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Original article

Retrospective study of epidemiological, clinical and pathological findings of bovine babesiosis in Mato Grosso do Sul, Brazil (1995 –2017)

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ABSTRACT

Babesiosis is a tick-borne hemolytic disease caused by intraerythrocytic protozoan parasites of the genus *Babesia*. The present study describes epidemiological, clinical, and pathological features of cases of bovine babesiosis diagnosed over the last two decades in the state of Mato Grosso do Sul in central-western Brazil. Examination of a total of 5298 bovine samples resulted in a definitive or presumptive diagnosis of babesiosis in 41 cases from 33 outbreaks. *Babesia bovis* was the most common causal agent of bovine babesiosis, and animals of all ages were affected. Zebu cattle, which are more frequent in the study region than are taurine cattle, were the cattle most often affected. Although zebu cattle have been claimed to be highly tolerant, the present findings show that they can develop severe illness and die due to *Babesia* spp. infection. The disease was diagnosed almost every year over the time period covered in this study (1995–2017). However, the number of cases of bovine babesiosis diagnosed was low compared to the total number of cases reviewed. Veterinary practitioners that work on cattle farms should be able to diagnose the disease in its early stages so that treatment can be initiated promptly and economic losses can be minimized.

1. Introduction

Babesiosis is an infectious disease caused by protozoan parasites of the genus *Babesia* that infect and replicate exclusively within erythrocytes and induce hemolytic anemia (Bock et al., 2004; De Vos et al., 2004; Chauvin et al., 2009; Valli et al., 2017). These hemoprotozoan organism are transmitted mainly by ticks. Together, babesiosis and anaplasmosis in cattle have been commonly referred to as “tick fever” (Almeida et al., 2006; Farias, 2007).

The disease has a global distribution and occurs mainly in tropical and subtropical regions. It is particularly important in Asia, Africa, South America, Central America, parts of Southern Europe, and Australia (Spickler and Bovine babesiosis, 2008). *Babesia bovis* and *Babesia bigemina* are the species of *Babesia* cause this economically important disease of cattle in Brazil (De Vos et al., 2004; Farias, 2007) and other regions around the world (Bock et al., 2004).

Economic losses associated with this disease include not only losses due to animal death but also losses due to weight losses, reduced feed conversion efficiency, reduced milk production and abortion. Furthermore, there are losses due to the control of the disease and its tick vectors, such as veterinary care, acaricidal baths, vaccination, chemoprophylaxis and treatment of sick animals, and animal health-related international trade restrictions (Bock et al., 2004; Jonsson, 2006; Jonsson et al., 2008). A study showed that 62% of the economic losses from *Babesia* spp. are related to cattle death and the treatment of sick animals and that the remaining 38% of losses correspond to costs involved in the control of the disease, including the hiring of veterinarians, drug administration to cattle, and ancillary diagnostic tests (Guglielmone et al., 1999).

The epidemiological features of diseases affecting cattle may vary greatly depending on the geographical area where they occur (Rissi et al., 2010). Retrospective studies can be useful for identifying these

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features and using them for the early diagnosis of diseases and disease control, especially by veterinary practitioners working on large-scale farms (Lucena et al., 2010; Rissi et al., 2010). In Brazil, retrospective studies on the epidemiology of bovine babesiosis have been carried out in the states of Rio Grande do Sul in southern Brazil (Rodrigues et al., 2005; Almeida et al., 2006) and Paraíba in northeastern Brazil (Costa et al., 2011). Similar research from central-western Brazil has not been published in the veterinary literature to date.

The purpose of this study is to describe the epidemiological, clinical, and pathological features of cases of bovine babesiosis diagnosed over the last two decades (between January 1995 and December 2017) at the Veterinary Anatomic Pathology Laboratory from School of Veterinary Medicine and Animal Science (FAMEZ) Federal University of Mato Grosso do Sul (UFMS) in the city of Campo Grande, state of Mato Grosso do Sul in central-western Brazil. We believe that our study represents a significant contribution to the understanding and recognition of this disease in this state, where, unlike in other parts of the country, the majority of cattle herds comprise cattle of the Nelore breed of cattle. The present retrospective survey also adds important information to the existing body of scientific knowledge on the subject.

2. Materials and methods

Pathology records of bovine necropsies performed by members of the Anatomic Pathology Laboratory of the School of Veterinary Medicine and Animal Science (LAP-FAMEZ) at the Federal University of Mato Grosso do Sul (UFMS) at Campo Grande, state of Mato Grosso do Sul, Brazil, or by veterinarian practitioners in the field were systematically reviewed. This study covered a 23-year period (between January 1995 and December 2017). Cases with a presumptive or definitive diagnosis of babesiosis were included in the retrospective data collection. Medical records of experimental studies, out-of-state animals, and healthy cattle submitted by the Ministry of Agriculture, Livestock and Supply (MAPA) between 2001 and 2007 as part of a surveillance program for Bovine Spongiform Encephalopathy (BSE) were not included in this retrospective survey.

A definitive diagnosis of bovine babesiosis was made when the following characteristics were present: (1) gross jaundice, enlarged and yellow liver, enlarged spleen, dark brown kidneys, and dark urine (Fig. 1A–F); (2) microscopic lesions characterized by biliary stasis and centrilobular necrosis in the liver (Fig. 2A), acute tubular necrosis and deposition of orange pigment in kidneys (Fig. 2B); and (3) presence of intraerythrocytic stages of *Babesia* spp. were found in cytology preparations of internal organs or on blood smears (or both) screened under the microscope (Fig. 2C–D). Cerebral babesiosis was diagnosed when pink discoloration of brain gray matter was present (Fig. 3A–B), either alone or with the other lesions and was associated with intraerythrocytic stages of *Babesia bovis* in cytology preparations of the brain (Fig. 3C). A presumptive diagnosis of bovine babesiosis was made in those cases in which gross and microscopic lesions consistent with *Babesia* spp. infection, as described above, were present but piroplasms were not found within red blood cells on cytology touch preparations or on blood smears examined by light microscopy. Differentiation between *B. bovis* and *B. bigemina* was based on the morphology and size of merozoites within erythrocytes. *B. bovis* is smaller than *B. bigemina*, with merozoites measuring up to 2 µm, whereas *B. bigemina* may occupy the entire length of the red blood cell (Potgieter, 1977).

Each case of bovine babesiosis included in the present study was chronologically identified by Arabic numbers. Cases of *Babesia* spp. infection in cattle from the same farm that occurred within a short period and the same time frame were grouped as an outbreak.

The following data were retrieved from our database and then analyzed: epidemiological data (time of occurrence of the disease, age of the animals affected, total number of animals affected, number of sick cattle, number of cattle found dead), clinical and pathological data (clinical signs and gross lesions), and treatment data (medication used).

Cattle breeds were divided into the following groups: zebu (Nelore, Brahman, Gir, Guzará, and Tabapuã), crosses between zebu cattle and taurine cattle (Girolando, Brafrod, Brangus, ½ Angus x ½ Nelore, Senepol, Montana, Canchim, Bonsmara) and taurine (Jersey, Swiss Pardo, Caracu, Angus, Blond d'aquitaine, Charolais, Chianina, Hereford, Holstein, Limousin, Marchigiana, Piedmont, and Simental). Animals of unknown breed origin were assigned to the mixed breed cattle group. To compare the proportions of zebuine and non-zebuine animals affected by babesiosis, statistical analysis was performed using a Chi-square test. Data were considered statistically significant at a *p*-value ≤ 0.05.

3. Results

Between January 1995 and December 2017, 11,426 samples of different animal species were submitted to our laboratory. During this 23-year period, 5298 bovine samples representing 46.36% of the total number of samples were processed for histopathology. We investigated 33 babesiosis outbreaks involving a total of 41 animals; 27 out of the 41 animals corresponded to confirmed cases of bovine babesiosis, of which 21 were diagnosed as having cerebral babesiosis. The remaining 14 of the 41 animals received a presumptive diagnosis of bovine babesiosis. Epidemiological data of each outbreak are presented in Table 1.

Babesia bovis was the species of *Babesia* most often found associated with the disease outbreaks, causing 23 out of the 27 confirmed cases of bovine babesiosis (85%). Co-infection with *B. bovis* and *B. bigemina* was detected in 1 animal (4%). In 3 outbreaks (11%), the species of *Babesia* responsible for the disease was not recorded in our pathology reports.

Information regarding the total number of animals affected, the number of sick animals and the number of animals found dead were lacking in some of the pathology reports. Information regarding the months of occurrence and the age of the affected animals are given in Figs. 4 and 5. In outbreaks 3, 7 and 16, treatment of affected animals was instituted by using the antiprotozoal drug 4,4'-(diazamino)di-benzamidine.

Zebu cattle breeds were the breeds most often affected by babesiosis, accounting for 52% of the outbreaks of the disease, of which 14 involved the Nelore breed and 3 involved the Brahman breed. Zebu and taurine crosses were affected in 5 episodes (15%): 2 outbreaks in Girolando, 1 in Brangus, 1 in Angus x Nelore, and 1 in Brafrod. Specimens from taurine cattle were collected in 5 outbreaks (15%): 1 Caracu, 1 Jersey, 1 Holstein, and 2 Swiss Pardo. In 5 outbreaks (15%), the cattle breed was listed as “mixed” in the pathology reports, and in 1 outbreak (3%), this information was not provided. There was no significant difference in the proportion of animals affected between the zebu and non-zebu breeds (*p* = 0.7086).

The major clinical signs manifested by the affected animals are shown in Table 2. Necropsy findings on these cases are included in Table 3.

4. Discussion

The results of the present study show that bovine babesiosis occurs in cattle from the state of Mato Grosso do Sul in central-western Brazil. The disease was diagnosed almost every year over the time period covered in this retrospective survey (1995–2017). Definitive or presumptive diagnoses of bovine babesiosis corresponded to 0.77% of all diagnoses of diseases affecting cattle in Mato Grosso do Sul, Brazil, during the period of January 1995 to December 2017.

Most of the outbreaks of bovine babesiosis were due to *B. bovis* infection. Similarly, a higher prevalence of this *Babesia* species in cases of babesiosis in cattle has been reported in previous retrospective studies conducted in Brazil and elsewhere, including Argentina, Bolivia, and Australia (Guglielmono et al., 1999; Carrique-Mas et al., 2000; Almeida et al., 2006; Jonsson et al., 2008). The higher lethality of *B. bovis* in cattle may be because this species is more pathogenic than *B. bigemina*

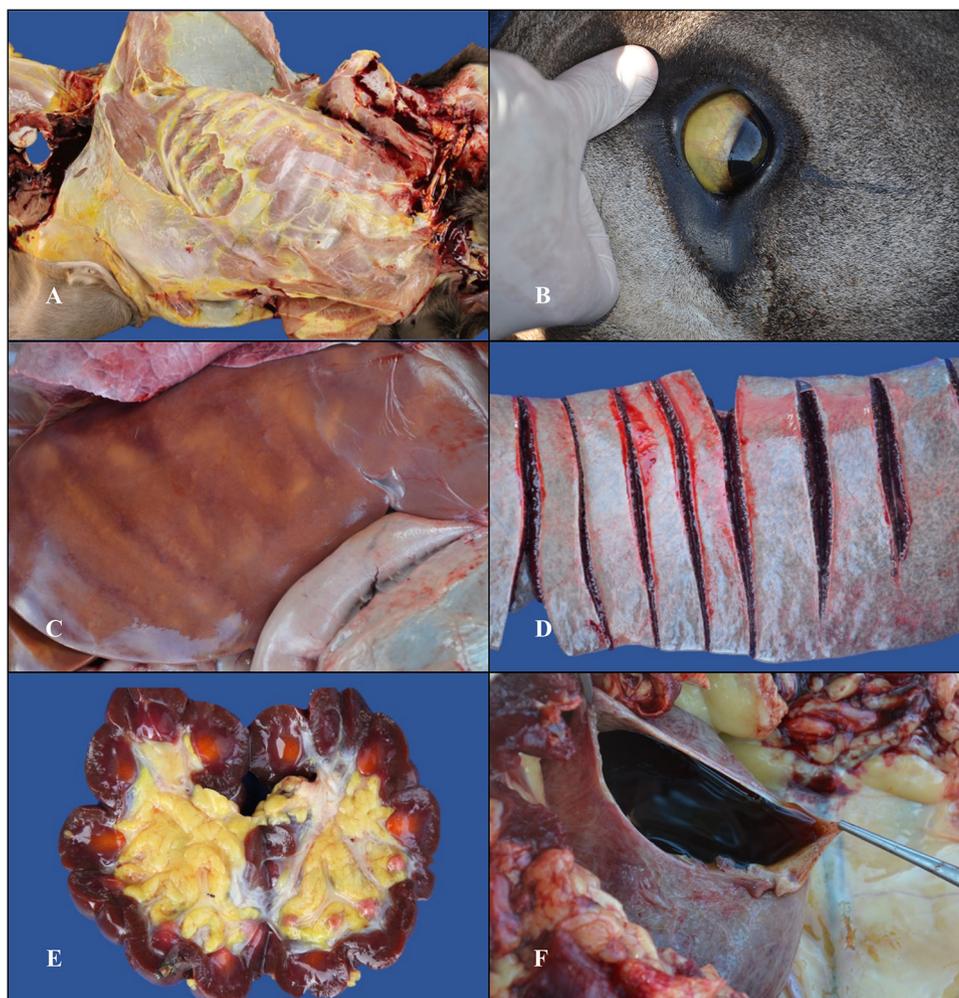


Fig. 1. Macroscopic lesions of bovine babesiosis. (A,B) – jaundice; (C) – enlarged and yellow liver; (D) – enlarged spleen (E) – dark brown kidney; (F) – dark urine.

(Bock et al., 1997, 2004; De Vos et al., 2004; Zintl et al., 2005; Spickler and Bovine babesiosis, 2008) and may be associated with hypotensive shock, coagulation disorders, and cytoadherence (Bock et al., 2004; De Vos et al., 2004). However, a higher prevalence of *B. bigemina* than *B. bovis* was reported in retrospective surveys of bovine babesiosis in Italy (Cringoli et al., 2002), Egypt (Elsify et al., 2015; Fereig et al., 2017), and Ethiopia (Abdela et al., 2018). Abdela et al. (2018) suggested that *B. bigemina* was more prevalent than *B. bovis* in Ethiopia because *B. bovis* was introduced more recently into the country than was *B. bigemina*. Fereig et al. (2017) claimed that in Egypt, *B. bigemina* prevails over *B. bovis* because of the greater number of tick vectors capable of transmitting *B. bigemina* than of those capable of transmitting *B. bovis* in that country. Our survey was based on necropsy and histopathology examinations of tissue samples and not on serological and PCR analyses of serum and blood samples, which have been reported in some previous retrospective studies on bovine babesiosis (Carrique-Mas et al., 2000; Cringoli et al., 2002; Elsify et al., 2015; Fereig et al., 2017). Therefore, we were unable to determine whether the higher frequency of *B. bovis* than of *B. bigemina* in cases of bovine babesiosis in the state of Mato Grosso do Sul is due to the former's higher prevalence in this state or its higher pathogenicity and lethality.

In the present study, outbreaks occurred during all seasons of the year: 9 outbreaks occurred during the summer, 6 occurred during the autumn, 9 occurred during the winter, and 9 occurred during the spring. Our findings are similar to previous from studies on bovine babesiosis conducted in the state of Paraíba in northeastern Brazil (Costa et al., 2011) and in the state of São Paulo in southeastern Brazil

(Gonçalves et al., 2011). Our findings differ from those reported for the state of Rio Grande do Sul in southern Brazil, in which no cases of *Babesia* spp. infection in cattle were diagnosed during the winter (Almeida et al., 2006). Additionally, in Bolivia, no cases of the disease were recorded in colder and high-altitude areas (Carrique-Mas et al., 2000). These study differences are related to the influence of climate on the life cycle of the tick vector. The state of Mato Grosso do Sul, which lies in the central-western region of the country, has a tropical climate that is characterized by rainy summers and dry winters (Aw) according to the updated of Köppen-Geiger climate classification (Kottek et al., 2006). It has monthly average temperatures above 18 °C and an average precipitation of less than 60 mm for at least 1 month of the year. Ticks that thrive under such climatic conditions are therefore able to infest cattle throughout the year (Madruca et al., 2000), increasing the chance of transmission of *Babesia* to animals by these arthropod vectors.

A similar situation occurs in Karnataka, India, which also has an Aw weather classification (Kottek et al., 2006), where cases of bovine babesiosis are diagnosed year-round (Dharanesh et al., 2017). In Zambia, a *B. bigemina* prevalence close to zero was reported during the dry season and was associated with a lower number of ticks infesting cattle than that observed during the rainy season (Simuunza et al., 2011). This African country has a warm temperate climate with dry winters and hot summers (Cwa). Average temperatures during the coldest three months of the year vary from –3 °C to 18 °C (Köppen, 1948). There is a reduction in tick populations at lower environmental temperatures; as vector numbers in the environment are low during the colder periods of the year, pathogen transmission rates are decreased during these

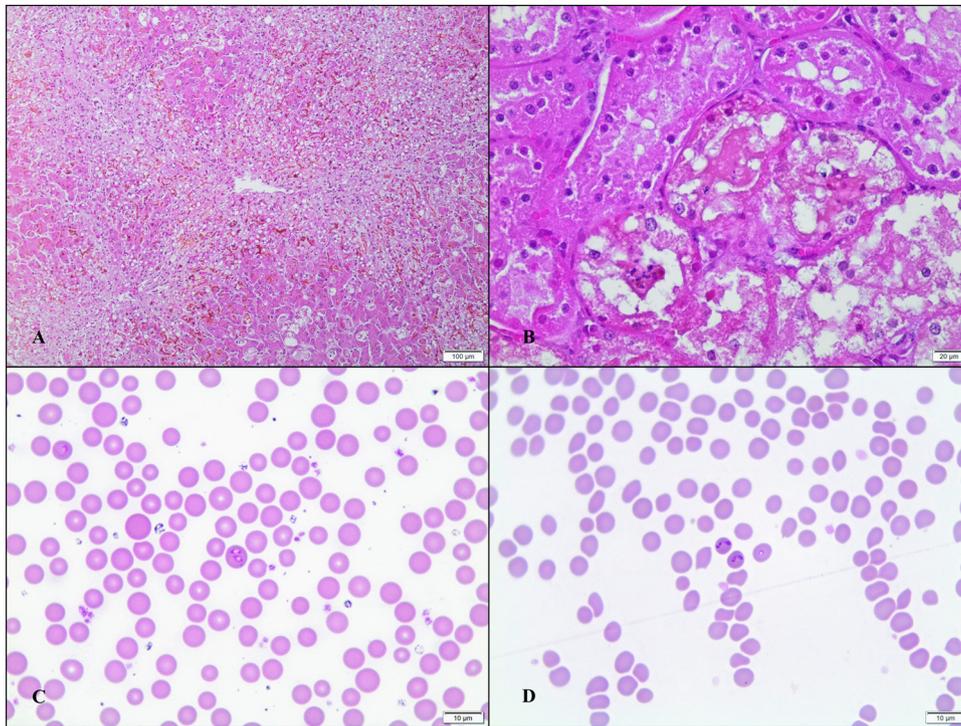


Fig. 2. Cytological findings and microscopic lesions of bovine babesiosis. (A) liver - marked centrilobular vacuolation and biliary stasis, HE; (B) kidney - acute tubular necrosis and deposition of orange pigment, HE; (C) - *Babesia bigemina*, blood smear panoptic staining; (D) - *B. bovis*, blood smear, panoptic staining.

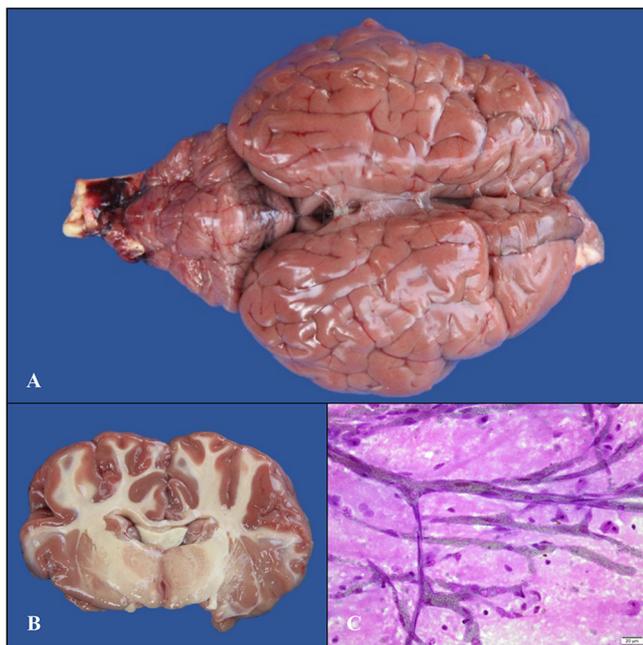


Fig. 3. Cerebral babesiosis. (A–B) pink discoloration of brain gray matter; (C) stasis of erythrocytes parasitized by *B. bovis* in capillary of brain, cytology preparation of brain and panoptic staining.

periods.

In our retrospective study, the morbidity rate of most outbreaks was less than 5% (11 disease outbreaks) and ranged from 8 to 21.6% in 6 outbreaks. In one of the outbreaks (outbreak 5), the morbidity rate reached 75%; however, in this area there were only four cattle in total. In those outbreaks in which early therapy was instituted, treated animals recovered, and there were reductions in the lethality rates. Similar outcomes have been described by other authors (Antoniassi et al.,

2009).

All age groups of cattle were affected in the outbreaks studied; 14 outbreaks involved animals up to 12 months old, and 19 outbreaks involved animals older than 12 months. An outbreak of bovine babesiosis occurred in 2-day-old calves, which suggested transplacental transmission as previously reported by other researchers (Yeruham et al., 2003). A higher prevalence of cases of *Babesia* spp. infection in adult animals than in young animals has also been observed in other regions of Brazil (Almeida et al., 2006; Antoniassi et al., 2009). In endemic areas, such as Mato Grosso do Sul in central-western Brazil, disease outbreaks and the deaths of adult animals are not expected (Gonçalves, 2000). In the present study, the deaths of animals older than 12 months of age due to babesiosis were likely due to a disruption of enzootic stability. A number of factors can breakdown the enzootic stability to babesiosis in a particular region, including poor management of cattle, which allows tick numbers to escalate and heavy tick infestations to occur, and declines in antibody levels against *Babesia* spp., as the immunity from exposure to this pathogen gradually decreases if no tick infestations are found in the herd for a certain period of time (D'Andrea et al., 2006; Farias, 2007). Other authors have suggested that even if conditions for the development and maintenance of enzootic stability to babesiosis are favorable, antigenic variations of the protozoan parasite, climate changes, variation in animal genotype, and variation in management strategies may prevent enzootic stability from arising or make it transient (Jonsson et al., 2012). This scenario could also help explain the occurrence of outbreaks of bovine babesiosis in adult animals in these areas.

Some studies suggest that calves up to 6 months of age rarely develop clinical disease because younger animals are naturally resistant to *Babesia* spp. infection (Bock et al., 2004; De Vos et al., 2004; Chauvin et al., 2009). However, in our study, there was a large number of cases of bovine babesiosis affecting animals up to 12 months old, especially calves up to 1 month of age. With the exception of one outbreak of bovine babesiosis affecting animals that died at the second day of age and in which *Babesia* spp. was presumably acquired through transplacental infection, outbreaks of the disease were likely associated with

Table 1

Number of outbreaks of babesiosis diagnosed by the Anatomic Pathology Laboratory, School of Veterinary Medicine and Animal Science from 1995 to 2017 in the state of Mato Grosso do Sul in central-western Brazil.

Case	Outbreak	Month/ year	Age	Breed	Total number of animals	Sick	Died	Note
1	1	Apr/95	8 months	Nelore	NI*	NI*	NI*	Presumptive
2	2	Jun/99	7 months	NI	500	3	3	<i>Babesia bovis</i>
3,4	3	Sep/99	24 months	Mixed	500	78	18	Cerebral babesiosis
5	4	Feb/01	15 days	Caracu	NI*	NI*	NI*	Cerebral babesiosis
6	5	Feb/02	24 months	Mixed	4	3	3	<i>B. bovis</i> and <i>B. bigemina</i>
7	6	Jan/05	9 months	Mixed	55	6	6	Presumptive
8, 9, 10, 11, 12	7	Jul/05	30 months	Nelore	895	194	20	Cerebral babesiosis
13	8	Nov/05	24 months	Brahman	NI*	NI*	NI*	Presumptive
14	9	Jan/06	24 months	Brahman	NI*	NI*	NI*	Presumptive
15	10	Sep/08	24 months	Nelore	NI*	NI*	NI*	Presumptive
16	11	Nov/08	1.5 month	Swiss Pardo	NI*	1	1	Cerebral babesiosis
17	12	Mar/09	2 days	Nelore	500	2	2	Presumptive
18	13	Mar/09	28 months	Nelore	452	10	10	Presumptive
19	14	Jul/09	12 months	Nelore	780	4	3	<i>Babesia</i> sp.
20	15	Oct/09	24 months	Brangus	5000	NI*	1	<i>Babesia bovis</i>
21	16	Mar/10	26 months	Nelore	1000	10	2	Presumptive
22	17	Mar/10	15 months	Nelore	NI*	1	1	Presumptive
23	18	Aug/10	96 months	Mixed	400	1	1	Presumptive
24	19	Nov/10	15 days	Swiss Pardo	200	1	1	Cerebral babesiosis
25	20	Mar/11	60 months	Jersey	50	4	4	Presumptive
26	21	Mar/11	24 months	Nelore	NI*	NI*	NI*	Cerebral babesiosis
27	22	Jul/11	14 months	Nelore	NI*	NI*	NI*	<i>Babesia</i> sp.
28	23	Aug/11	24 months	Nelore	218	8	7	Presumptive
29	24	Sep/11	12 months	Mixed	2000	1	1	Presumptive
30	25	Dec/11	10 days	Brahman	NI*	NI*	NI*	Presumptive
31, 32	26	Sep/15	15 days	½ Angus ½ Nelore	100	8	7	Cerebral babesiosis
33	27	Oct/15	23 days	Girolando	50	4	1	Cerebral babesiosis
34	28	Dec/15	18 months	Nelore	3500	NI*	NI*	Cerebral babesiosis
35	29	Jan/16	15 months	Braford	82	1	1	Cerebral babesiosis
36, 37, 38	30	Apr/16	36 months	Nelore	NI*	NI*	3	Cerebral babesiosis
39	31	Aug/16	15 days	Girolando	NI*	NI*	NI*	Cerebral babesiosis
40	32	Jul/17	6 months	Nelore	750	1	1	Cerebral babesiosis
41	33	Nov/17	36 months	Holstein	NI*	NI*	NI*	<i>Babesia</i> sp.

*NI = not informed.

decreasing levels of colostral antibodies starting at 20 days of age (Gonçalves, 2000; Farias, 2007) and a high tick load. Animals are most susceptible to infection between 31 and 45 days of age (Santana et al., 2008).

In our survey, the majority of the cases of bovine babesiosis occurred in zebu-derived animals, mainly those of the Nelore breed. This finding should be interpreted with caution since this particular cattle breed outnumbers the other breeds in bovine herds from the study area (Souza, 2010). There was no statistically significant difference in the

occurrence of babesiosis between zebuine and non-zebuine animals. These findings demonstrate that all breeds of cattle in the geographic area studied are susceptible to *Babesia* spp. Although it has been claimed that *Bos indicus* is relatively resistant to tick infestations and to babesiosis (Bock et al., 1997, 1999a, b; Gonçalves, 2000; Bock et al., 2004; De Vos et al., 2004; Almeida et al., 2006; Jonsson, 2006; Farias, 2007; Jonsson et al., 2008; Spickler and Bovine babesiosis, 2008; Antoniasse et al., 2009; Costa et al., 2011), they can still develop severe illness and die due *Babesia* spp. infection.

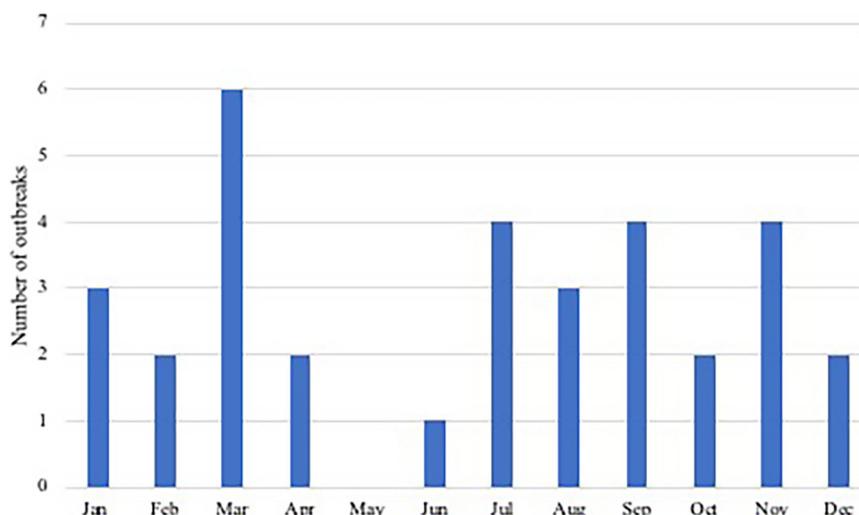


Fig. 4. Number of outbreaks of babesiosis diagnosed by Anatomic Pathology Laboratory, School of Veterinary Medicine and Animal Science (Campo Grande, state of Mato Grosso do Sul, central-western Brazil) from January 1995 until December 2017 according to the month of babesiosis diagnosis.

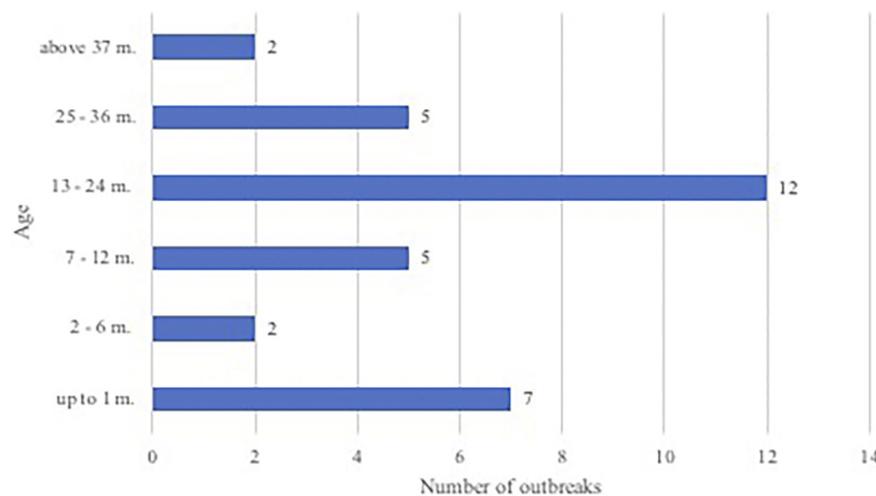


Fig. 5. Number of outbreaks of babesiosis diagnosed by Anatomic Pathology Laboratory, School of Veterinary Medicine and Animal Science (Campo Grande, state of Mato Grosso do Sul, central-western Brazil) from January 1995 until December 2017 according to the age of the animals affected.

Table 2

Number of outbreaks of babesiosis diagnosed by Anatomic Pathology Laboratory, School of Veterinary Medicine and Animal Science (Campo Grande, state of Mato Grosso do Sul, Brazil) from 1995 to 2017 and clinical signs.

Clinical sign	Total number of cases	%
Apathy	17	41
Incoordination	16	39
Tremors	10	24
Dark urine	9	21
Behavioral changes/ aggressive behavior	6	15
Blindness	5	12
Drooling	5	12
Opisthotonus	4	10
Icteric mucous membranes	4	10
Paddling	4	10
Tachypnea/dyspnea	4	10
Pale mucous membranes	4	10
Anorexia	4	10
Wobbling/circling	4	10
Nystagmus	3	7
Lacrimation, droopy ears, unthrifty, dull, rough haircoat, fever, tachycardia	2	5

Table 3

Number of outbreaks of babesiosis diagnosed by Anatomic Pathology Laboratory, School of Veterinary Medicine and Animal Science (Campo Grande, state of Mato Grosso do Sul, Brazil) from 1995 to 2017 and necropsy findings.

Gross lesion (necropsy finding)	Total number of cases	%
Yellow, swollen, enlarged liver	24	59
Dark urine	23	56
Enlarged spleen (splenomegaly)	22	54
Icterus (jaundice)	19	46
Dusky pink discoloration (congestion) of the gray matter of the brain (cerebral cortex, telencephalon)	19	46
Good nutritional status	17	41
Dark kidneys	15	37
Serosal petechiae and ecchymoses	15	37
Pale carcass	13	32
Tick infestation	11	27
Diffuse congestion of all organs	1	2
Not informed	3	7

The higher prevalence of this disease in zebu breeds could be because they are the predominant cattle breeds in Mato Grosso do Sul, central-western Brazil, where this study was carried out. The higher

prevalence may also be associated with lower protective antibody levels against *Babesia* spp. In zebu animals than in *B. taurus* animals raised in the same region (Jonsson et al., 2008). Seroprevalence studies have shown that Nelore herds have lower antibody levels against *Babesia* spp., especially against *B. bigemina*, than do Holstein herds (D'Andrea et al., 2006), which corroborates these hypotheses. Zebu cattle are highly efficient in removing tick larvae from their coats during the first 24 h of tick infestation by licking themselves. Vigorous self-grooming likely interrupts the life cycle of the tick vector for *B. bigemina*, thereby precluding protozoa infection and, therefore, decreasing antibody levels against this piroplasm (D'Andrea et al., 2006; Jonsson et al., 2008).

An outbreak (outbreak 26) occurred in calves of 50% *Bos indicus* lineages. Some authors claim that breeding cows of 50% *Bos indicus* heritage can be expected to give rise to offspring that are more resistant to *Babesia* spp. than are pure taurine animals. This breeding strategy can be expected to result in a significant decrease in the number of cases of bovine babesiosis (Bock et al., 1999a, b; Bock et al., 2004). In contrast, in another study of bovine babesiosis, animals of 25% *Bos indicus* heritage were affected less often by this disease than were pure *Bos taurus* animals. However, the inclusion of zebu breeds in cattle breeding programs is insufficient to reduce the overall economic losses associated with *B. bovis* infections (Bock et al., 1997). In addition, lower tick infestations in crossbred cattle results in lower infection rates. As a result, these animals do not reach a minimum antibody level to achieve enzootic stability (Mahoney et al., 1981). There is variation in the individual susceptibility of animals to *Babesia* spp. infection within the same herd and among breeds (Bock et al., 1999a; Benavides and Sacco, 2007). In naive zebu cattle introduced into pastures with large numbers of *Babesia*-infected ticks, high transmission rates of this pathogen can result in the disease and/or death of these animals (Bock et al., 1999b, 2004; Jonsson et al., 2008). Such a scenario occurred in outbreak 28, in which Nelore cattle were moved within the state of Mato Grosso do Sul from Pantanal to the city of Nova Andradina. This geographic region is considered an area of enzootic instability due to the floods that occur during the rainy season (from November to March). Flooding occurs between 30 and 60 days after the onset of moderate to heavy rains (Rodela and Neto, 2007) and interferes with the development of the free-living stages of the tick, limiting reproduction of this arthropod.

In the present retrospective study, the clinical signs, necropsy and microscopic findings of cases of bovine babesiosis diagnosed by our laboratory were similar to those reported in the veterinary literature (Bock et al., 2004; De Vos et al., 2004; Rodrigues et al., 2005; Almeida et al., 2006; Farias, 2007; Jonsson et al., 2008; Spickler and Bovine babesiosis, 2008; Antoniassi et al., 2009).

Although the disease occurred nearly every year during the last 23 years of diagnostic activities in our laboratory covered in this retrospective survey, the number of cases of bovine babesiosis diagnosed was low relative to the total number of cases reviewed. Furthermore, the number of cases was lower than that reported in the southern region of Brazil (Almeida et al., 2006). Since central-western Brazil is an endemic area for babesiosis and because southern Brazil has enzootic instability, a higher number of cases and, consequently, a higher number of deaths are expected in the latter region. The total number of animals affected in each outbreak of bovine babesiosis is generally low. However, disease outbreaks involving large numbers of animals may also occur, e.g., outbreak 3 and outbreak 7. This observation is in agreement with the statement made by Guglielmo in his review article published in 1995 that outbreaks of babesiosis are often overestimated. Veterinary practitioners that work at cattle farms should be familiar with the epidemiology, clinical signs, and necropsy findings of bovine babesiosis and be able to diagnose the disease in its early stages. Treatment should be initiated promptly so that the economic losses related to the illness and death of animals can be minimized between the first manifestations of the disease and the release of laboratory results.

Conflict of interest

The authors declare that they have no competing interests.

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References

- Abdela, N., Ibrahim, N., Begna, F., 2018. Prevalence, risk factors and vectors identification of bovine anaplasmosis and babesiosis in and around Jimma town, Southwestern Ethiopia. *Acta Trop.* 177, 9–18.
- Almeida, M.B., Tortelli, F.P., Riet-Correa, B., Ferreira, J.L.M., Soares, M.P., Farias, N.A.R., Riet-Correa, F., Schild, A.L., 2006. Tick fever in southern Brazil: a retrospective study of 1978–2005. *Pesqui. Vet. Bras.* 26, 237–242 (article published in Portuguese).
- Antonassi, N.A.B., Corrêa, A.M.R., Santos, A.S., Pavarini, S.P., Sonne, L., Bandarra, P.M., Driemeier, D., 2009. Cerebral babesiosis outbreak in bovines in the State of Rio Grande do Sul, Brazil. *Ciênc. Rural.* 39, 933–936 (article published in Portuguese).
- Benavides, M.V., Sacco, A.M.S., 2007. Differential *Bos taurus* cattle response to *Babesia bovis* infection. *Vet. Parasitol.* 150, 54–64.
- Bock, R.E., De Vos, A.J., Kingston, T.G., McLellan, D.J., 1997. Effect of breed of cattle in innate resistance to infection with *Babesia bovis*, *B. bigemina* and *Anaplasma marginale*. *Aust. Vet. J.* 75, 337–340.
- Bock, R.E., Kingston, T.G., Standfast, N.F., De Vos, A.J., 1999a. Effect of cattle breed on innate resistance to inoculations of *Babesia bigemina*. *Aust. Vet. J.* 77, 465–466.
- Bock, R.E., Kingston, T.G., De Vos, A.J., 1999b. Effect of breed of cattle on transmission rate and innate resistance to infection with *Babesia bovis* and *B. bigemina* transmitted by *Boophilus microplus*. *Aust. Vet. J.* 77, 461–464.
- Bock, R., Jackson, L., De Vos, A., Jorgensen, W., 2004. Babesiosis of cattle. *Parasitology* 129, S247–S269.
- Carrique-Mas, J.J., Widdowson, M.A., Cuéllar, A.M., Ribera, H., Walker, A.R., 2000. Risk of babesiosis and anaplasmosis in different ecological zones of Santa Cruz Department. Bolivia. *Vet. Parasitol.* 93, 29–38.
- Chauvin, A., Moreau, E., Bonnet, S., Plantard, O., Malandrin, L., 2009. Babesia and its hosts: adaptation to long-lasting interactions as a way to achieve efficient transmission. *Vet. Res.* 40, 1–18.
- Costa, V.M.M., Rodrigues, A.L., Medeiros, J.M.A., Labruna, M.B., Simões, S.V.D., Riet-Correa, F., 2011. Cattle tick fever in the semiarid region of the Brazilian state of Paraíba. *Pesqui. Vet. Bras.* 31, 239–243 (article published in Portuguese).
- Cringoli, G., Otranto, D., Testini, G., Buono, V., Di Giulio, G., Traversa, D., Lia, R., Rinaldi, L., Veneziano, V., Puccini, V., 2002. Epidemiology of bovine tick-borne diseases in Southern Italy. *Vet. Res.* 33, 421–426.
- D'Andrea, L.A.Z., Sartor, I.F., Madruga, C.R., Freitas, S.B.Z., Kroll, L.B., Kronka, S.N., 2006. Immunological condition of cattle in Holstein and Nelore breed in regard to *Babesia bovis* and *B. bigemina* in two regions of the state of São Paulo. *Pesqui. Vet. Bras.* 26, 74–78 (article published in Portuguese).
- De Vos, A.J., De Wall, D.T., Jackson, L.A., 2004. Bovine babesiosis. In: Coetzer, J.A.W., Tustin, R.C. (Eds.), *Infectious Diseases of Livestock*, 2nd ed. Oxford Southern Africa, South Africa, pp. 406–420.
- Dharanesh, N.K., Giridhar, P., Byregowda, S.M., Venkatesh, M.D., Ananda, K.J., 2017. Seasonal prevalence of blood parasitic diseases in crossbred cattle of Mysore and its surrounding districts of Karnataka. *J. Parasit. Dis.* 41, 773–777.
- Elsify, A., Sivakumar, T., Nayel, M., Salama, A., Elkhtam, A., Rizk, M., Mosaab, O., Sultan, K., Elsayed, S., Igarashi, I., Yokoyama, N., 2015. An epidemiological survey of bovine *Babesia* and *Theileria* parasites in cattle, buffaloes, and sheep in Egypt. *Parasitol. Int.* 64, 79–85.
- Farias, N.A., 2007. Cattle tick fever. In: 3rd ed. In: Riet-Correa, F., Schild, A.L., Lemos, R.A.A., Borges, J.R.J. (Eds.), *Doenças de Ruminantes e equídeos*. 2. Pallotti, Santa Maria, pp. 524–532 (Chapter published in Portuguese).
- Fereig, R.M., Mohamed, S.G.A., Mahmoud, H.Y.A.H., Aboulaila, M.R., Guswanto, A., Nguyen, T., Mohamed, A.E.A., Inoue, N., Igarashi, I., Nishikawa, Y., 2017. Seroprevalence of *Babesia bovis*, *B. bigemina*, *Trypanosoma evansi*, and *Anaplasma marginale* antibodies in cattle in Southern Egypt. *Ticks Tick Borne Dis.* 8, 125–131.
- Gonçalves, P.M., 2000. Epidemiology and control of bovine babesiosis and anaplasmosis in Southeast region of Brazil. *Ciênc. Rural.* 30, 187–194 (article published in Portuguese).
- Gonçalves, R.C., Silva, A.A., Ferreira, D.O.L., Chiacchio, S.B., Lopes, R.S., Borges, A.L., Amorim, R.M., 2011. Tick fever in cattle in the region of Botucatu – SP: a retrospective study of 1986–2007. *Semina Ciênc. Agrárias.* 32, 307–312 (article published in Portuguese).
- Guglielmo, A.A., 1995. Epidemiology of babesiosis and anaplasmosis in South and Central America. *Vet. Parasitol.* 57, 109–119.
- Guglielmo, A.A., Aguirre, D.H., Späth, E.J.A., Gaido, A.B., Mangold, A.J., Ríos, L.G., 1999. Long-term study of incidence and financial loss due to cattle babesiosis in a Argentinian dairy farm. *Prev. Vet. Med.* 12, 307–312.
- Jonsson, N.N., 2006. The productivity effects of cattle tick (*Boophilus microplus*) infestation on cattle, with particular reference to *Bos indicus* cattle and their crosses. *Vet. Parasitol.* 137, 1–10.
- Jonsson, N.N., Bock, R.E., Jorgensen, W.K., 2008. Productivity and health effects of anaplasmosis and babesiosis on *Bos indicus* cattle and their crosses, and the effects of differing intensity of tick control in Australia. *Vet. Parasitol.* 155, 1–9.
- Jonsson, N.N., Bock, R.E., Jorgensen, W.K., Morton, J.M., Stear, M.J., 2012. Is endemic stability of tick-borne disease in cattle a useful concept? *Trends Parasitol.* 28, 85–89.
- Köppen, W., 1948. *Climatology With a Study of the Climates of the Earth*. México, 496 p. (article published in Spanish).
- Kottek, M., Grieser, J., Beck, C., Rudolf, B., Rubel, F., 2006. World Map of the Köppen-Geiger climate classification updated. *Meteorol. Zeith.* 15, 259–263.
- Lucena, R.B., Pierezan, F., Kommers, G.D., Irigoyen, L.F., Figuera, R.A., Barros, C.S.L., 2010. Diseases of cattle in southern Brazil: 6706 cases. *Pesqui. Vet. Bras.* 30, 428–434 (article published in Portuguese).
- Madruga, C.R., Araújo, F.R., Marques, A.P.C., Carvalho, C.M.E., Cusinato, F.Q., Crocci, A.J., Kessler, R.H., Miguita, M., 2000. Development of an enzyme-linked immunosorbent assay for the detection of antibodies against *Babesia bovis*. *Pesqui. Vet. Bras.* 20, 167–170 (article published in Portuguese).
- Mahoney, D.F., Wright, I.G., Goodger, B.V., Mirre, G.B., Sutherst, R.W., Utech, K.B.W., 1981. The transmission of *Babesia bovis* in herds of European and Zebu x European cattle infested with the tick, *Boophilus microplus*. *Aust. Vet. J.* 57, 461–469.
- Potgieter, F.T., 1977. The Life Cycle of *Babesia Bovis* and *Babesia Bigemina* in Ticks and in Cattle in South Africa [PhD Thesis]. Rand Afrikaans University, Johannesburg.
- Rissi, D.R., Pierezan, F., Oliveira-Filho, J.C., Lucena, R.B., Carmo, P.M.S., Barros, C.S.L., 2010. Diagnostic approaches for the main neurological diseases of ruminant and horses in Brazil. *Pesqui. Vet. Bras.* 30, 958–967 (article published in Portuguese).
- Rodella, L.G., Neto, J.P.Q., 2007. Climate seasons on Nhecolândia Pantanal, Mato Grosso do Sul state. Brazil. *Rev. Bras. Cartografia.* 59, 101–113 (article published in Portuguese).
- Rodrigues, A., Rech, R.R., Barros, R.R., Figuera, R.A., Barros, C.S.L., 2005. Cerebral babesiosis in cattle: 20 cases. *Ciênc. Rural.* 35, 121–125.
- Santana, A.P., Linhares, G.F.C., Murata, L.S., Bernal, F.E., Torres, F.A., Madruga, C.R., 2008. Dynamic of natural infection in newborn calves exposed to by *Babesia bigemina* as detected by polymerase reaction chain. *Ciênc. Anim. Bras.* 9, 721–730 (article published in Portuguese).
- Simunza, M., Weir, W., Courcier, E., Tait, A., Shiels, B., 2011. Epidemiological analysis of tick-borne diseases in Zambia. *Vet. Parasitol.* 175, 331–342.
- Souza, C.B.M., 2010. Beef cattle in state Mato Grosso do Sul: Evolution and competitiveness. [Master thesis]. Universidade Estadual de Campinas, Campinas (published in Portuguese).
- Spickler, A.R., Bovine babesiosis. 2008. <http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php> (accessed 30 October 2017).
- Valli, V.E.O., Kiupel, M., Bienzle, D., 2017. Hematopoietic system. In: 6th ed. In: Maxie, M.G. (Ed.), *Jubb, Kennedy, and Palmer's – Pathology of Domestic Animals* 3. Elsevier, St. Louis, pp. 117–120.
- Yeruham, I., Avidar, Y., Aroch, I., Hadani, A., 2003. Intra-uterine infection with *Babesia bovis* in a 2-day-old calf. *J. Vet. Med.* 50, 60–62.
- Zintl, A., Gra, J.S., Skerret, H.E., Mulcahy, G., 2005. Possible mechanisms underlying age-related resistance to bovine babesiosis. *Parasite Immunol.* 27, 115–120.