (46.8%) submissions were female and 672 (37.9%) were male. In 272 (15.3%) submissions, information about the sex was not available. The state of postmortem preservation was good in 594 (33.5%), fair in 330 (18.6%), and poor in 211 (11.9%) of the cases. In 639 (36.0%) cases, information about the state of postmortem decomposition was not available. In 1,371 (77.3%) submissions, placental tissues were received with the fetuses.

Gross abnormalities were observed in 457 (25.8%) submissions; no significant gross abnormalities were observed in 1,214 (68.4%) submissions. No gross description of tissues was available in 103 (5.8%) submissions. Microscopic abnormalities were observed in 681 (38.4%) submissions.

Causes of abortions and stillbirths

A definitive etiology for the cases of abortion and stillbirth was established in 518 (29.2%) cases. Most were infectious causes ($n = 331$; 18.7%). Noninfectious abortions or stillbirths occurred in 187 (10.5%) cases. Bacterial agents represented the most frequent infectious cause of abortion, followed by viral, mycotic, and coinfections (Table 1). Briefly, bacterial abortions were mostly characterized grossly by placentitis, and occasionally inflammation of several fetal tissues. EHV1 was the most prevalent cause of viral abortions, and gross lesions, when present, included random white pinpoint foci throughout the liver parenchyma (Fig. 1) and fibrin plugs within the tracheal lumen (Fig. 2). Mycotic abortions were characterized by severe fibrinonecrotizing placentitis (Fig. 3) and funisitis. The most common noninfectious cause of abortion was umbilical torsion (Table 2; Fig. 4).

Briefly, histologic findings in equine abortions and stillbirths caused by most bacterial infections were characterized by necrosuppurative placentitis with inflammation of several other organs with intralesional bacterial colonies (Tables 3–5; Fig. 5). In mycotic abortions, the microscopic lesions consisted of necrosis and granulomatous inflammation with intralesional fungal hyphae; lesions were most frequently seen in placenta (Fig. 6), lung, and liver. In abortions caused by EHV1 infection, the most characteristic lesion was necrosis in various organs with prominent eosinophilic intranuclear inclusion bodies; the organs most frequently affected were liver (Figs. 7, 8), lung (Fig. 9), spleen, and thymus.

Statistical analysis

No association between the period of gestation or the inclusion of placenta among the submitted samples and the establishment of a confirmed diagnosis was detected ($p > 0.05$). When the association between the state of postmortem preservation and the establishment of a final diagnosis was evaluated, a higher percentage of confirmed diagnoses was achieved in cases with a good state of postmortem preservation ($p = 0.01$). Abortions caused by *Streptococcus* spp. and EHV1 occurred most frequently in the second and third period of gestation ($p < 0.01$). No association between period of gestation and abortion caused by *Leptospira* spp. or mycotic abortions ($p > 0.05$) was detected.

Discussion

In agreement with previous studies,[2,14,17,18,24] most cases submitted to CAHFS during this time frame were predominantly late-term abortions (third period). Although this could indicate that equine abortions occur more frequently in the second half of the pregnancy, it is more likely that earlier abortions were underestimated,[23] probably because most of them were more difficult to find on the farm given the size of the fetus.[14,17]

Seasonal variations in the frequency of abortions have been described. Abortions occur most commonly between November and May in the Northern Hemisphere, in concordance with the seasonal reproductive cycle of the mare,[14,24] as observed in our study in California. Furthermore, most of the fetuses submitted to CAHFS were Thoroughbred, some

Table 1. Infectious causes of equine abortion and stillbirth diagnosed at the California Animal Health and Food Safety Laboratories, 1990–2022.

	Abortions*						
	1st	2nd	3rd	Stillbirth†	Unknown‡	Total	%§
Infectious abortions	17	107	49	108	50	331	18.7
Single bacterial infections	15	81	33	54	27	210	11.8
Streptococcus spp.	9	55	19	27	18	128	7.2
Leptospira spp.	0	3	4	7	4	18	1.0
Escherichia coli	0	4	3	1	1	9	0.5
Actinobacillus spp.	0	2	0	6	0	8	0.5
Enterobacter spp.	4	0	1	0	1	6	0.3
Pseudomonas aeruginosa	0	2	0	3	0	5	0.3
Aeromonas spp.	2	0	1	1	0	4	0.2
Corynebacterium pseudotuberculosis	0	2	2	0	0	4	0.2
Acinetobacter spp.	0	2	0	0	1	3	0.2
Bacillus spp.	0	1	0	2	0	3	0.2
Mycobacterium spp.	0	2	0	1	0	3	0.2
Rhodococcus spp.	0	2	0	0	1	3	0.2
Staphylococcus spp.	0	1	0	2	0	3	0.2
Other bacteria	0	5	3	4	1	13	0.7
Multiple bacterial and/or mycotic infections	1	7	1	6	2	17	1.0
Streptococcus spp. + *E. coli*	0	4	0	1	1	6	0.4
Streptococcus spp. + *Klebsiella pneumoniae*	0	1	1	1	0	3	0.2
Other coinfections	1	2	0	4	1	8	0.5
Viral infections	0	9	12	45	19	85	4.8
Equine herpesvirus 1	0	7	11	45	19	82	4.6
Equine arteritis virus	0	2	1	0	0	3	0.2
Mycotic infections	1	10	3	3	2	19	1.1
Aspergillus spp.	0	3	1	2	1	7	0.4
Mycotic, not specified	0	4	1	0	1	6	0.3
Coccidioides spp.	1	0	1	1	0	3	0.2
Other fungi	0	3	0	0	0	3	0.2

* Abortion: fetuses < 10-mo gestation. 1st = 0–4-mo gestation; 2nd = 5–8-mo gestation; 3rd = 9–10-mo gestation.
† Stillbirth: fetuses ≥ 10-mo gestation.
‡ Exact gestational age undetermined.
§ % calculated of the total 1,774 cases.

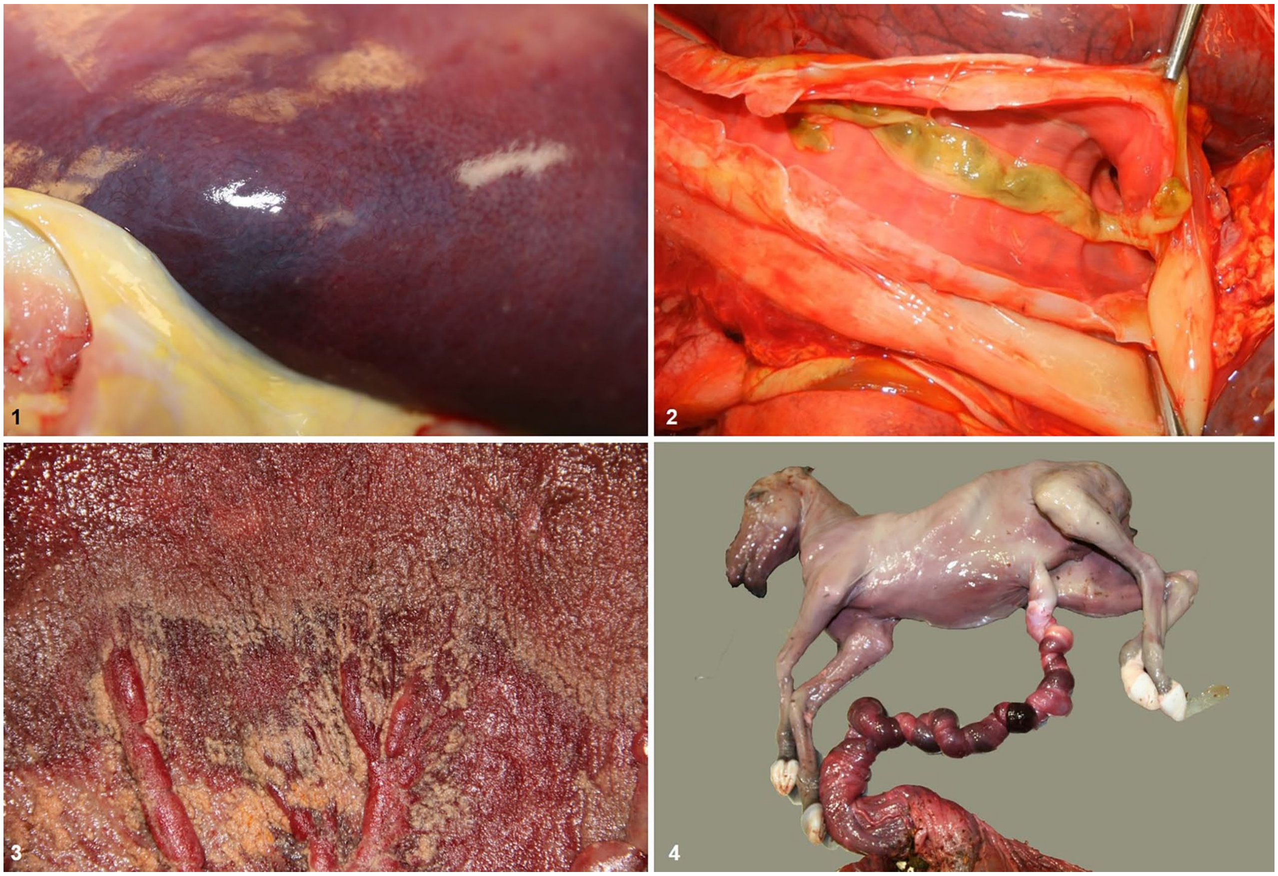
of them probably used for racing, which may affect breeding schedules, particularly in the United States.

Despite advances in tests, a definitive cause of abortion was not determined in most of the cases. Comparison with other retrospective studies worldwide is difficult because different methods and diagnostic criteria were often used, and diseases and management conditions vary around the world.[2] In some studies from the United Kingdom and United States, the cause of equine abortion remained undiagnosed in ~10% of the cases[21–23]; in other studies, the undiagnosed cases reached up to 60% of submissions.[2,6,14,18] In another study, an etiologic diagnosis was obtained successfully more frequently in late-term abortions compared to abortions in earlier stages of gestation.[14,23] We found no statistical differences in detection of the etiology at different stages of pregnancy. Advanced autolysis usually jeopardizes the chances of determining an etiologic diagnosis in abortions,[6,14] and, in our study, the degree of postmortem decomposition affected the success of establishing a final diagnosis.

In our study, the most common causes of infectious abortions were bacterial infections, in accordance with previous data.[12,14] Gross or microscopic pathologic findings are not evident in many bacterial equine abortions.[17] It has been hypothesized that, in some cases, a septicemic process could be so rapid that there is no time for the development of inflammatory or necrotizing lesions.

Among the bacterial causes of abortion identified, *Streptococcus* spp. were the most prevalent, which agrees with previous reports.[14,15,17,19,24] *Streptococcus* spp. are part of the normal microbiota of the genital canal, but they can invade the uterus and cause endometritis, ascending placentitis, and fetal death opportunistically.[23]

Leptospiral abortions were not detected or were uncommonly diagnosed in several previous reports.[2,6,9,22,27] However,



Figures 1–4. Gross findings in equine abortions and stillbirths. **Figure 1.** Equine herpesviral abortion. Miliary pale foci in the liver. **Figure 2.** Equine herpesviral abortion. Fibrin cast in the lumen of the trachea. **Figure 3.** Fibrinonecrotizing mycotic placentitis in an equine stillbirth. **Figure 4.** Umbilical cord torsion in an equine fetus showing many twists with intercalated dark and blanched segments.

Table 2. Noninfectious and undetermined causes of equine abortion and stillbirth diagnosed at the California Animal Health and Food Safety Laboratories, 1990–2022.

	Abortions*						
	1st	2nd	3rd	Stillbirth†	Unknown‡	Total	%§
Noninfectious abortions and stillbirths	10	80	31	39	27	187	10.5
Umbilical torsion	1	36	17	6	18	78	4.4
Malformation	1	20	6	13	3	43	2.4
Mummification	8	7	1	0	2	18	1.0
Selenium and/or vitamin E deficiency	0	7	4	6	0	17	1.0
Dystocia	0	0	1	9	0	10	0.7
Placental-origin	0	4	1	2	2	9	0.7
Twinning	0	6	0	0	2	8	0.4
Other noninfectious abortions/stillbirths	0	0	1	3	0	4	0.2
Undetermined diagnosis, presumably infectious¦	8	23	9	30	25	95	5.4
Undetermined diagnosis, presumably noninfectious#	43	484	175	322	137	1,161	65.4

* Abortion: fetuses < 10-mo gestation. 1st: 0–4-mo gestation; 2nd: 5–8-mo gestation; 3rd: 9–10-mo gestation.
† Stillbirth: fetuses ≥ 10-mo gestation.
‡ Exact gestational age undetermined.
§ % calculated of 1,774 cases in the study.
¦ Inflammatory lesions compatible with infectious abortion, with no identification of a particular abortifacient.
\# No lesions and identification of a particular abortifacient.

Table 3. Main gross findings of the most frequent causes of infectious equine abortions and stillbirths diagnosed at the California Animal Health and Food Safety Laboratories, 1990–2022.

	Streptococcus spp. (*n*=128)		*Leptospira* spp. (*n*=18)		EHV1 (*n*=82)		Mycotic (*n*=19)	
	n	%	*n*	%	*n*	%	*n*	%
Gross lesions present	22	17.2	4	22.2	36	43.9	8	42.1
Placenta	11	8.6	1	5.6	9	11.0	7	36.8
Thickening of placental membranes	6	4.7	0	0.0	0	0.0	6	31.6
Multifocal necrotizing placentitis	3	2.3	0	0.0	0	0.0	1	5.3
Multifocal hemorrhagic placentitis	2	1.6	1	5.6	9	11.0	0	0.0
Liver	9	7.0	2	11.1	34	41.5	4	21.1
Hepatomegaly	8	6.3	2	11.1	18	22.0	4	21.1
Multifocal necrotizing hepatitis	1	0.8	0	0.0	21	25.6	0	0.0
Lung	4	3.1	0	0.0	36	43.9	4	21.1
Pulmonary consolidation	2	1.6	0	0.0	0	0.0	0	0.0
Pulmonary edema	0	0.0	0	0.0	35	42.7	0	0.0
Fibrin casts in bronchi and/or trachea	0	0.0	0	0.0	6	7.3	0	0.0
Pleural effusions	2	1.6	0	0.0	0	0.0	0	0.0
Multifocal necrotizing pneumonia	0	0.0	0	0.0	0	0.0	4	21.1
Heart, epicardial and/or endocardial hemorrhages	0	0.0	0	0.0	12	14.6	0	0.0
Spleen, splenomegaly	0	0.0	0	0.0	20	24.4	0	0.0
Thymus, enlarged and/or edematous	0	0.0	0	0.0	7	8.5	0	0.0
Skin, multifocal dermatitis	0	0.0	0	0.0	0	0.0	1	5.3
Jaundice	6	4.7	1	5.6	10	12.2	0	0.0
Hydrothorax	0	0.0	0	0.0	20	24.4	0	0.0
Ascites	0	0.0	0	0.0	7	8.5	0	0.0
Partial mummification	2	1.6	0	0.0	0	0.0	0	0.0
Gross lesions absent	106	82.8	14	77.8	46	56.1	11	57.9

Table 4. Main histopathologic findings in the most frequent causes of infectious equine abortions and stillbirths diagnosed at the California Animal Health and Food Safety Laboratories, 1990–2022.

	Streptococcus spp. (*n*=128)		*Leptospira* spp. (*n*=18)		EHV1 (*n*=82)		Mycotic (*n*=19)	
	n	%	*n*	%	*n*	%	*n*	%
Histologic lesions present	103	80.5	16	88.9	81	98.8	19	100.0
Placenta	88	68.8	7	38.9	11	13.4	16	82.4
Suppurative placentitis	78	60.9	0	0.0	0	0.0	0	0.0
Necrotizing placentitis	70	54.7	0	0.0	9	11.0	14	73.7
Pyogranulomatous placentitis	0	0.0	0	0.0	0	0.0	3	15.8
Lung	29	22.7	5	27.8	63	76.5	9	47.4
Bronchopneumonia	29	22.7	0	0.0	0	0.0	3	15.8
Bronchointerstitial pneumonia	0	0.0	5	27.8	14	17.1	0	0.0
Bronchiolar epithelial necrosis	0	0.0	0	0.0	36	43.9	0	0.0
Intranuclear inclusion bodies	0	0.0	0	0.0	34	41.5	0	0.0
Pyogranulomatous bronchopneumonia	0	0.0	0	0.0	0	0.0	8	42.1
Septicemia (bacterial colonies in several tissues)	26	20.3	0	0.0	0	0.0	0	0.0
Liver	0	0.0	4	22.2	68	82.9	5	26.3
Multifocal necrotizing hepatitis	0	0.0	4	22.2	60	73.1	2	10.5
Intranuclear inclusion bodies	0	0.0	0	0.0	46	56.1	0	0.0
Nonsuppurative hepatitis	0	0.0	0	0.0	31	37.8	2	10.5
Kidney, nephritis	0	0.0	3	16.7	0	0.0	0	0.0

(continued)

Table 4. (continued)

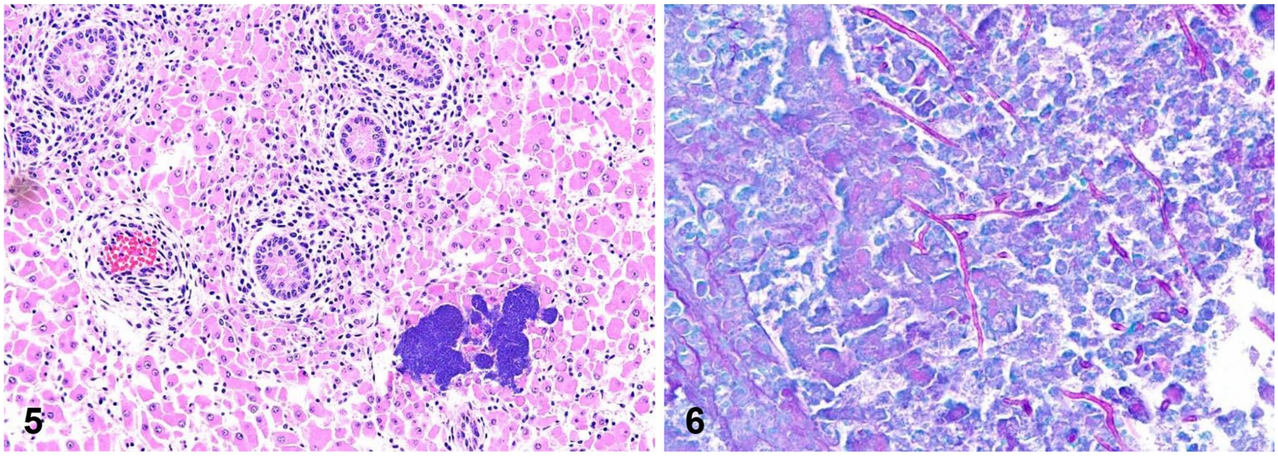
	Streptococcus spp. ($n=128$)		*Leptospira* spp. ($n=18$)		EHV1 ($n=82$)		Mycotic ($n=19$)	
	n	%	*n*	%	*n*	%	*n*	%
Spleen	0	0.0	0	0.0	45	54.9	0	0.0
Necrotizing (depletion) splenitis	0	0.0	0	0.0	44	53.7	0	0.0
Intranuclear inclusion bodies	0	0.0	0	0.0	10	12.2	0	0.0
Nonsuppurative splenitis	0	0.0	0	0.0	8	9.8	0	0.0
Thymus	0	0.0	0	0.0	34	41.5	0	0.0
Intranuclear inclusion bodies	0	0.0	0	0.0	28	34.1	0	0.0
Necrotizing (depletion) thymitis	0	0.0	0	0.0	26	31.7	0	0.0
Nonsuppurative thymitis	0	0.0	0	0.0	14	17.1	0	0.0
Adrenal glands	0	0.0	0	0.0	24	29.3	0	0.0
Necrotizing adrenalitis	0	0.0	0	0.0	23	28.0	0	0.0
Intranuclear inclusion bodies	0	0.0	0	0.0	12	14.6	0	0.0
Brain, gliosis	0	0.0	0	0.0	4	4.9	0	0.0
Heart, nonsuppurative myocarditis	0	0.0	0	0.0	4	4.9	0	0.0
Histologic lesions absent	25	19.5	2	11.1	1	1.2	0	0.0

Table 5. Ancillary techniques used for the identification of the most frequent causes of infectious equine abortions and stillbirths diagnosed at the California Animal Health and Food Safety Laboratories, 1990–2022.

	n	%
Streptococcus spp. isolated in aerobic culture from:	128	100.0
Placenta	80	62.5
Fetal tissues	107	83.6
Lung	51	47.6
Stomach content	30	28.0
Liver	24	22.4
Leptospira spp. detected by:	18	100.0
FAT on kidney smears	12	66.7
Dam or fetal serology	10	55.6
Silver staining on kidney, liver, and/or placenta	5	27.8
IHC on kidney and/or placenta	3	16.7
PCR on kidney	2	11.1
EHV1 detected by:	82	100.0
FAT	52	63.4
Lung	24	29.3
Not specified tissue smear	24	29.3
Liver	16	19.6
Thymus	1	1.2
IHC	19	23.2
Not specified tissue	10	12.2
Liver	8	9.8
Lung	7	8.5
Spleen	4	4.9
Placenta	3	3.7
Thymus	2	2.4
Adrenal gland	2	2.4
PCR	12	14.6
Lung	8	9.8
Liver	7	8.5
Not specified tissue	3	3.7
Kidney	1	1.2
Placenta	1	1.2
Viral isolation	6	7.3
Not specified tissue	4	4.9
Thymus	1	1.2
Placenta	1	1.2
Fungi detected or isolated from:	19	100.0
Placenta	10	52.6
Lung	7	36.5
Stomach content	2	10.5
Skin	1	5.3
Liver	1	5.3

Leptospira spp. has been detected frequently in other studies in the United States.[10,11] The differences among these studies could be related to geographic and climatic variations associated with the characteristic of this spirochete, or the use of systematic vaccination in certain locations.[6,25] *Leptospira* spp.-placentitis/funisitis with no fetal lesions has been reported as a frequent cause of equine abortion,[13] as detected in our study. This finding emphasizes the importance of placental submission in equine abortion to improve the chances of reaching an etiologic diagnosis.

EHV1 was the most common viral cause of abortion in our study. Despite the availability of vaccines and the implementation of good husbandry conditions, EHV1 continues to be one of the most commonly reported causes of equine



Figures 5, 6. Microscopic findings in bacterial and fungal equine abortions. **Figure 5.** Cholangiohepatitis with large bacterial colonies in an equine fetus aborted as a result of *Streptococcus* spp. infection. H&E. **Figure 6.** Mycotic placentitis characterized by extensive necrosis of chorionic villi accompanied by mild-to-moderate inflammatory infiltrates. Large numbers of intralesional, slender, septate fungal hyphae are compatible with *Aspergillus* spp. Periodic acid–Schiff.

abortion worldwide.[7,14,15,18,26] In our study, information about the vaccination status of the dam was not available in most cases.

The other cause of viral abortion in our case series was EAV. Cases of equine viral arteritis (EVA) were, however, very rare; only 1 confirmed case and 2 presumptive cases were found in our case series. In the presumptive cases, compatible microscopic lesions were observed, but EAV was not detected. EVA in horses is associated with respiratory and reproductive disease, although the vast majority of EAV infections are subclinical[3] and abortions are detected only rarely.[14] A diagnosis of EVA-associated abortion may be challenging given that detection of the virus and lesions in fetal tissues is rare.[4,8] In most cases of EVA, the abortion is associated with uterine lesions (e.g., myometritis), with a subsequent decrease in blood supply to the placenta and fetus.[4]

Fungal infections were diagnosed uncommonly in our study. *Aspergillus* spp. was the most frequently detected fungus, which agrees with previous reports.[12,14] Although some authors mentioned that fetal fungal infection is rare,[20] in our retrospective analysis, both placenta and fetal tissues (particularly the lungs and the liver) were affected.

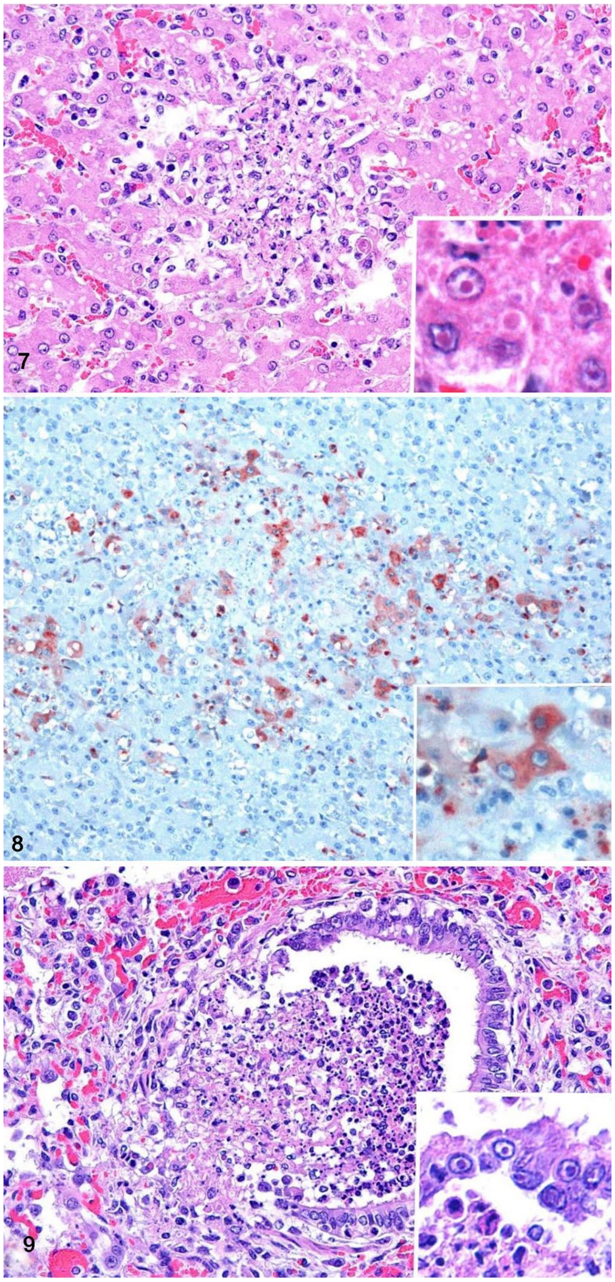
In several studies, the most frequent causes of abortions were noninfectious.[14,18,22] Among them, umbilical cord torsion with vascular compromise represents the most prevalent postmortem finding associated with equine abortion, stillbirth, and perinatal death.[2,23,24] A confirmed diagnosis of umbilical cord torsion must be based on circulatory disturbances in the cord, such as edema, hemorrhage and/or thrombosis leading to placental vascular compromise, as well as the detection of >5 umbilical twists and an excessively long cord (>80 cm).[2,13,14,21]

Congenital malformations were observed most frequently in the CNS and the skeletal system, which agrees with previous reports.[12–14,23] As in our study, the cause of such malformations is rarely established. Twinning-related abortion was rare, in agreement with previous studies.[2,12,15] The occurrence of abortion of twins has decreased over time, which can likely be attributed to the use of early ultrasonography and appropriate management of multiple pregnancies.[16,23]

Selenium and/or vitamin E deficiency has been mentioned as a cause of equine gestational losses and perinatal mortality.[24] In our study, selenium and vitamin E deficiency with compatible histologic lesions was detected as the cause of 1% of the abortions. Selenium deficiency was detected in several other fetuses in which no compatible gross or microscopic lesions were observed (data not shown). Although considered an incidental finding, we cannot rule out that these deficiencies acted as factors predisposing to other causes of abortions and perinatal mortality.[5]

Pathologic findings compatible with dystocia-perinatal asphyxia syndrome were detected in 12 late-term fetuses in our study. This syndrome is usually associated with malpresentation of foals, maiden mares, and/or large foals.[13] In our study, no clinical information about malpresentations was available in these fetuses, and their size was estimated to be appropriate.

Placental submission is key to reaching an etiologic diagnosis of abortion in several animal species, including the horse.[17,21,23] Placental-origin abortion has been associated with idiopathic and infectious causes. In several studies, placentitis was one of the most important causes of equine reproductive loss.[13,23,24] In our study, a presumptive or confirmed diagnosis of abortion was achieved in 172 (9.7%) of the fetuses, based on observation of placental lesions in association with detection of an etiologic agent in only the placenta. Complete placenta and umbilical cord were key for the confirmation of umbilical cord torsion, bacterial and



Figures 7–9. Microscopic changes in equine herpesviral abortion. **Figure 7.** Necrotizing hepatitis. Inset: some hepatocytes contain eosinophilic intranuclear inclusion bodies. H&E. **Figure 8.** Necrotizing hepatitis with positive staining for equine herpesvirus 1 immunohistochemistry. Inset: positive immunostaining was located in the cytoplasm of infected cells. **Figure 9.** Necrotizing bronchiolitis. Inset: some epithelial cells have eosinophilic intranuclear inclusion bodies. H&E.

mycotic abortions or stillbirths, as well as premature placental separation, as the cause of abortion. However, our statistical analysis suggests that submission of the placenta with the fetuses did not increase the chances of achieving a confirmed diagnosis.

Our study was carried out using the fetuses and/or fetal and placental tissues submitted for laboratory examination; therefore, this may not reflect the actual incidence at the population level. Consequently, it is challenging to accurately compare our results with other regions and/or studies about risk factors. Given that a cause of abortion was not identified in a large percentage of the submitted equine abortion and stillbirth cases included in our study, a more comprehensive approach should be considered to improve the chances of achieving an etiologic diagnosis. For instance, other factors, such as hormonal or endocrine deficiencies in the dam, toxicoses, and other nutritional and husbandry conditions,[12] may also play a role in equine reproductive losses and should also be considered.

Acknowledgments

We thank pathologists and technicians of the 3 branches of CAHFS, who conducted the postmortem examinations and ancillary testing (UC Davis). This research was supported by the U.S. Fulbright Program and INTA (Argentina).

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Germán J. Cantón https://orcid.org/0000-0003-3494-8193
Javier Asin https://orcid.org/0000-0002-6178-4801
Eileen E. Henderson https://orcid.org/0000-0002-5043-9308
Asli Mete https://orcid.org/0000-0002-7612-6713
Francisco A. Uzal https://orcid.org/0000-0003-0681-1878

References

1. Abraham M, Bauquier J. Causes of equine perinatal mortality. Vet J 2021;273:105675.
2. Agerholm JS, et al. A diagnostic survey of aborted equine fetuses and stillborn premature foals in Denmark. Front Vet Sci 2021;8:740621.
3. Balasuriya UBR, et al. Equine viral arteritis: a respiratory and reproductive disease of significant economic importance to the equine industry. Equine Vet Educ 2018;30:497–512.
4. Coignoul FL, Cheville NF. Pathology of maternal genital tract, placenta, and fetus in equine viral arteritis. Vet Pathol 1984;21:333–340.
5. Cunha TJ. Horse Feeding and Nutrition. 2nd ed. Academic Press, 1991.
6. da Silva AA, et al. Causes of equine abortion, stillbirth, and perinatal mortality in Brazil. Arq Inst Biol 2020;87:e0092020.
7. Damiani AM, et al. A severe equine herpesvirus type 1 (EHV-1) abortion outbreak caused by a neuropathogenic

strain at a breeding farm in northern Germany. Vet Microbiol 2014;172:555–562.
8. Del Piero F. Equine viral arteritis. Vet Pathol 2000;37:287–296.
9. Divers TJ, et al. Leptospirosis: an important infectious disease in North American horses. Equine Vet J 2019;51:287–292.
10. Donahue JM, et al. Diagnosis and prevalence of leptospira infection in aborted and stillborn horses. J Vet Diagn Invest 1991;3:148–151.
11. Donahue JM, Williams NM. Emergent causes of placentitis and abortion. Vet Clin North Am Equine Pract 2000;16:443–456.
12. Giles RC, et al. Causes of abortion, stillbirth, and perinatal death in horses: 3,527 cases (1986–1991). J Am Vet Med Assoc 1993;203:1170–1175.
13. Hong CB, et al. Equine abortion and stillbirth in Central Kentucky during 1988 and 1989 foaling seasons. J Vet Diagn Invest 1993;5:560–566.
14. Laugier C, et al. A 24-year retrospective study of equine abortion in Normandy (France). J Equine Vet Sci 2011;31:116–123.
15. Macleay CM, et al. A scoping review of the global distribution of causes and syndromes associated with mid- to late-term pregnancy loss in horses between 1960 and 2020. Vet Sci 2022;9:186.
16. Macpherson ML, Reimer JM. Twin reduction in the mare: current options. Anim Reprod Sci 2000;60-61:233–244.
17. Marcolongo-Pereira C, et al. Abortos em equinos na região Sul do Rio Grande do Sul: estudo de 72 casos [Equine abortion in southern Brazil: study of 72 cases]. Pesq Vet Bras 2012;32:22–26. Portuguese.
18. Marenzoni ML, et al. Causes of equine abortion, stillbirth and neonatal death in central Italy. Vet Rec 2012;170:262.
19. Murase H, et al. Aborted fetal sizes of thoroughbred horses in Hidaka, Japan, between 2005 and 2015. J Equine Sci 2017;28:47–53.
20. Orellana-Guerrero D, et al. Fungal placentitis caused by *Aspergillus terreus* in a mare: case report. J Equine Vet Sci 2019;83:102799.
21. Ricketts SW, et al. Equine abortion. Equine Vet Educ 2003;15(Suppl 6):18–21.
22. Roach JM, et al. Incidence and causes of pregnancy loss after day 70 of gestation in thoroughbreds. Equine Vet J 2021;53:996–1003.
23. Smith KC, et al. A survey of equine abortion, stillbirth and neonatal death in the UK from 1988 to 1997. Equine Vet J 2003:35:496–501.
24. Tengelsen LA, et al. A 12-year retrospective study of equine abortion in Michigan. J Vet Diagn Invest 1997;9:303–306.
25. Timoney JF, et al. A unique genotype of *Leptospira interrogans* serovar Pomona type kennewicki is associated with equine abortion. Vet Microbiol 2011;150:349–353.
26. Tong P, et al. Outbreak of neuropathogenic equid herpesvirus 1 causing abortions in Yili horses of Zhaosu, North Xinjiang, China. BMC Vet Res 2022;18:83.
27. Wilkie IW, et al. Giant cell hepatitis in four aborted foals: a possible leptospiral infection. Can Vet J 1988;29:1003–1004.
28. Williams NM. Disorders of horses. In: Njaa BL, ed. Kirkbride's Diagnosis of Abortion and Neonatal Loss in Animals. 4th ed. Wiley-Blackwell, 2012:147–172.