Pesq. Vet. Bras. 37(8):820-828, agosto 2017

Suppurative infectious diseases of the central nervous system in domestic ruminants[1]

Guilherme Konradt[2], Daniele M. Bassuino[2], Klaus S. Prates[2], Matheus V. Bianchi[2], Gustavo G.M. Snel[2], Luciana Sonne[2], David Driemeier[2] and Saulo P. Pavarini[2]*

ABSTRACT.- Konradt G., Bassuino D.M., Prates K.S., Bianchi M.V., Snel G.G.M., Sonne L., Driemeier D. & Pavarini S.P. 2017. **Suppurative infectious diseases of the central nervous system in domestic ruminants**. *Pesquisa Veterinária Brasileira 37(8):820-828*. Setor de Patologia Veterinária, Departamento de Patologia Clínica Veterinária, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9090, Prédio 42505, Porto Alegre, RS 91540-000, Brazil. E-mail: saulo.pavarini@ufrgs.br

This study describes suppurative infectious diseases of the central nervous system (CNS) in domestic ruminants of southern Brazil. Reports from 3.274 cattle, 596 sheep and 391 goats were reviewed, of which 219 cattle, 21 sheep and 7 goats were diagnosed with central nervous system inflammatory diseases. Suppurative infectious diseases of the CNS corresponded to 54 cases (28 cattle, 19 sheep and 7 goats). The conditions observed consisted of listerial meningoencephalitis (8 sheep, 5 goats and 4 cattle), suppurative leptomeningitis and meningoencephalitis (14 cattle, 2 goats and 1 sheep), cerebral (6 cattle and 2 sheep), and spinal cord (7 sheep) abscesses, and basilar empyema (4 cattle and 1 sheep). Bacterial culture identified *Listeria monocytogenes* (9/54 cases), *Escherichia coli* (7/54 cases), *Trueperella pyogenes* (6/54 cases) and *Proteus mirabilis* (1/54 cases). All cases diagnosed as listeriosis through histopathology yielded positive immunostaining on immunohistochemistry, while 12/17 of the cases of suppurative leptomeningitis and meningoencephalitis presented positive immunostaining for *Escherichia coli*. Meningoencephalitis by *L. monocytogenes* was the main neurological disease in sheep and goats, followed by spinal cord abscesses in sheep. In cattle, leptomeningitis and suppurative meningoencephalitis was the most frequent neurological disease for the species, and *E. coli* was the main cause of these lesions. Basilar empyema, mainly diagnosed in cattle, is related to traumatic injuries, mainly in the nasal cavity, and the main etiologic agent was *T. pyogenes.*

INDEX TERMS: Infectious diseases, central nervous system, diseases of ruminants, neuropathology, suppurative meningitis, listeriosis, cerebral and spinal cord abscesses.

RESUMO.- [**Doenças infecciosas supurativas do sistema nervoso central de ruminantes domésticos.**] Neste trabalho são descritas as doenças neurológicas infecciosas supurativas de ruminantes domésticos na Região Sul do Brasil. Foram avaliados laudos de 3.274 bovinos, 596 ovinos e 391 caprinos, dos quais 219 bovinos, 21 ovinos e sete caprinos foram diagnosticados como doenças inflamatórias no sistema nervoso central. As doenças neurológicas infecciosas supurativas corresponderam a 54 casos (28 bovinos, 19 ovinos e sete caprinos). As enfermidades observadas foram meningoencefalite por *Listeria monocytogenes* (oito ovinos, cinco caprinos e quatro bovinos), leptomeningite e meningoencefalite supurativa (14 bovinos, dois caprinos e um ovino), abscessos cerebrais (seis bovinos e dois ovinos) e medulares (sete ovinos); e empiema basilar (quatro bovinos e um ovino). Através do isolamento bacteriano foram identificados: *L. monocytogenes* (9/54 casos), *Echerichia coli* (7/54 casos), *Trueperella pyogenes* (6/54 casos) e *Proteus mirabilis* (1/54 casos). Todos os casos diagnosticados como listeriose por histologia foram positivos na imuno-histoquímica para *L. monocytogenes*, e 12/17 casos de leptomeningite e meningoencefalite supurativa foram positivos na imuno-histo-

[1] Received on March 21, 2017.
Accepted for publication on March 24, 2017.

[2] Departamento de Patologia Clínica Veterinária, Setor de Patologia Veterinária, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul (UFRGS), Avenida Bento Gonçalves 9090, Prédio 42505, Porto Alegre, RS 91540-000, Brazil. *Bolsista da CAPES. **Corresponding author: saulo.pavarini@ufrgs.br

química para *E. coli.* A meningoencefalite por *L. monocytogenes* representou a principal enfermidade neurológica em ovinos e caprinos, seguido dos abscessos medulares em ovinos. A leptomeningite e meningoencefalite supurativa foi a doença neurológica supurativa mais frequente em bovinos e o principal agente causador da lesão foi *E. coli.* O empiema basilar, frequentemente, diagnosticado em bovinos, foi relacionado com lesões traumáticas, principalmente, de cavidade nasal e o principal agente causador foi *T. pyogenes*.

TERMOS DE INDEXAÇÃO: Doenças infecciosas, sistema nervoso central, doenças de ruminantes, neuropatologia, meningites supurativas, listeriose, abscessos cerebrais e medulares.

INTRODUCTION

Central nervous system (CNS) diseases affecting domestic ruminants comprise conditions that cause economic losses globally, and bacterial infections are important causes of mortality and, also, neurological disturbances of livestock animals (Fecteau et al. 1997, Kessell et al. 2011, Allen et al. 2013). The main inflammatory neurological diseases caused by bacteria in ruminants are: listeriosis, suppurative leptomeningitis and meningoencephalitis, cerebral and spinal cord abscesses, basilar empyema and neurotuberculosis (Loretti et al. 2003, Rissi et al. 2010, Câmara et al. 2014, Konradt et al. 2016). CNS may be affected by infectious agents through four paths: from hematogenous or lymphatic dissemination deriving from distant sites (Morin 2004, Stöber 2005); direct penetrating lesions; through an adjacent suppurative lesion; or centripetal ascending infection through peripheral nerves (Barros et al. 2006 2006, Radostits et al. 2007). *L. monocytogenes* is an important cause of encephalitis in ruminants, yet *Escherichia coli*, *Salmonella* sp. and *Pasteurella* sp. are relevant causes of encephalitis in calves (Vandevelde et al. 2012), as well as *Streptococcus* sp., *Staphylococcus* sp. and *Trueperella pyogenes* in sheep and goat (Fecteau & George 2004, Filioussis et al. 2013). This study aims to describe the suppurative infectious diseases affecting the CNS of domestic ruminants in Rio Grande do Sul state, Brazil.

MATERIAL AND METHODS

A retrospective study of the necropsy and anatomopathological database of domestic ruminants was conducted in search of suppurative infectious neurological diseases (SIND) diagnoses from January 1996 to December 2015. All animals were from Rio Grande do Sul state, Brazil, mainly from the metropolitan area of Porto Alegre. Epidemiological, pathological and diagnostic methods [bacterial culture and/or immunohistochemistry (IHC)] data were reviewed and grouped according to the main SIND of cattle, sheep and goats. CNS sections were submitted to IHC for *L. monocytogenes*, when listeriosis was suspected, and for *E. coli* in suppurative leptomeningitis and meningoencephalitis cases.

Bacterial culture consisted in inoculate the suspected tissue fragments and abscesses contents in Blood agar plates (5% sheep blood, Columbia base, Kasvi®, Brazil) and MacConkey agar (Kasvi®, Brazil) incubated aerobically at 37ºC for 72 hours. Additionally, samples of suspected listeriosis cases were processed through the enrichment method at 4ºC (Markey et al. 2013) and at 30ºC with the employment of selective Broth and Agar growth media (UVM *Listeria* Broth, DIFCO®, USA, e PALCAM Agar, Oxoid®, UK). The identification of the agents was based on morpho-tinctorials, culture and biochemistry features of the isolates.

For the IHC exams, a monoclonal anti-*L. monocytogenes* antibody (BD®, New Jersey, USA) and a polyclonal anti-*E. coli* antibody (Rabbit Antibody to *E .coli* 1001-Virostat-USA) were employed, at a dilution of 1:200 in phosphate buffered saline solution (PBS). Antigenic retrieval was obtained with Citrate buffer pH 6.0 for 10 min at maximum potency in microwave, and unspecific reactions were blocked with 5% skimmed milk. Both primary antibodies were incubated overnight at room temperature, followed by biotin-conjugated antibody (LSAB-HRP) and streptavidin-peroxidase (LSAB-HRP) for 20 min each. Revelation was obtained with 3-amino-9-ethylcarbazole (AEC) chromogen, followed by Mayers hematoxylin for counterstain and slides were mounted in aqueous media. Positive controls were previously tested sections of *E. coli* enteritis and *L. monocytogenes* meningoencephalitis that were inserted simultaneously with the tested sections. As negative controls, sections were incubated with PBS instead of the primary antibody.

RESULTADOS

In the analyzed period, gross and histopathological reports of necropsies and mailed in materials of 3,274 cattle, 596 sheep and 391 goats were evaluated. Of these 219 cattle, 21 sheep and seven goats were diagnosed with inflammatory diseases at the CNS (total of 247 cases). The SIND accounted for 54 cases, which affected 28 cattle, 19 sheep and seven goats, and were further divided on *L. monocytogenes* meningoencephalitis (eight sheep, five goats and four cattle), suppurative leptomeningitis and meningoencephalitis (14 cattle, two goats and one sheep), cerebral (6 cattle and 2 sheep) and spinal cord (7 sheep) abscesses and basilar empyema (four cattle and one sheep).

Listeria monocytogenes meningoencephalitis

Most of the listeriosis cases were diagnosed in sheep (8/19 cases), followed by goats (5/7 cases) and cattle (4/28 cases). The average age was of 18 months for sheep and goats, whilst for cattle it was 24 months. No breed or sex predisposition was observed. Animals were consuming poor quality corn silage (pH > 5.5) in eight cases (four cattle, three goats and one sheep). Gross lesions on the CNS consisted of mild to marked hyperemia of leptomeningeal blood vessels (Fig.1A). Histological examination revealed a meningoencephalitis affecting mainly the rhombencephalon (17/17), sometimes extending to the mesencephalon (12/17), diencephalon (9/17) and cerebellar white matter (3/17). These lesions were composed by a perivascular inflammatory infiltrate of lymphocytes, macrophages and plasma cells (Fig.1B), besides multifocal random areas at the neuropil of degenerate neutrophils infiltrate (microabscesses, Fig.1C). These areas also presented numerous Gitter cells, neuronal necrosis, neuronophagia and axonal spheroids on the white matter. In three cases (2 sheep and 1 goat) intralesional bacillary basophilic bacterial structures were observed at HE (Fig.1D). All cases presented mild infiltrate of macrophages and lymphocytes at the leptomeninges. Bacterial culture was obtained in nine cases (four goats, three sheep and two cattle). On IHC for *L. monocyto-*

genes, all cases presented a mild to marked pinpoint immunostaining mainly in the cytoplasm of neutrophils and macrophages, and occasionally free on the neuropil adjacent to the lesions (Fig.1E). Another pattern of immunostaining was observed in three cases where the bacteria was seen through HE stain, and it consisted of immunostaining of free bacteria on the neuropil (Fig.1F).

Suppurative leptomeningitis and meningoencephalitis

Suppurative leptomeningitis and meningoencephalitis were diagnosed more frequently in cattle (14/28 cases), followed by goats (2/7 cases) and sheep (1/19 cases). Data regarding species, age, sex, breed, extraneural lesions and bacterial culture are presented on Table 1. Grossly, lesions affected mainly the leptomeninges of the CNS and consisted of opacity, hyperemia and mild to moderate fibrin deposition over these surfaces (Fig.2A). Additionally, malacic areas were observed in one bovine, which were characterized by multifocal irregular greyish cavitations that extended from striated body to diencephalon (Fig.2B). Histologically, the leptomeninges presented a marked inflammatory infiltrate composed by healthy and degenerated neutrophils, besides mild to moderate infiltrate of macrophages, lymphocytes and plasma cells, associated to fibrin deposition

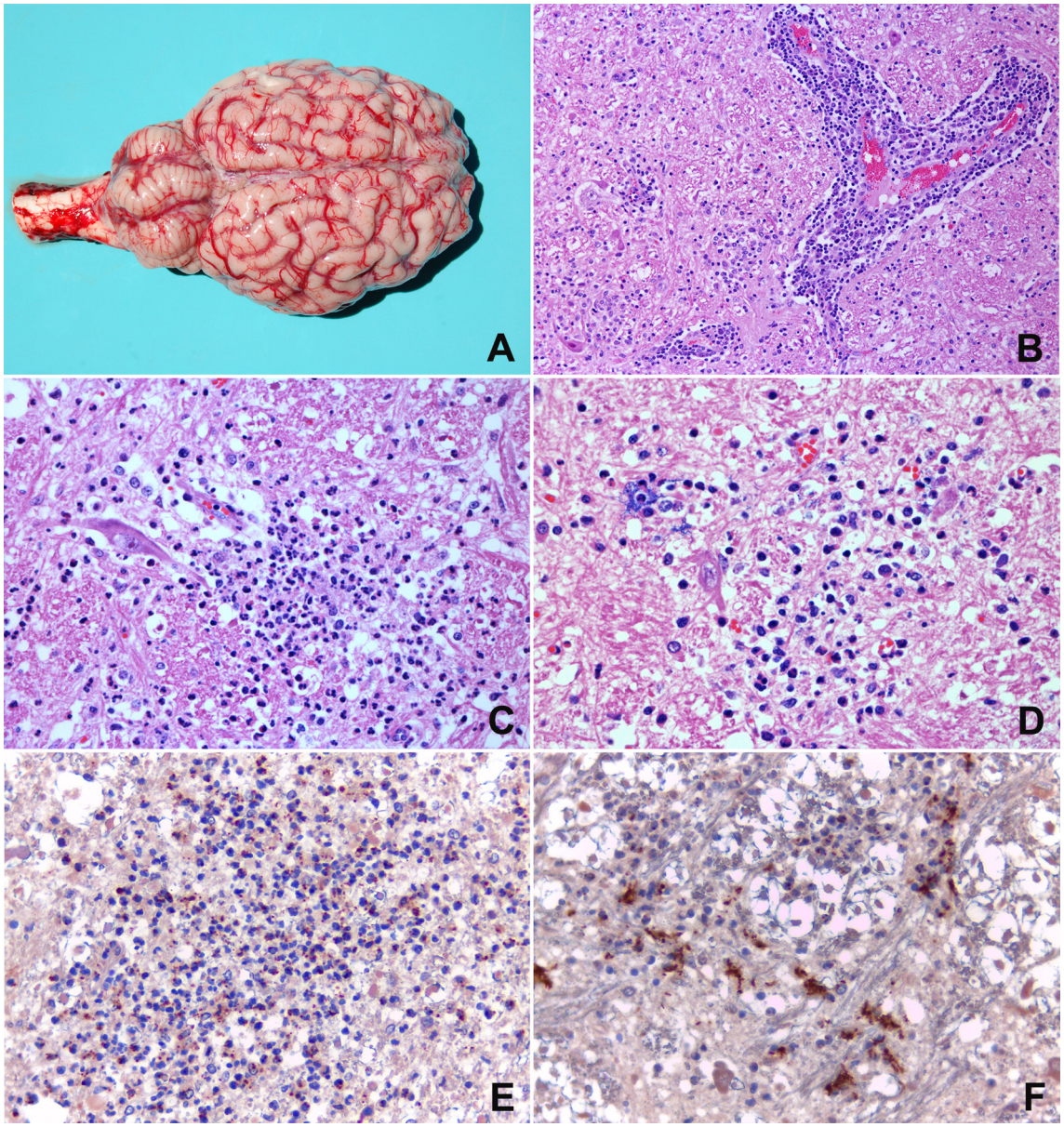

Fig.1. *Listeria monocytogenes* meningoencephalitis in ruminants. (**A**) Goat. Marked hyperemia of blood vessels at the leptomeninges of the brain. (**B**) Cattle. Marked perivascular inflammatory infiltrate of lymphocytes, macrophages and plasma cells. HE, 200x. (**C**) Sheep. Multifocal random areas in neuropile of inflammatory infiltrate composed by degenerated neutrophils (microabscesses). HE, obj.40x. (**D**) Sheep. Numerous bacillary basophilic bacterial structures in neuropile associated to multifocal infiltrate of neutrophils. HE, obj.20x. (**E**) Goat. Immunohistochemistry (IHC) for *L. monocytogenes* showing pinpoint immunostaining mainly in the cytoplasm of neutrophils and macrophages. AEC chromogen, obj.40x. (**F**) Sheep. IHC for *L. monocytogenes*. Immunostaining of bacillary structures that were evident on HE. AEC chromogen, obj.40x.

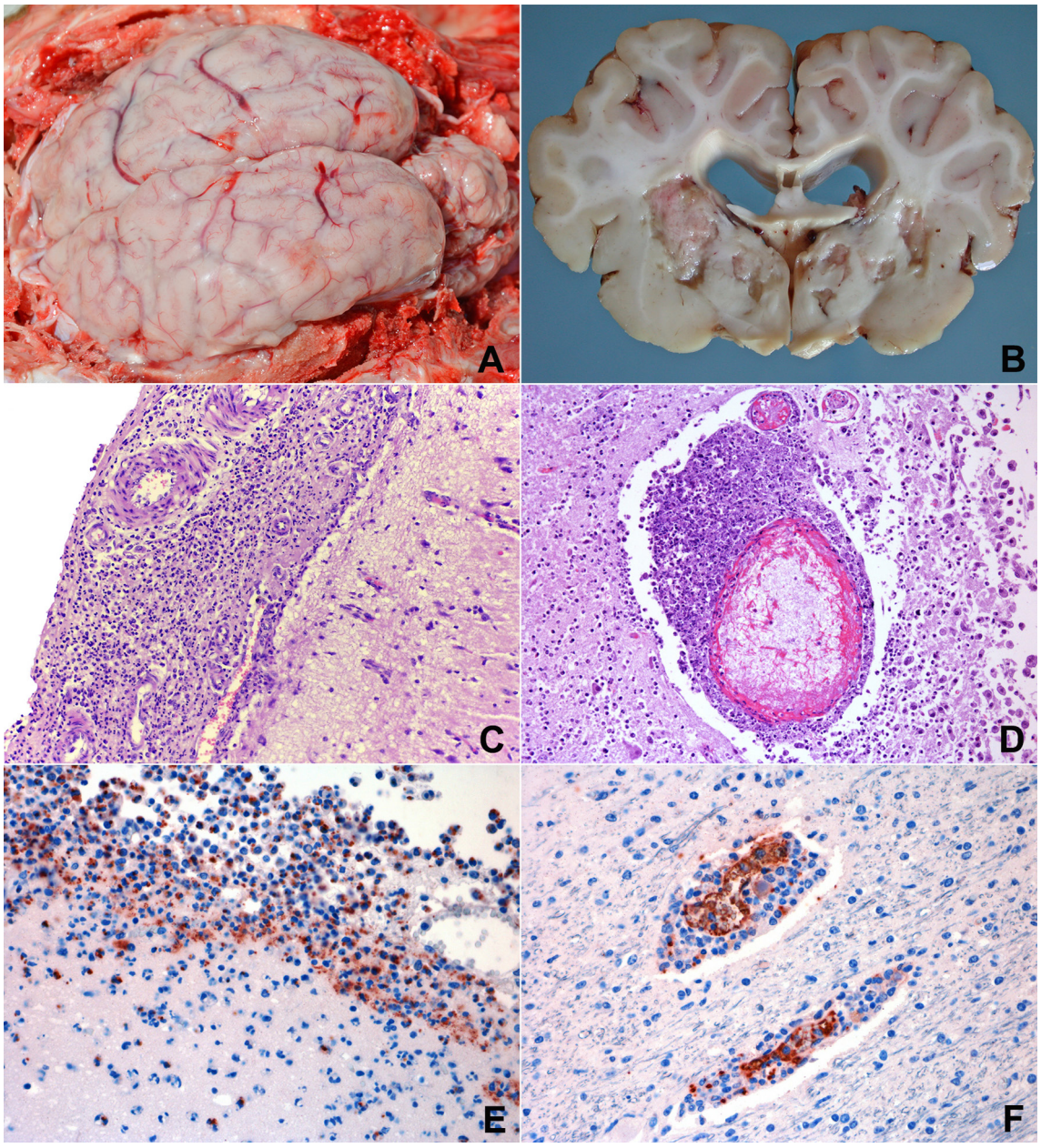

Fig.2. **Suppurative meningitis and meningoencephalitis in cattle.** (**A**) Diffuse deposition of yellowish friable material (fibrin) over the leptomeningeal surface. (**B**) Multifocal areas of malacia characterized by irregular greyish cavitations in striated body. (**C**) Marked inflammatory infiltrate of healthy and degenerated neutrophils, besides mild infiltrate of macrophages, lymphocytes and plasma cells, associated to fibrin deposition at the leptomeninges. HE, obj.20x. (**D**) Severe fibrinoid degeneration and necrosis of blood vessels, multifocal thrombosis and marked infiltrate of Gitter cells associated to perivascular cuffs composed by neutrophils, macrophages, lymphocytes and plasma cells. HE, obj.20x. (**E**) Immunohistochemistry (IHC) for *Escherichia coli*. Marked immunostaining at leptomeninges in the cytoplasm of neutrophils and macrophages, and occasionally intermixed with the fibrin deposition. AEC chromogen, obj.40x. (**F**) IHC for *E. coli*. Marked perivascular immunostaining. AEC chromogen, obj.40x.

and intralesional basophilic coccobacilli bacteria myriads (Fig.2C). Distinct histological lesions were observed in three cattle, which consisted of severe blood vessel degeneration and fibrinoid necrosis, multifocal thrombosis and marked Gitter cells infiltrate, associated to perivascular cuffs composed by neutrophils, macrophages, lymphocytes and plasma cells (Fig.2D). *E. coli* was cultured from six cattle and one goat samples; while *T. pyogenes* was cultured from one cattle sample. On IHC for *E. coli*, 12/17 cases (nine cattle, two goats and one sheep) presented immunostaining in the cytoplasm of macrophages and neutrophils at the leptomeninges, and interspersed at the fibrin deposition (Fig.2E). Also, the three cases that presented meningoencephalitis showed a marked immunostaining around blood vessels (Fig.2F).

Cerebral and spinal cord abscesses

Spinal cord abscesses were observed only in sheep (7/19), with an average age of five months. All cases had the associated factor of contamination after caudectomy.

Grossly, there were large amounts of yellow friable material inside the spinal cord lined by a thin whitish capsule and extending from sacral to lumbar segments of the spinal cord (Fig.3A). Histologically, there were extensive areas of liquefactive necrosis on the medular region of the spinal cord surrounded by a severe inflammatory infiltrate of healthy and degenerated neutrophils and macrophages, lined by mild fibrous connective tissue proliferation and neovascularization, besides intralesional basophilic coccobacilli bacteria myriads (Fig.3B). Adjacent to these lesions, there was moderate white matter vacuolization with axonal spheroids, numerous Gitter cells and perivascular infiltrate of neutrophils, macrophages and lymphocytes. Additionally, there were marked inflammatory infiltrate and fibrin deposition at the leptomeninges. Bacterial culture was obtained from three cases: *E. coli*, *T. pyogenes* and *Proteus mirabilis*.

Cerebral abscesses affected six cattle and two sheep. These animals were 18 months-old to 7 years-old. Three cattle also presented extra-CNS lesions, which consisted of otitis interna (two cases) and chronic suppurative pneumonia (one case). The remaining of the cases did not present any associated factor to the development of abscesses. Grossly, there were flattened circumvolutions, cerebellar

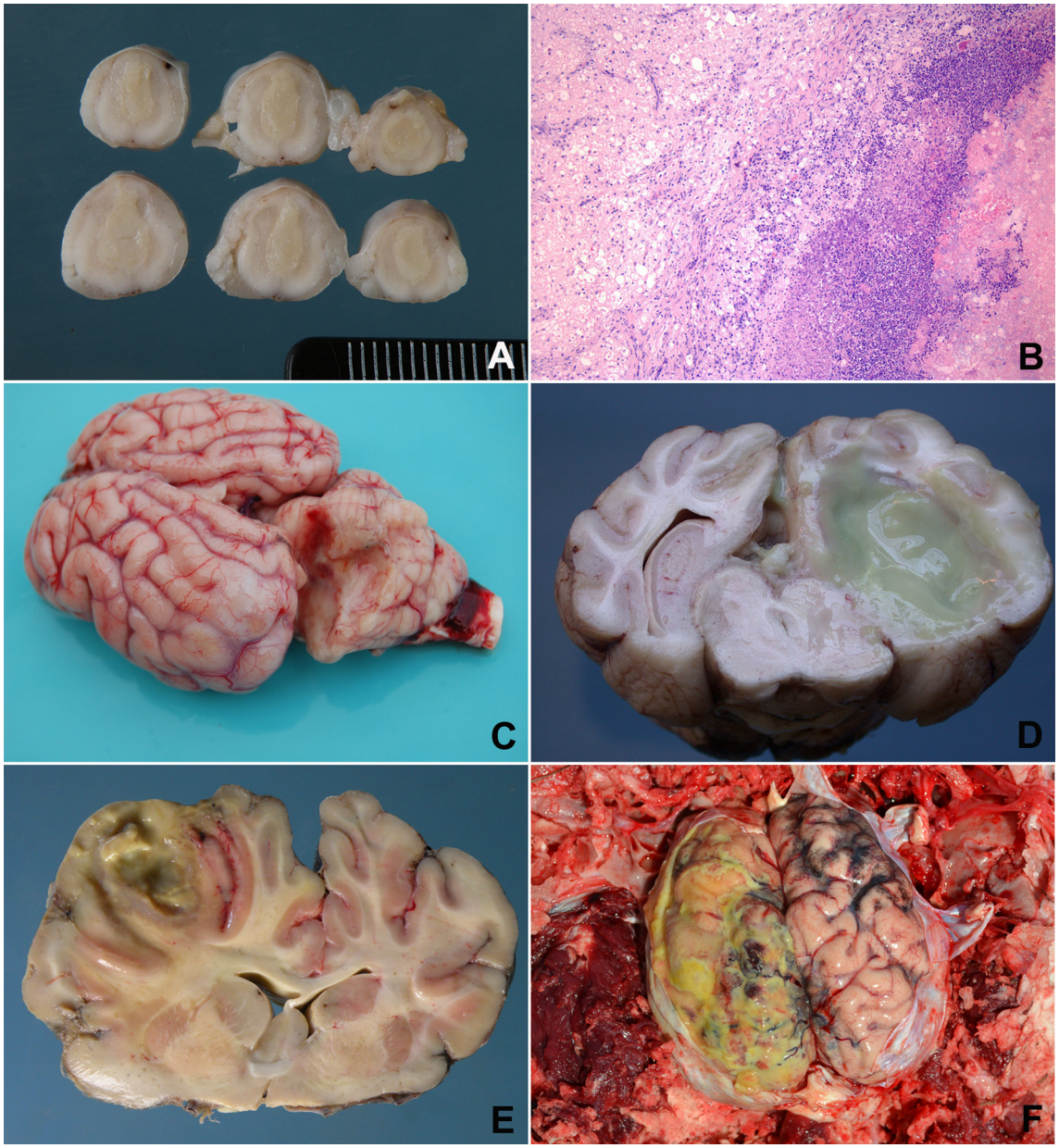

Fig.3. Cerebral and spinal cord abscesses in ruminants. (**A**) Sheep. Intramedular abscess at the sacral and lumbar segments of the spinal cord. (**B**) Sheep. Focally extensive area of liquefactive necrosis at the central region of the spinal cord associated to a severe inflammatory infiltrate composed by neutrophils and macrophages at the periphery, lined by a mild fibrous connective tissue proliferation. HE, obj.10x. (**C**) Sheep. Telencephalic asymmetry and cerebellar herniation. (**D**) Sheep. Cerebral abscess in parietal telencephalic cortex. (**E**) Cattle. Cerebral abscess at parietal telencephalic cortex that ruptured and communicated with the leptomeningeal surface. (**F**) Cattle. Marked deposition of yellowish amorphous material over the leptomeninges of the left telencephalic cortex (abscess rupture).

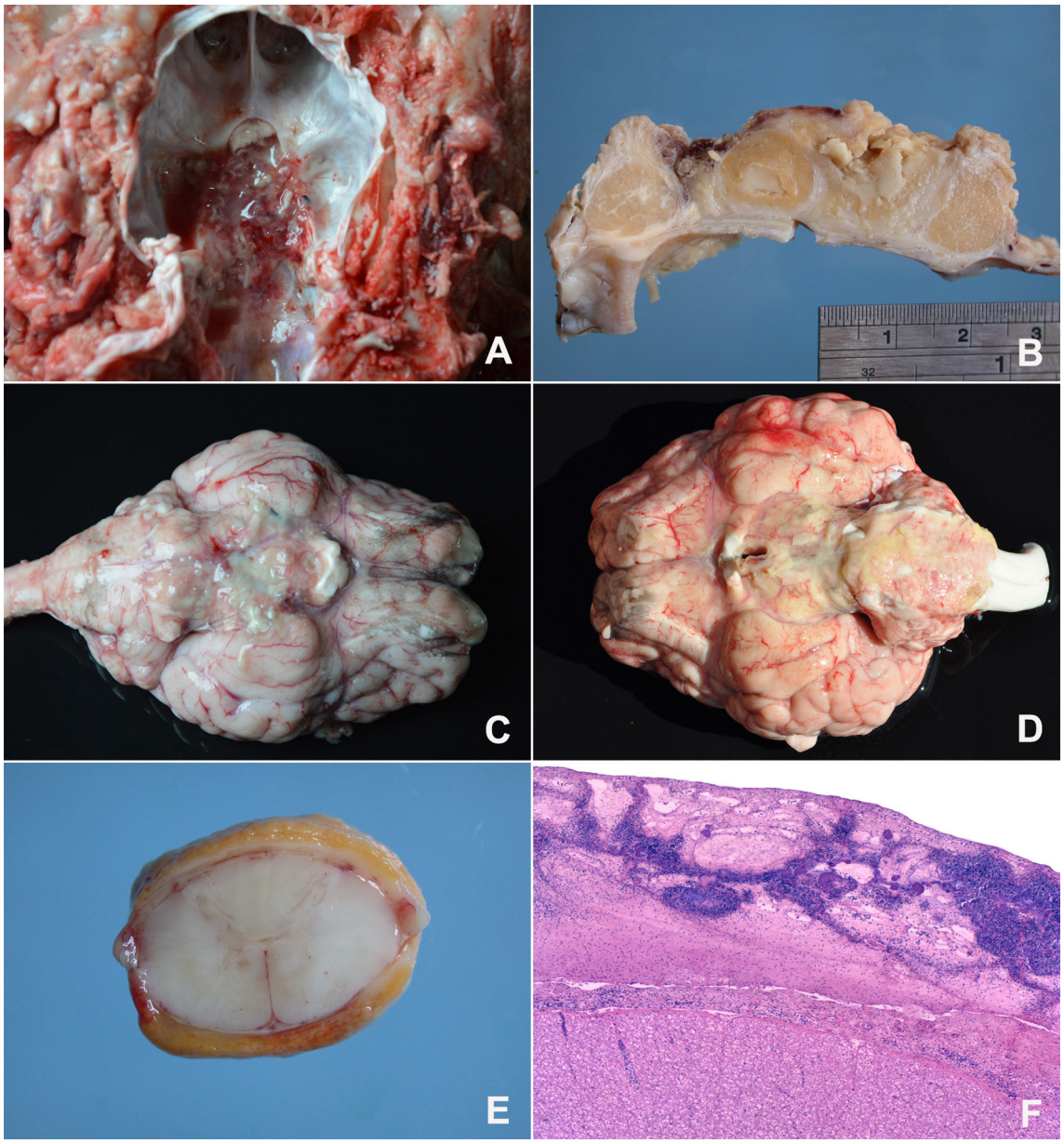

Fig.4. **Basilar empyema in ruminants.** (**A**) Sheep. Severe deposition of yellowish purulent material at the basisphenoid bone surface. (**B**) Cattle. Large amounts of purulent material have involved the carotid rete mirabile. (**C** and **D**) Sheep and cattle. Large amounts of purulent material at the basilar region of the brain (hypothalamic region extending to the brainstem). (**E**) Cattle. Marked yellowish thickening of the leptomeninges at the cervical segment of the spinal cord. (**F**) Cattle. Severe fibrin deposition associated to moderate infiltrate of neutrophils, macrophages and lymphocytes over the leptomeningeal surface of the cervical segment of the spinal cord. HE, obj.40x.

herniation and telencephalic asymmetry in three cattle and one sheep (Fig.3C). On cut surface, lesions affected mainly the telencephalic cortex (6/8) and less commonly the cerebellum (2/8), consisting of large amounts of purulent yellowish material lined by a thin whitish capsule (Fig.3D and 3E). Still, one bovine presented a marked and diffuse deposition of yellowish purulent material over the leptomeninges of the left telencephalic cortex which resulted from the rupture of the abscess capsule (Fig.3F). Histologically, the lesions were characterized by extensive areas of liquefactive necrosis associated to a marked inflammatory infiltrate of healthy and degenerated neutrophils intermixed by large amounts of basophilic coccobacilli bacteria myriads, lined by mild fibrosis, neovascularization and perivascular inflammatory infiltrate of lymphocytes and plasma cells. *T. pyogenes* was cultured from CNS samples of two cattle and two sheep.

Basilar empyema

Basilar empyema was diagnosed in four cattle and one sheep. Data regarding the species, age, sex, breed, predisposing factor and bacterial culture are summarized in Table 2. At necropsy, all the animals presented moderate to marked deposition of yellowish purulent material at

Table 1. Species, age, breed, sex, extra-central nervous system lesions and bacterial agent identification in cases of suppurative leptomeningitis and meningoencephalitis in ruminants

Species	Age	Breed	Sex	Associated lesions	Agent identification
Cattle	7 days	Angus	Female	Polyarthritis	*Escherichia coli* (BC e IHC)
Cattle	3 days	Mixed breed	Male	NI	*Escherichia coli* (BC e IHC)
Cattle	8 days	Mixed breed	Male	Polyarthritis	*Escherichia coli* (BC e IHC)
Cattle	4 months	Mixed breed	Female	NI	*Escherichia coli* (IHC)
Cattle	30 days	Angus	Male	Polyarthritis	*Escherichia coli* (IHC)
Cattle	7 days	Angus	Female	Bilateral hypopyon, pericarditis and polyarthritis	*Escherichia coli* (IHC)
Cattle	14 days	Mixed breed	Male	Unilateral hypopyon and polyarthritis	*Escherichia coli* (BC e IHC)
Cattle	10 days	Mixed breed	Male	Arthrogryposis	NI
Cattle	30 days	Angus	Female	Omphalophlebitis and hepatic abscesses	*Trueperella pyogenes* (BC)
Cattle	30 days	Devon	Male	Omphalophlebitis and polyarthritis	*Escherichia coli* (BC e IHC)
Cattle	3 days	Charolais	Male	Unilateral hypopyon	NI
Cattle	2 months	Angus	Female	Hepatic abscesses and esophagic obstruction	NI
Cattle	30 days	Holstein	Female	Acute bacterial enteritis	NI
Cattle	15 days	Mixed breed	Male	Aspirative pneumonia and unilateral hypopyon	*Escherichia coli* (IHC)
Goat	5 months	Boer	Female	NI	*Escherichia coli* (IHC)
Goat	2 months	Boer	Female	Acute bacterial enteritis	*Escherichia coli* (BC e IHC)
Sheep	10 days	Mixed breed	Male	Hepatic abscesses and bilateral hypopyon	*Escherichia coli* (IHC)

BC = bacterial culture, IHC = immunohistochemistry, NI = not identified.

Table 2. Species, age, breed, sex, predisposing factor and bacterial agent identification in cases of basilar empyema in ruminants

Nº	Species	Age	Breed	Sex	Predisposing factor	Agent identification
1	Cattle	4 months	Angus	Male	Traumatic rhinitis (weaner nose rings)	*Trueperella pyogenes* (BC)
2	Cattle	48 months	Gir	Male	Traumatic rhinitis (metal nose ring)	*Trueperella pyogenes* (BC)
3	Cattle	24 months	Holstein	Female	Traumatic rhinitis (weaner nose rings)	*Trueperella pyogenes* (BC)
4	Cattle	6 Months	Mixed breed	Female	Traumatic rhinitis (weaner nose rings)	NI
5	Sheep	18 months	Corriedale	Male	Purulent sinusitis (traumatic origin)	*Trueperella pyogenes* (BC)

BC = bacterial culture, NI = not identified.

basisphenoid bone (Fig.4A), involving also carotid rete mirabile, pituitary gland (Fig.4B) and hypothalamic region (Fig.4C), which also extended to the leptomeninges, mainly at the basal region of the diencephalon, mesencephalon and rhombencephalon (Fig.4D) and cervical segment of the spinal cord (cattle 3 and 4) (Fig.4E). Histologically, a marked inflammatory infiltrate composed by degenerated neutrophils intermixed by large amounts of fibrin and basophilic coccobacilli bacteria myriads was observed, and sometimes extensive areas of coagulation necrosis were observed at carotid rete mirabile, pituitary gland and basal hypothalamus. Adjacent to these areas there were moderate fibrosis and lymphoplasmacytic infiltrate. Also, the leptomeninges presented large amounts of fibrin associated to moderate infiltrate of neutrophils, macrophages and lymphocytes that extended to the cervical segment of the spinal cord (Fig.4F).

DISCUSSION

Bacterial infections are important causes of neurological diseases in ruminants (Fecteau et al. 1997, Kessell et al. 2011). In cattle of the present study, SIND had a frequency of 13.2% among the CNS inflammatory conditions, which is mildly above to previously described at the Northeast region (Galiza et al. 2010) and below to what has been described at the Southern region from Brazil (Sanches et al. 2000) of 12.3% and 14.2% respectively. On this species the most frequent diseases were suppurative leptomeningitis and meningoencephalitis, which is similar to the findings of Sanches et al. (2000), followed by cerebral abscesses. In North America, 41.5% of the neurological diseases of sheep are caused by bacteria (Rimoldi et al. 2016), similar to the observed in the present study, where these were mainly composed by *L. monocytogenes* meningoencephalitis, followed by spinal cord abscesses.

L. monocytogenes meningoencephalitis in sheep and goats is the main neurological disease caused by bacteria (Oevermann et al. 2010, Allen et al. 2013, Câmara et al. 2014). According to Allen et al. (2013), two thirds of the SIND diagnosed in goats from the USA were composed of *L. monocytogenes* meningoencephalitis, which is similar to the findings of the present study in which 71.42% of the goats were affected by this condition. Brugére-Picoux (2008) has described previously that sporadic or outbreaks of the disease are related to the consumption of poorly fermented silage (pH>5.5), which is an important predisposing factor. Cases not related to the consumption of silage are occasionally described and often related to the environment bacterial contamination (George 2002, Brugére-Picoux 2008). Gross lesions are usually absent. However, in the present study leptomeningeal congestion and hyperemia were observed in all cases. Occasionally, malacic areas may be observed at the rhombencephalon and mesencephalon (Rissi et al. 2006, Oevermann et al. 2010). Histopathological lesions are considered pathognomonic (Braun et al. 2002, Oevermann et al. 2010), including a combination of lesions on the neuropil (microabscesses, liquefactive necrosis, gliosis and perivascular lymphoplasmacytic infiltra-

te) observed mainly at the rhombencephalon and sometimes extending into the mesencephalon and diencephalon (Rissi et al. 2006). Besides these already described lesions, three sheep presented lesions at the cerebellar white matter, which may be related to the longer clinical course of the condition (Oevermann et al. 2010). Numerous bacteria were observed lying free in the neuropil in three cases (two sheep and one goat) through HE stain, which is rare and is directly related to acute listeriosis lesions (Oevermann et al. 2010). IHC exam was an important tool to diagnose listeriosis, which resulted in positive immunostaining in all cases (17 cases), differing from the previously described by Johnson et al. (1995) of 83.3% of cases with immunostaining.

Suppurative leptomeningitis and meningoencephalitis were the main causes of SIND in cattle, which is similar to the previously described by Ribas et al. (2013) and Assis-Brasil et al. (2013). Bacterial leptomeningitis is the main neurological condition in ruminant newborns (Barros et al. 2006, Fecteau et al. 2009), as it was observed in the present study, which has found that animals affected were three to 30 days old. This age group predisposition is related, mainly, to the failure in passive immunity transmission due to inadequate intake of colostrum, malnutrition and concomitant viral infections (Fecteau et al. 2009). The opacity, hyperemia, fibrin deposition and suppurative infiltrate over the leptomeninges are similar to lesions previously described (Barros et al. 2006, Fecteau et al. 2009, Vandevelde et al. 2012, Cantile & Youssef 2016). Fibrinoid degeneration and necrosis of blood vessels in the CNS associated to multifocal thrombosis and Gitter cells infiltrate have also been observed, and are directly related to *E. coli* infection, resulting in cerebral infarcts (Seimiya et al. 1992). *E. coli* is the main bacteria related to neonatal suppurative meningitis and septicemia (Kessell et al. 2011, Assis-Brasil et al. 2013), which is attributed to its capacity of adhesion, serum survival, aerobactin production and toxin syntheses (Fecteau et al. 2009). Other agents are also involved in septicemic processes that culminate with the development of neurological diseases during the neonatal period, including *Salmonella* sp., *Streptococcus* sp., *Mycoplasma* sp., *Pasteurella* sp., *T. pyogenes* and *Chromobacterium violaceum* (Ajithdoss et al. 2009, Kessell et al. 2011). Extra-CNS lesions as polyarthritis, hypopyon and omphalophlebitis are consequences of the bacterial septicemia (Catry et al. 2004, Ajithdoss et al. 2009, Cantile & Youssef 2016) and were observed in 14 cases, which also included hepatic abscesses, pericarditis and congenital malformations (arthrogryposis). IHC exam for *E. coli* was essential for the conclusive diagnosis of 70.6% of the cases of suppurative leptomeningitis and meningoencephalitis in the present study.

Cerebral and spinal cord abscesses were the second most frequent neurological diseases in cattle and sheep. In sheep, the main predisposing factor previously described is caudectomy, which favors ascending bacterial infections and culminate with spinal cord meningomyelitis and abscesses (Rissi et al. 2010). According to Kessell et al. (2011), young animals less than one year-old are more frequently affected by cerebral abscesses than adult ruminants, differing from the present study, which has found that cerebral abscesses affected mainly adult ruminants. Abscesses may develop at any region of the CNS, however, they were observed mainly at the telencephalic cortex. Cantile & Youssef (2016) suggested that these sites are predisposed to the development of abscesses through secondary hematogenous dissemination. *T. pyogenes* is the main bacteria cultivated from suppurative processes at the CNS (Mayhew 2009) and it was observed in four cases of the present study. Other less common cultivated bacteria from these conditions are: *Staphylococcus aureus*, *E. coli*, *Streptococcus* sp., *Fusobacterium necrophorum* and *Pseudomonas* sp. (Radostits et al. 2007, Kessell et al. 2011).

Basilar empyema, also named pituitary abscess syndrome, has been described in cattle and, occasionally, in sheep and goats (Morin 2004, Smith 2006, Câmara et al. 2009, Helmann 2010, Ribas et al. 2013). It is characterized as a sporadic or outbreak neurologic disease that affects mainly calves and, occasionally, adult cattle and sheep (Radostits et al. 2007, Câmara et al. 2009, Helmann 2010), which is similar to the present study. Basilar empyema is usually related to chronic lesions at the nasal cavity through weaner nose rings in calves and/or metal nose rings in adult cattle (Barros et al. 2006, Smith 2006, Câmara et al. 2009), which were observed in all cattle with basilar empyema of the present study. The condition pathogenesis is related to the proximity with pituitary, carotid rete mirabile and cavernous sinus vascular structures, that enhance the susceptibility of bacterial dissemination from other infectious sites (Morin 2004, Câmara et al. 2009, Müller et al. 2014). The most frequent bacteria obtained from these cases is *T. pyogenes* (Câmara et al. 2009), which was cultivated in four cases of the present study. Other bacteria, as *Staphylococcus* sp., *Streptococcus* sp., *F. necrophorum* and *Corynebacterium pseudotuberculosis*, may also be observed (Morin 2004, Radostits et al. 2007).

CONCLUSIONS

Suppurative infectious diseases of the central nervous system are important conditions diagnosed in ruminants.

L. monocytogenes meningoencephalitis was the main neurological disease of small ruminants. Suppurative leptomeningitis and meningoencephalitis were the main conditions of cattle, where *E. coli* was identified as the causative agent in 70.6% of the cases, being related to septicemic processes and neurological disturbances in neonate ruminants.

Spinal cord abscesses were the second most common condition in sheep and are related to ascending bacterial infection after caudectomy.

Basilar empyema was a frequent neurologic condition in cattle, and it is directly related to previous traumatic lesions at the nasal cavity, where the main etiologic agent was *T. pyogenes.*

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