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Causes of death in growing-finishing pigs in two technified farms in southern Brazil[1]

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ABSTRACT.- Piva M.M., Schwertz C.I., Bianchi R.M., Kemper R.T., Henker L.C., Nagae R.Y., Cê T.R.M., Barcellos D.E.S.N., Driemeier D. & Pavarini S.P. 2020. **Causes of death in growing-finishing pigs in two technified farms in southern Brazil.** *Pesquisa Veterinária Brasileira 40(10):758-775.* Setor de Patologia Veterinária, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9090, Porto Alegre, RS 91540-000, Brazil. E-mail: saulo.pavarini@ufrgs.br

The aim of this study was to investigate the main causes of death in growing-finishing pigs in southern Brazil. During a one-year period (from 2018 to 2019), two industrial pig herds (18 and 20 thousand pigs each farm) in southern Brazil were monitored along the four seasons of the year (12 days per season on each farm), in order to perform necropsies of all pigs that died in that period. The two farms had an average monthly mortality rate ranging from 0.94 to 3.93% in the evaluated months. At necropsy, tissues were collected, fixed in 10% formalin solution and processed routinely for histopathological examination. When necessary, samples were sent for bacterial culture and PCR to identify etiologic agents. A total of 601 necropsies were performed, with 94.9% of conclusive diagnoses. Infectious diseases corresponded to 64.4% of conclusive diagnosis and non-infectious diseases to 35.6%. The most prevalent causes of death were: pneumonia (33%), gastric ulcers (15.4%), circovirosis (9.9%), systemic bacterial embolism (5.4%), polyserositis (4.4%), dilated cardiomyopathy and torsion of abdominal organs (4.3% each), and bacterial pericarditis (3.4%). Regarding pneumonias (199/601), the main agents identified in these cases were *Pasteurella multocida, Influenza A* virus and *Mycoplasma hyopneumoniae*, mainly in associations.

INDEX TERMS: Growing-finishing pigs, farms, Brazil, swine pathology, mortality, pneumonia, gastric ulcer, circovirus.

RESUMO.- [**Causas de morte em suínos de crescimento e terminação em duas granjas tecnificadas no Sul do Brasil.**] O objetivo do presente trabalho foi investigar as principais causas de morte de suínos em fase de crescimento e terminação no Sul do Brasil. Durante o período de um ano (entre 2018 e 2019), duas granjas tecnificadas de suínos no Sul do Brasil foram acompanhadas nas quatro estações (12 dias por estação em cada granja), para realização de necropsias dos suínos que morreram nesse período. As duas propriedades apresentavam mortalidade mensal média entre 0,94 e 3,93% nos meses avaliados. Na necropsia, amostras de órgãos foram colhidas, fixadas em formol 10% e processadas rotineiramente para o exame histopatológico. Quando necessário, amostras foram enviadas para o cultivo bacteriano e PCR para identificação de agentes etiológicos. Foram realizadas um total de 601 necropsias, com 94,9% de diagnósticos conclusivos. As doenças infecciosas corresponderam a 64,4% dos diagnósticos conclusivos e as não infecciosas a 35,6%. As principais causas de morte foram: pneumonias (33%), úlcera gástrica (15,4%), circovirose (9,9%), embolia bacteriana sistêmica (5,4%), polisserosite (4,4%), cardiomiopatia dilatada e torção de órgãos abdominais (4,3% cada) e pericardite bacteriana (3,4%). Com relação às pneumonias (199/601), os principais agentes associadas as lesões foram *Pasteurella*

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multocida, vírus da Influenza A e *Mycoplasma hyopneumoniae*, principalmente associados entre si.

TERMOS DE INDEXAÇÃO: Suínos de crescimento e terminação, granjas, Brasil, patologia suína, mortalidade, pneumonia, úlcera gástrica, circovirose.

INTRODUCTION

To investigate and define the patterns of diseases that affect pigs is an efficient way to identify specific problems of the farms, whether they are sanitary, nutritional, structural or related to management practices. Recognizing the causes of mortality in swine farms may represent an important tool to assess the general health status of the herd. Therefore, determining the causes of death may be important to assess the efficiency of programs of disease prevention and control (Mondal et al. 2012). The mortality rate considered acceptable for growing-finishing pig herds varies from 2.5 to 3.3%. The diseases that occur more frequently in this phase are generally multifactorial, and the severity of their occurrence does not depend only on the virulence of the agents involved, but mainly on the risk factors present in the system (Sobestiansky et al. 2012).

Some studies have been conducted to investigate the aspects of swine mortality in pre-weaning piglets and weaned pigs (Straw et al. 1983, Tubbs et al. 1993, Dutta & Rahman 2006, Mondal et al. 2012). However, there are few studies that broadly assess the causes of death in pigs (Straw et al. 1983, Wilson 1970, Mondal et al. 2012), since there is a greater focus on the evaluation of epidemiological aspects (Losinger 1998, Dutta & Rahman 2006) and risk factors (Maes et al. 2004, Jensen & Toft 2009). Thus, the aim of this study was to determine the main diseases that cause mortality in pig herds from two commercial farms in southern Brazil, through necropsy and histopathological analysis, as well as to identify the etiology of the diseases and evaluate their distribution throughout the year and during the growing-finishing period.

MATERIALS AND METHODS

Two farms (Farms A and B) located in the western region of the state of Santa Catarina, were assessed in this study. Farm A contained 14 pig-sheds with total capacity to house 20,000 pigs and had mortality rates ranging from 0.94 to 3.93% during the months of data gathering. Farm B had eight pig-sheds with capacity to house 18,000 pigs, and mortality rates ranged from 0.90 to 1.54% during the period. Each of the farms housed piglets from a single origin, with an average age of 70 days. The two farms were GRSC (Granjas de Reprodutores Suídeos Certificadas - Certified Suidae Breeder Farms) and used to transfer the selected gilts with approximately 140 days of age. The males and the gilts not selected were usually sent to slaughter at 175 days of age, with an average weight of 125kg. In both farms, automatic feeding systems were used, with *ad libitum* supply of ration. In both farms flooring consisted of solid concrete and slat concrete. The pigs received commercial vaccines for swine circovirus type 2 and *Mycoplasma hyopneumoniae* (days 21 and 42 of age), in addition to autogenous vaccination against *Actinobacillus pleuropneumoniae*, *Bordetella bronchiseptica,* and *Pasteurella multocida* (days 42 and 63 of age). Farm A implemented autogenous vaccination during the visits, while Farm B underwent updating of vaccine strains for these agents.

Each farm was visited in four moments, which covered the four seasons, with a total of eight visits (Table 1). Each of the visits lasted 12 days, during which all pigs that died spontaneously or were euthanized by farm employees (usually fallen pigs which could no longer be fed without aid) were submitted for necropsy.

During the necropsies, organ fragments were collected, fixed in 10% formalin solution and subsequently routinely processed for the preparation of histological slides, which were stained by the hematoxylin and eosin (HE) technique. Data from individual pigs, including age, sex, clinical history, and treatments performed by the employees were recorded. When infectious agents were suspected to be involved in the lesions, fragments of organs and body fluids were collected, kept refrigerated and sent for bacteriological and biochemical examinations within 24 hours.

The diagnoses were concluded through the association of clinical history, macroscopic and microscopic lesions, as well as complementary tests, when necessary. Based on this, specific criteria were established for the completion of the diagnosis of each condition, as described below. For the diagnosis of pneumonia as the cause of death, pigs with severe macroscopic and microscopic lesions in the lungs (more than 30% of the pulmonary parenchyma affected), associated with the absence of significant lesions in other vital organs were considered. All lungs were evaluated according to the Pneumonia Severity Index (PSI), in order to quantify the pulmonary lesions through a validated methodology described elsewhere (Piffer et al. 1991). Due to the complex etiological character of respiratory diseases in pigs (Rech et al. 2018), different techniques were used to detect etiological agents and/or characteristic lesions, including bacteriology, histology and PCR. In all cases of pneumonia, lung fragments were inoculated in blood agar plates (BA) and MacConkey agar (MC) and incubated at 36°C+/-1°C for 18-48 hours in aerobiosis atmosphere. A colony of *Staphylococcus hyicus* supplemented with nicotinamide adenine dinucleotide (NAD) was added to the blood agar plates and these were incubated in microaerophilia at 36°C+/-1°C for 24-48h, enabling the growth of *Glaesserella (Haemophilus) parasuis* and *A. pleuropneumoniae.* Biochemical characterization of

Table 1. Temporal distribution of the collections, number of necropsied pigs and monthly mortality rate in each of the farms visited

Visit	Farm	Month/Year	Number of necropsies	Monthly mortality rate (%)
01	A	July/2018	64	3.93
02	B	August/2018	69	1.12
03	B	November/2018	90	1.54
04	A	November/2018	61	0.94
05	B	February/2019	88	1.39
06	A	February /2019	59	2.05
07	B	April/2019	85	0.90
08	A	May/2019	94	2.84

the colonies was performed according to Quinn et al. (2011) for the identification of bacteria. For the capsular type of *Pasteurella multocida,* the hyaluronidase test described by Carter & Rundell (1975) was performed to identify type A strains. The neutral acryflavine test (Carter & Subronto 1973) was used to characterize type D strains.

Diagnoses of bacterial pneumonia included cases with marked cranioventral consolidation (Fig.1A), which sometimes extended to the caudal lobes, often associated with pleuritis (Fig.1B). These areas of consolidation were dark red, firm, and the cut surface revealed yellowish-white areas that sometimes coalesced, as well as abscesses (Fig.1C and 1D) (López & Martinson 2017). The pattern of histological lesions in these cases consisted of marked suppurative bronchopneumonia with fibrin deposition, in bronchi, bronchioles and alveoli, associated or not with areas of coagulative necrosis, hemorrhage and sometimes abscess formation.

The participation of influenza virus in the etiology of pneumonia was considered through the observation of the macroscopic and histological lesions characteristic of the disease. Polymerase chain reaction techniques (PCR) and immunohistochemistry (IHC) were not used for the detection of this virus due to the rapid period of elimination of infection, as well as the subacute and chronic nature of the lesions observed in many cases. The lungs of pigs with diagnosis compatible with influenza virus pneumonia did not collapse after the opening of the thoracic cavity and showed multifocal areas of consolidation and/or atelectasis, interspersed with areas of normal appearance ("checkerboard appearance") (Fig.1E). Microscopic findings observed in these cases included necrotizing and obliterative bronchiolitis (Fig.1F), associated with bronchointerstitial pneumonia (Schaefer et al. 2013), which are highly suggestive of influenza infection in pigs in Brazil, since other diseases that could cause similar lesions such as PRRS do not occur in the country (Rech et al. 2018). Frequently, concomitant occurrence of the two described patterns was observed. Furthermore, to prove the concomitant involvement of *M. hyopneumoniae* in lung lesions, 80 samples of pig lungs (10 samples from each visit) with final diagnosis of pneumonia were randomly chosen and submitted to PCR for amplification of the 16S rRNA m gene of *M. hyopneumoniae* (Yamaguti et al. 2008), added to ROX as a reference dye. The extraction was performed with a commercial kit (MagMAX CORE Nucleic Acid Purifications, Thermo Fisher Scientific) according to the manufacturer's instructions, and the samples were stored at -20°C.

The diagnosis of gastric ulcer was established through the observation of ulceration of the *pars oesophagea* of the stomach (Fig.2A and 2B), associated with signs of blood loss from the lesion, such as the presence of clots in the gastric lumen (Fig.2C), pallor of the carcass (Fig.2D) and organs, as well as dark and pasty fecal content inside the intestinal lumen (melena) (Fig.2E). Gastric ulcers were graded according to Sobestiansky et al. (2012) and only grade IV ulcers, when in association with signs of hemorrhage, were considered as the cause of death of the animal. Pigs with peritonitis due to rupture of gastric ulcers were also allocated in this group (Fig.2F).

In the diagnosis of circovirosis, pigs with lesions of porcine dermatitis and nephropathy syndrome (PDNS) and post-weaning multisystemic wasting syndrome (PMWS) were included. All pigs with PDNS presented fibrinosuppurative glomerulonephritis (Fig.3A and 3B), granulomatous lymphadenitis, systemic vasculitis and, in most cases, characteristic skin lesions (Fig.3C). All pigs with PMWS presented emaciation, systemic granulomatous lymphadenitis with lymphoid depletion, mononuclear interstitial pneumonia and nephritis, besides vasculitis (Caswell& Willians 2016, Cianciolo & Mohr 2016) (Fig.3D-F). Pool samples of lymph nodes from 21 pigs were submitted to PCR for the detection of swine circovirus type 2 (PCV2) following the methodology of Xiangdong et al. 2018.

The diagnosis of systemic bacterial embolism comprised pigs with multifocal suppurative and abscedative lesions of hematogenous origin, such as embolic pneumonia, arthritis, osteomyelitis and endocarditis, often associated with a primary lesion, usually tail lesions (Fig.4). Fragments and swabs of the lesions were inoculated on BA and MC agar and incubated at 36°C+/-1°C for 18-48 hours in aerobic atmosphere.

The diagnosis of bacterial polyserositis was attributed to pigs with large amounts of fluid and fibrin exudation in both the abdominal and thoracic cavities (Fig.5A and 5B), with concomitant involvement of other sites, including joints, pericardial sac, meninges and lungs. For the diagnoses of bacterial pericarditis, the presence of a large amount of exudate inside the pericardial sac was used as a criterion (Fig.5C-E), associated with extracardiac lesions of congestive heart failure, such as ascites and mottled liver ("nutmeg liver") (Fig.5F). In both cases, swabs and fluids were collected and kept refrigerated for microbiological examination using methodology similar to that used for cases of bacterial pneumonia.

Pigs with dilated cardiomyopathy presented cardiomegaly (Fig.6A), with marked dilation of the cardiac chambers (Fig.6B), especially the ventricles (Cruz et al. 2019). These pigs also had extracardiac lesions of congestive heart failure, such as ascites (Fig.6C), pulmonary edema and "nutmeg liver" (Fig.6D). The group of cardiorespiratory failure associated with fights included pigs with a history of recent fight (up to 12 hours), with abrasions and hyperemia of the skin, in addition to marked pulmonary edema and congestion.

Pigs presenting displacement of viscera were classified into a group of torsion of abdominal cavity organs. In this group, the macroscopic visualization of mesenteric torsion (Fig.7A), hepatic lobe torsion (Fig.7B) and spleen torsion, together with histological lesions supported the diagnosis. Similar criteria were used to reach the diagnosis of pigs with hemoperitoneum due to liver rupture. In this case, a large amount of free blood was observed in the abdominal cavity and ruptures of the capsule and hepatic parenchyma were seen (Fig.7C and 7D).

For the diagnosis of meningoencephalomyelitis, four distinct histopathological patterns were considered: suppurative meningoencephalitis, of bacterial origin (Fig.8A); non-suppurative meningoencephalitis of probable viral origin; ascending myelitis of bacterial origin (Fig.8B); and eosinophilic meningoencephalitis, compatible with salt poisoning or water deprivation. In cases of meningoencephalitis, fragments of the central nervous system and/or liquor were submitted to bacteriological examination. These were inoculated in BA and MC, maintained in similar conditions of samples from cases of bacterial pneumonia in microaerobiosis, adding *a Staphylococcus hyicus* streak to the plate culture.

Pigs that presented bone fractures in various places, and who died because of this injury, comprised a group called "bone fracture". Acute bleeding associated with this lesion was often observed (Fig.8C). Some animals with umbilical or inguinal hernias presented intestinal incarceration or rupture within the hernia. This diagnosis was established through the macroscopic observation of the lesions (Fig.8D-F).

For the diagnosis of bacterial enterocolitis, affected pigs presented acute and chronic lesions in the intestines, associated with the absence of alterations in other vital organs. In the diagnosis of salmonellosis, cases with characteristic fibrinonecrotic lesions in the intestinal mucosa were included (Fig.9A and 9B). Fragments of intestines, spleen and bile were submitted to bacterial isolation in BA

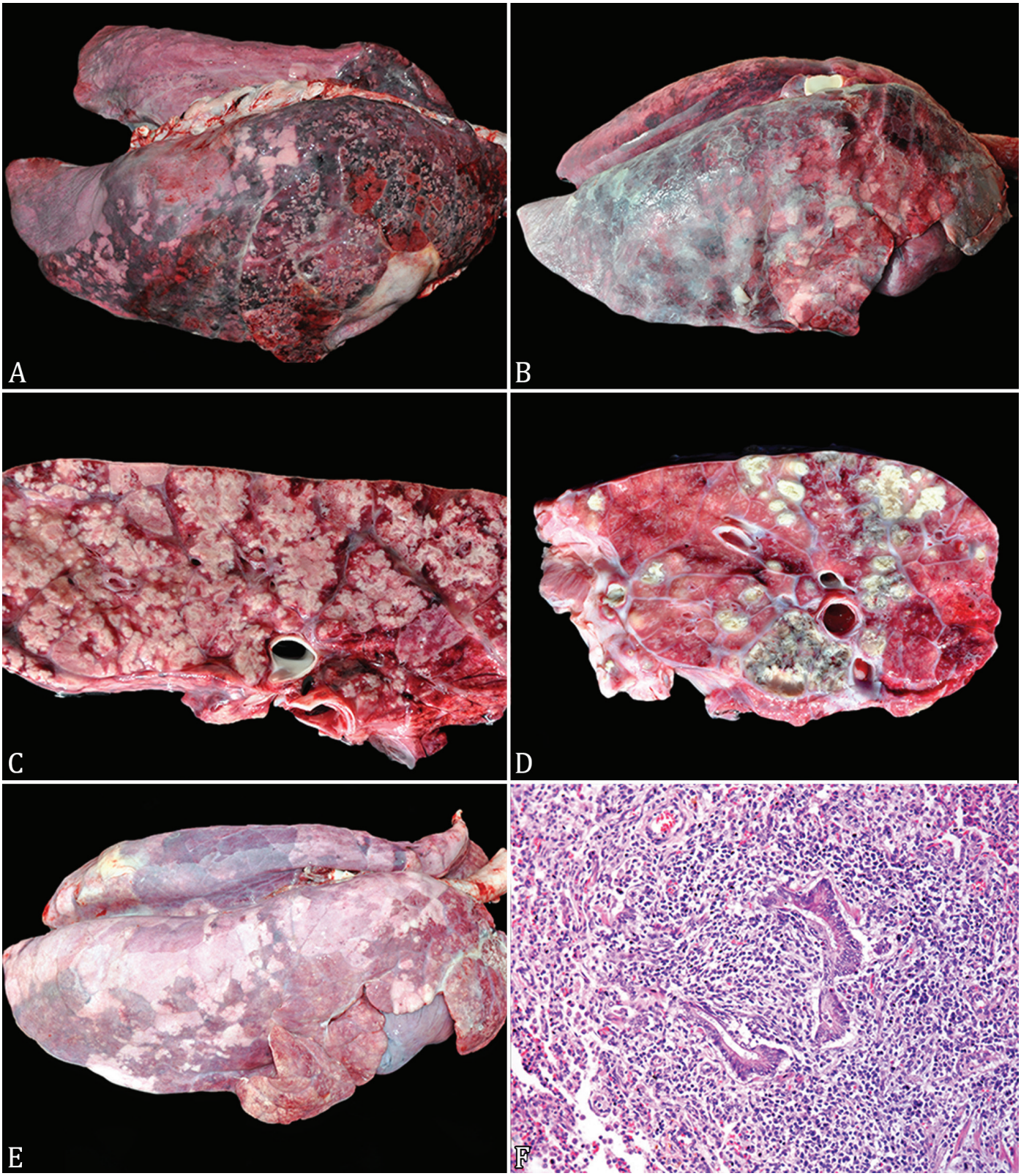

Fig.1. Pneumonias in growing-finishing pigs. (**A**) Bacterial pneumonia. Non-collapsed lungs, with marked consolidation affecting predominantly the cranioventral area. (**B**) Bacterial pleuropneumonia. Non-collapsed lungs, with marked consolidation affecting the cranial, middle and caudal lobes, and intense fibrin deposition on the pleura. (**C**) Bacterial pneumonia (cut surface). Multifocal to coalescent whitish and friable areas (necrosis), surrounded by reddish areas. (**D**) Bacterial pneumonia (cut surface). Areas of necrosis and multifocal abscesses are seen in the pulmonary parenchyma. (**E**) Bronchointerstitial pneumonia suggestive of influenza and secondary bacterial infection. Non-collapsed lungs, with "checkerboard aspect", as well as marked cranioventral consolidation. (**F**). Swine influenza. Obliterative bronchiolitis with marked peribronchiolar infiltrate of lymphocytes. HE, obj.20x.

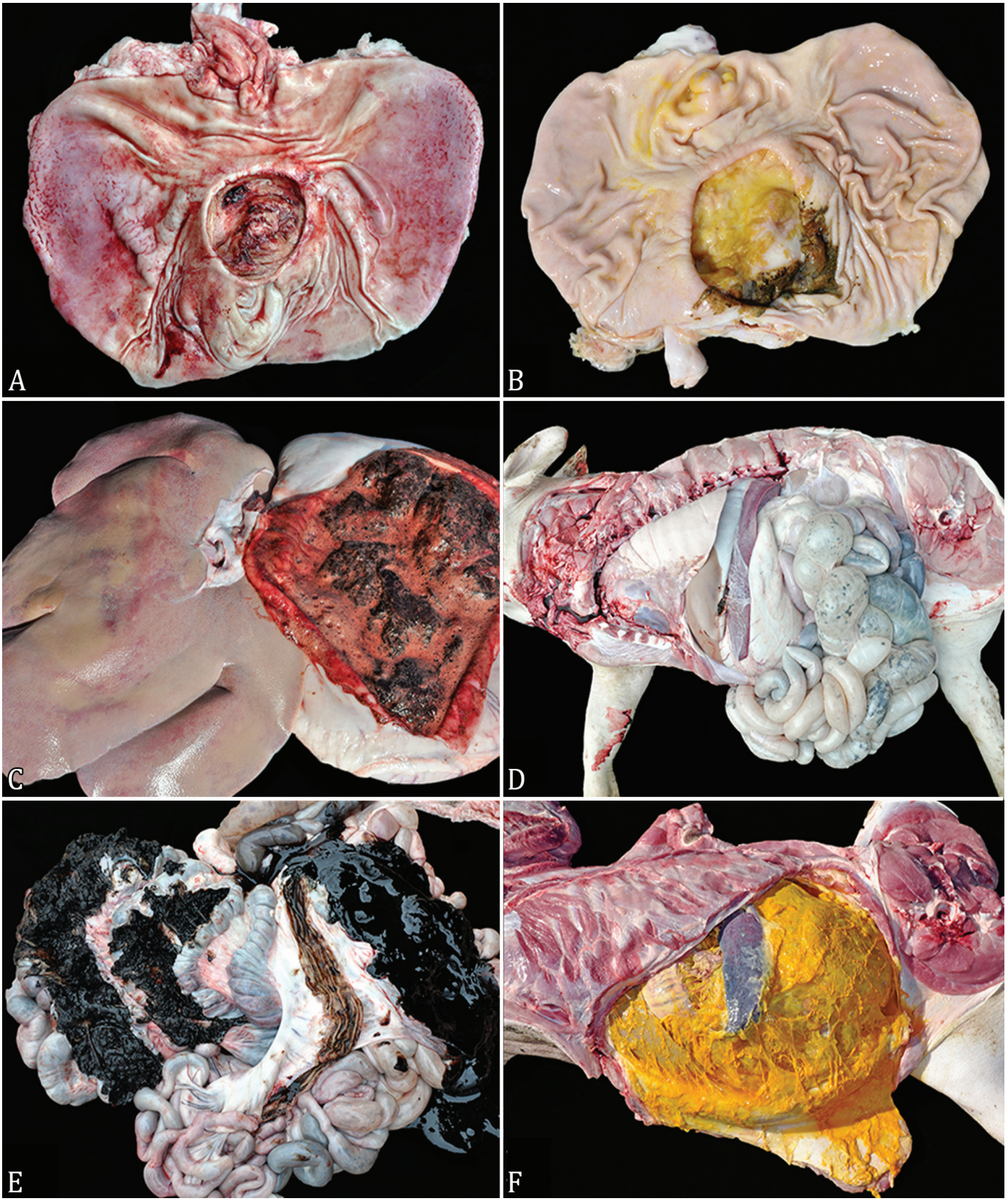

Fig.2. Gastric ulcer in growing-finishing pigs. (**A**) Stomach with focally extensive ulceration affecting the *pars oesophagea*. (**B**) Stomach with marked ulceration of the *pars oesophagea*, which presents elevated edges and yellowish coloration (fibrin deposition). (**C**) Stomach filled with blood clots, and diffusely pale liver. (**D**) Diffuse pallor of the carcass and organs in a pig with gastric ulcer. (**E**) Intestines. In the lumen of large gut there is a great amount of pasty and blackened feces. (**F**). Fibrinous peritonitis in a pig with perforated gastric ulcer. Abdomen filled with fibrillar and intensely yellowish material (bile discoloration).

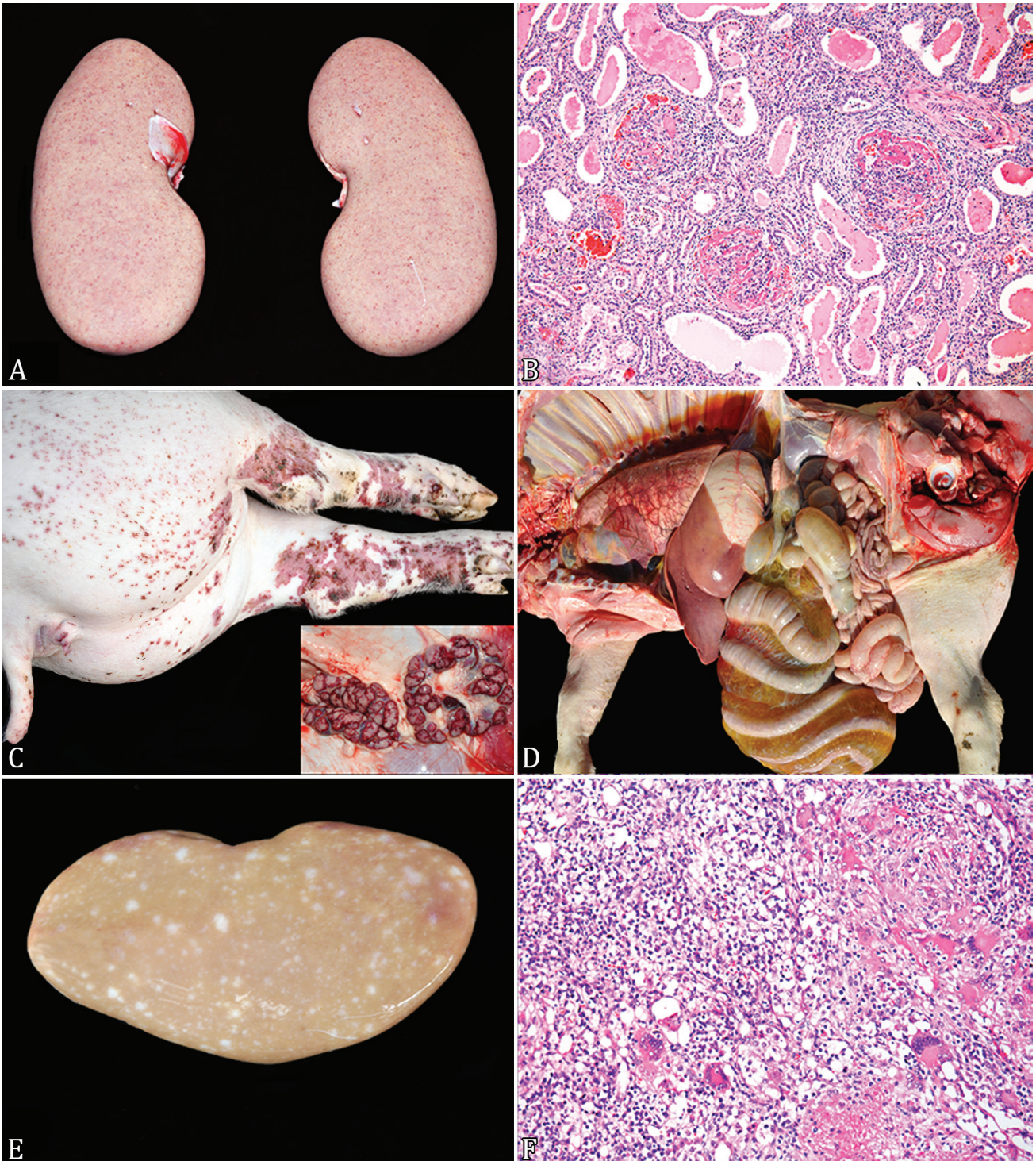

Fig.3. Circovirosis in growing-finishing pigs. (**A**) Porcine dermatitis and nephropathy syndrome (PDNS). Enlarged kidneys with reddish multifocal pinpoint areas throughout the cortical surface. (**B**) PDNS. Fibrinosuppurative glomerulonephritis. Enlarged glomeruli, with intense deposition of densely fibrillar and eosinophilic material in the urinary spaces (fibrin), in addition to infiltrate of neutrophils, lymphocytes, plasma cells, and macrophages that extends to the interstitium. The urinary tubules are dilated and filled with proteinaceous material (proteinuria). HE, obj.20x. (**C**) PDNS. Skin of the perineal region and pelvic limbs with multifocal irregular areas of reddish discoloration, sometimes covered by crusts (necrotic dermatitis). Inset: enlarged inguinal lymph nodes are observed, which present reddish peripheral areas (hemorrhage). (**D**) Post-weaning multisystemic wasting syndrome (PMWS) in pigs. At the opening of the carcass, marked edema of the mesocolon is observed, in addition to mild deposition of clear effusion in the abdominal and thoracic cavities (ascites and hydrothorax, respectively). The lung is not collapsed and shows interlobular septa demarcated by intense edema (interlobular edema). (**E**) PMWS. Kidney with whitish multifocal areas throughout the cortical surface (interstitial nephritis). (**F**) PMWS. Lymph node with lymphoid necrosis and depletion, inflammatory infiltrate and fibrin deposition, as well as infiltrate of Langhans-type multinucleated giant cells (granulomatous lymphadenitis). HE, obj.20x.

and MC agar, incubated for 24-48 hours at 36°C+1°C in aerobiosis. In some cases of chronic *Salmonella* sp. infection, pigs presented marked stenosis of the final portion of the colon or rectum, with secondary megacolon (Fig.9C and 9D). In cases of swine proliferative enteropathy, marked thickening of the ileum wall was observed, which often extended to the jejunum and cecum, and resulted in the "ceribriform aspect" of the mucosa associated with a large amount of blood and necrotic debris in the lumen (Fig.9E). For these cases, the Warthin-Starry histochemical technique (WS) of silver impregnation was used to evidence the agent inside enterocytes (Fig.9F). Diseases with a frequency equal to or less than three cases were grouped as others.

RESULTS

In this study, 601 necropsies of growing-finishing pigs were performed, and in 94.9% (570/601) of the cases, the diagnosis was conclusive. The frequency of diagnosis of the main conditions, as well as the age and sex of the affected pigs are shown in Table 2. Figure 10 shows the seasonal distribution of the main diagnosed diseases and figure 11 highlights the main diseases diagnosed according to the age of the pigs, as well as the distribution of deaths in each age group. Figure 11 highlights that there was an increase in the number of deaths due to pneumonia in older pigs, and a similar pattern occurred for deaths due to gastric ulcer, producing greater mortality between 151 and 175 days. The occurrence of systemic bacterial embolism was higher in pigs after 111 days of life, and this condition was especially common in animals at the end of the finishing phase (151 to 175 days). Circovirosis, bacterial polyserositis and dilated cardiomyopathy were diagnosed at all ages, as well as pericarditis, but these presented a higher frequency of cases between 70-90 days of life. The mortality of growing-finishing pigs increased along with the time of housing, meaning that the mortality rate among older pigs was higher when compared with recently housed pigs.

Infectious diseases represented the majority of conclusive diagnosis, accounting for 64.4% of these (367/570), while non-infectious diseases accounted for 35.6% (203/570) of the cases. Pneumonia comprised the most frequent diagnosis of

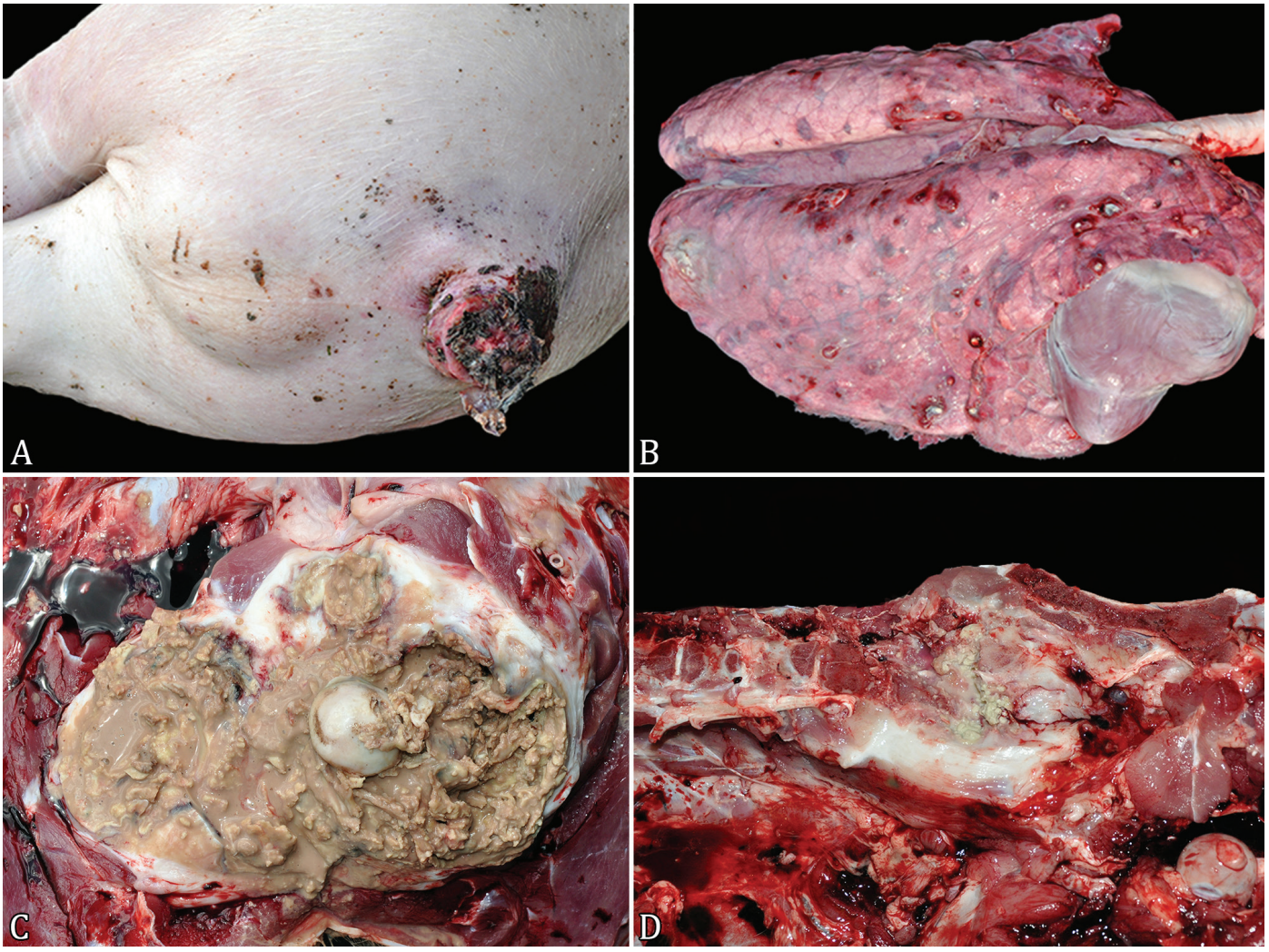

Fig.4. Systemic bacterial embolism in growing-finishing pigs. (**A**) Tail biting lesion. Tail with tissue laceration, ulcerated surface and crust formations. (**B**) Embolic pneumonia. Lungs with nodular and firm multifocal areas, yellowish and shrouded by a reddish halo (abscesses). (**C**) Suppurative arthritis. Coxofemoral joint with a marked amount of purulent content, surrounded by a thick fibrous capsule. (**D**) Abscedative spondylitis. The sacral region is enlarged and contains friable and purulent material in the center, surrounded by whitish and firm areas.

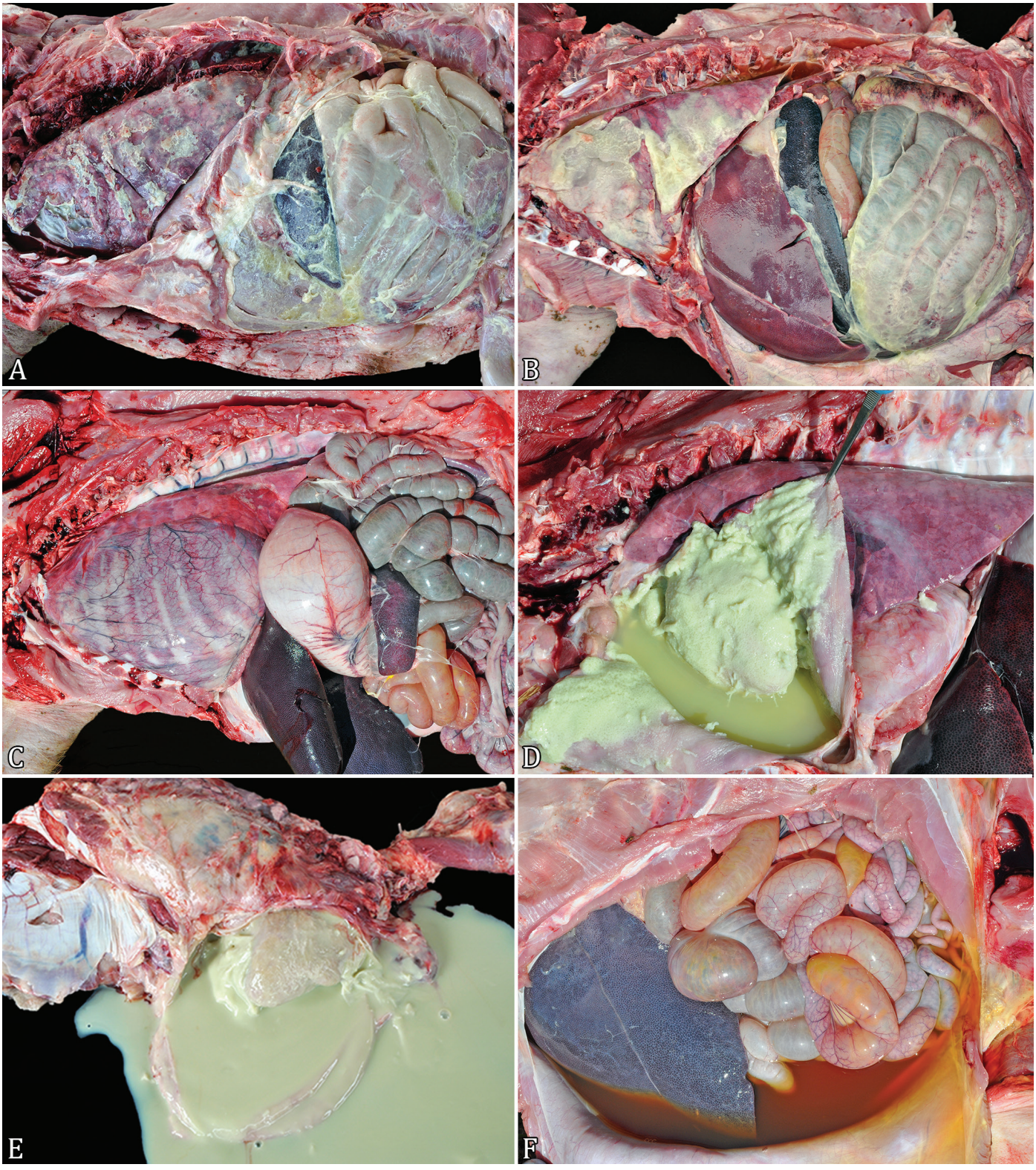

Fig.5. Bacterial polyserositis and pericarditis in growing-finishing pigs. (**A**) Pneumonia and polyserositis by *Pasteurella multocida.* Intense fibrin deposition in the abdominal and thoracic cavities. Not collapsed and markedly consolidated lungs. (**B**) Polyserositis by *Glaesserella (Haemophilus) parasuis*. Intense fibrin deposition in the abdominal and thoracic cavities. (**C**) Bacterial pericarditis. Pericardial sac severely distended and occupying nearly the entire thoracic cavity. Lung severely compressed and reduced in size (compressive atelectasis). (**D**) Bacterial pericarditis. In the opening of the pericardial sac there is a large amount of yellowish liquid and marked deposition of dense fibrin filaments on the surface of the epicardium. (**E**) Bacterial pericarditis. Pericardial sac with a large amount of purulent material, with adhesion of fibrin filaments in the pericardium. (**F**). Congestive heart failure in cases of bacterial pericarditis. Large amount of light orange fluid in the abdominal cavity (ascites) and severe liver enlargement (congestion).

this study, with 33% of the cases (199/601) and, from these, by the evaluation of PSI, the mean pulmonary involvement was 57.8%. Bacterial pneumonia corresponded to 93.9% of cases of pneumonia (187/199), and 79.1% had histological lesions suggestive of concomitant influenza infection (148/187). Bacterial isolation was possible in 61.30% of cases (122/199). The most commonly isolated bacterial agent was *Pasteurella multocida*, with a total of 101 isolations (50.7% of pneumonia diagnoses). Of these, 49 were capsular type A, 40 were capsular type D and 12 were non-typable. Other bacterial agents isolated were *Streptococcus suis* (10 cases), *Actinobacillus pleuropneumoniae* (five cases), *Trueperella pyogenes* (five cases), and *Actinobacillus suis* (one case). Viral pneumonia with changes compatible with primary swine influenza was diagnosed in 12 cases. Fibrinonecrotic tracheitis was also observed in seven cases of pneumonia, and in six of these, severe lesions suggestive of influenza were noted. In 75% of the lungs tested by PCR (60/80), the involvement of *Mycoplasma hyopneumoniae* was identified. It is also worth mentioning that in 72.88% (293/402) of the cases, the pigs died from other diseases also presented different degrees of pneumonia.

Gastric ulcers accounted for 15.4% of conclusive diagnoses (93/570), and this condition represented the second most frequent diagnosis in this study. In only three cases the gastric ulcer ruptured with secondary peritonitis was observed.

Of the 60 pigs diagnosed with circovirosis, 34 were classified as PDNS and 26 as PMWS. Ages ranged from 90 to 181 days old for PDNS and 80 to 190 for PMWS, with a median of 108 days old for both. In cases of PMWS, concomitant lesions caused by other infectious agents were identified in 23 cases and these were: valvular bacterial endocarditis (8/26), bacterial pneumonia (7/26), suppurative meningoencephalitis, and fibrinous pericarditis (3/26 each), fibrinonecrotic enterocolitis (salmonellosis), and bacterial arthritis (1/26 each). In cases of PDNS, the main concomitant conditions were bacterial pneumonia (5/34), and swine proliferative enteropathy, salmonellosis, polyserosites, and rectal prolapse at one opportunity each.

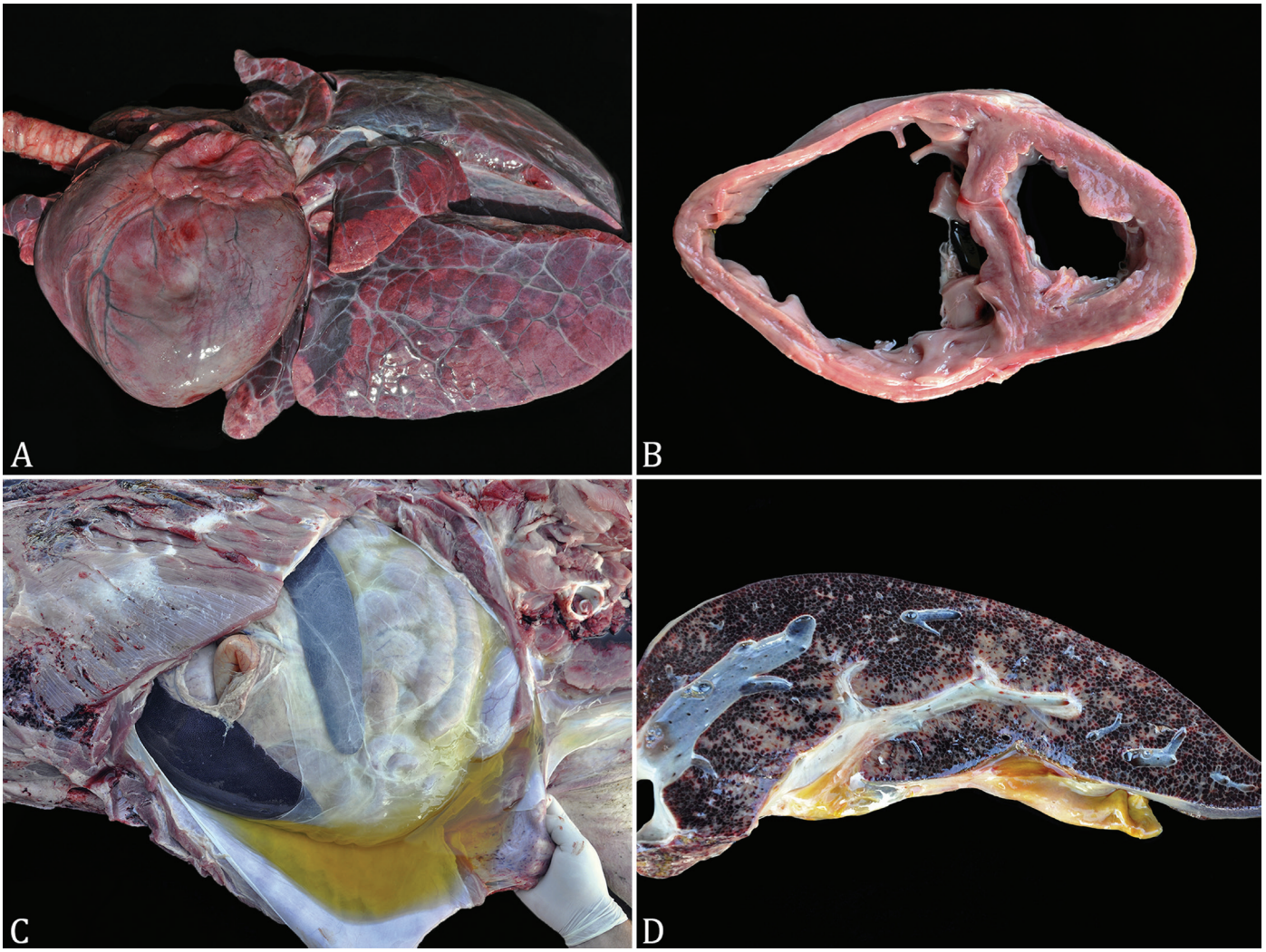

Fig.6. Dilated cardiomyopathy in growing-finishing pigs. (**A**) Heart enlarged (cardiomegaly) with globose aspect. Non-collapsed lungs, with diffuse reddish discoloration (congestion and edema). (**B**) Heart with marked dilation of the ventricular chambers and thinning of the myocardial wall, more evident in the right ventricle. (**C**) Large amount of citrine fluid in the abdominal cavity associated with moderate deposition of fibrin filaments (ascites). (**D**) Cut surface of the liver, dark red, with intense dilation of vascular spaces and marked enhancement of the lobular pattern ("nutmeg liver").

Of the 60 cases of circovirus, 21 were submitted to RT-PCR and all were positive for PCV-2 in samples of lymph nodes. In the remaining cases, the diagnosis was made based solely on the typical macroscopic and histopathological lesions.

Systemic bacterial embolism predominantly affected males (24/33), and the primary lesion of the embolic process was identified in 75.7% of the cases (25/33). In 92% of these (23/25), the laceration of the tail and perineal tissues due to biting was assumed to be the primary lesion, and in two cases, podal lesions (pododermatitis of unspecific cause) were incriminated. The pathological picture was characterized by combinations of suppurative and abscedative lesions, mainly arthritis (25/33), embolic pneumonia (21/33), osteomyelitis, especially in the spine (12/33), endocarditis (2/33), splenitis (2/33), and less frequently, serositis and regional lymphadenitis and (1/33 each).

From the 27 cases of bacterial polyserositis, in 20 (74%) it was possible to determine the etiology. Of these, in 17 pigs *P. multocida* was cultured (11 cases type D; three cases type A; and three cases non-typable); and in three cases, *Glaesserella* (*Haemophilus*) *parasuis* was cultured. These bacteria were often isolated in more than one site (e.g. exudates from the pericardium, abdomen and thorax, liquor and synovial fluid). In cases with isolation of *P. multocida* the median age of the animals was 100 days, while for *Glaesserella* (*Haemophilus*) *parasuis* it was 91 days old. In the 17 cases with isolation of *P. multocida*, 14 had suppurative pneumonia.

In the group of bacterial pericarditis, in 10 of the 21 cases, *P. multocida* was cultured, and it was the only agent identified in this condition. In these pigs with diagnosis of pericarditis, in addition to the lesions of chronic congestive heart failure, fibrinous pleuritis (5 cases), and pleuropneumonia (3 cases) were observed.

Of the 26 cases grouped into "torsion of abdominal cavity organs", 22 were mesenteric torsions (mean of 121 days of age), followed by two liver lobe torsions (mean of 175 days), and single cases of splenic torsion (160 days), and gastric torsion (125 days).

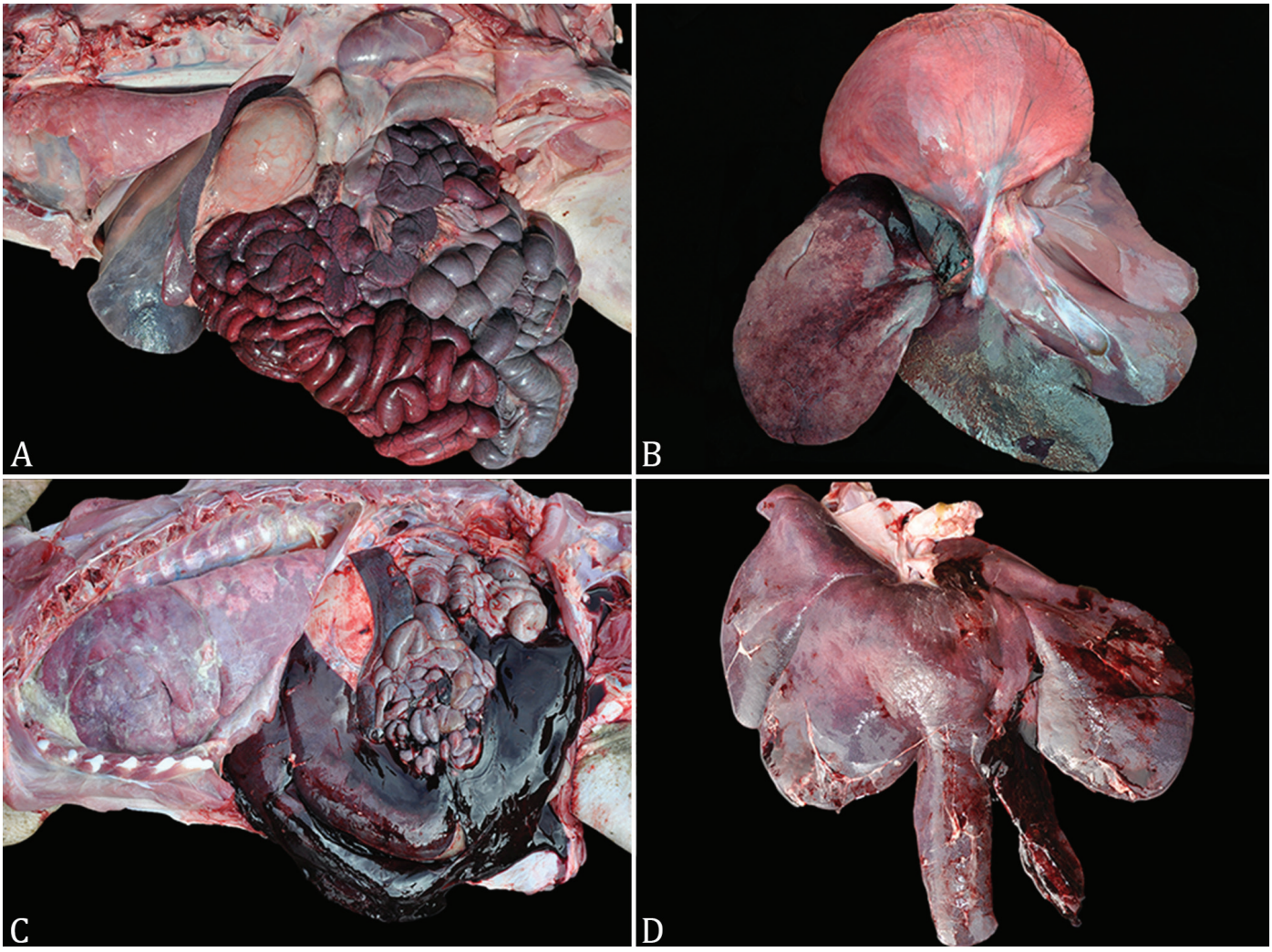

Fig.7. Torsions and ruptures of abdominal organs in growing-finishing pigs. (**A**) Mesentery torsion. Dark red intestinal wall (congestion), with 180° bowel displacement counterclockwise. (**B**)Liver lobe torsion. The left lateral lobe has a 360° twist counterclockwise. The twisted lobe is markedly enlarged and dark red in color. (**C**) Hemoperitoneum due to liver rupture. Abdominal cavity with large amount of blood clots. (**D**) Liver rupture. Left medial lobe with a focal, linear rupture of the capsule and parenchyma, with adhesion of blood clots and fibrin filaments on the capsule.

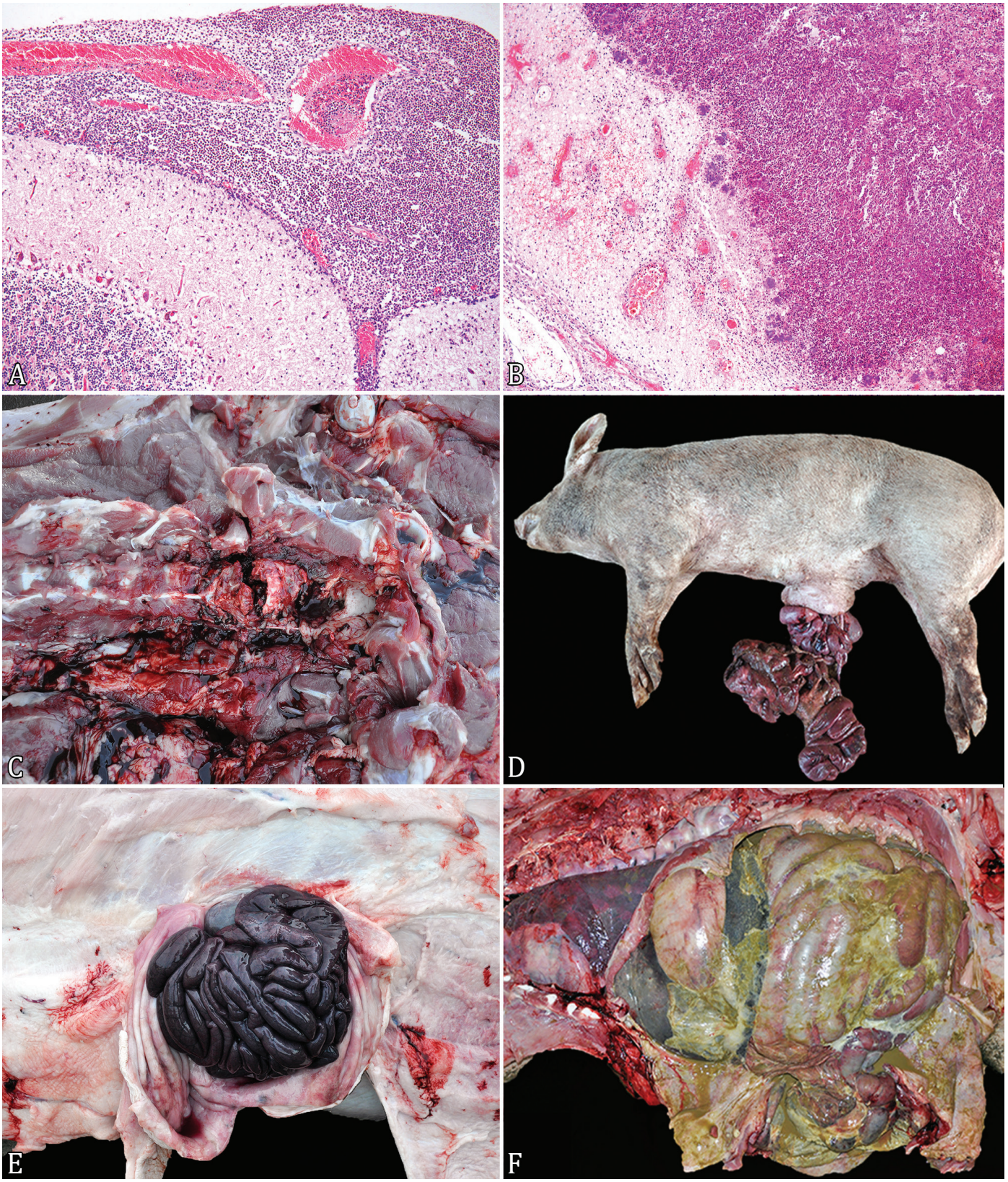

Fig.8. Causes of death in growing-finishing pigs. (**A**) Bacterial meningitis. Intense inflammatory infiltrate predominantly of neutrophils in leptomeninges. HE, obj.20x. (**B**) Ascending bacterial myelitis due to tail biting injury. Sacral spinal cord segment, with an area of central necrosis, with deposition of cellular debris, fibrin, neutrophil infiltrate, and bacterial aggregates. HE, obj.20x. (**C**) Vertebral fracture. Lumbar vertebra with total vertebral body fracture, associated with acute hemorrhage. (**D**) Hernia evisceration. Intestines exposed by umbilical hernia evisceration. (**E**) Umbilical hernia incarceration. Incarcerated intestine with dark red-colored wall. (**F**). Peritonitis secondary to incarceration and rupture of umbilical hernia. Fibrin deposition and intestinal contents spilled from the area of rupture.

Fig.9. Enteric diseases in growing-finishing pigs. (**A**) Salmonellosis. Small intestine with thickened, reddish wall and whitish nodular areas. **(B)** Salmonellosis. Mucosa markedly reddened, with multifocal areas of deposition of yellowish material forming small nodules (button ulcers). (**C**) Megacolon secondary to rectal stenosis due to chronic salmonellosis. Severe dilation of the large intestine, more evident in the colon, which is filled with feces. (**D**) Rectal stenosis associated with chronic salmonellosis. Rectum with a focal area of stenosis, with thickening and dilation of the anterior portion of the intestinal wall, in addition to a focally extensive area with fibrin deposition on the mucosa. (**E**) Swine proliferative enteropathy. Marked and diffuse thickening of the mucosa, with blood in the lumen. (**F**) Swine proliferative enteropathy. Ileus with intestinal crypt hyperplasia and evidence of bacteria compatible with *Lawsonia intracellularis* in the apical cytoplasm of epithelial cells. WS, obj.40x.

Cases of meningoencephalomyelitis were divided into four groups according to the morphological pattern of microscopic changes observed; non-suppurative meningoencephalomyelitis (six cases, affecting pigs between 81 and 170 days of age with a median of 120 days); meningitis or bacterial meningoencephalitis (five cases, affecting pigs between 70 and 80 days of age, with a median of 77 days), from which it was possible to isolate the etiological agent (*S. suis)* in only one case. The third pattern was ascending myelitis of bacterial origin, totaling three cases, which were associated with tail biting. And finally, one animal presented eosinophilic meningoencephalitis, compatible with salt poisoning or water deprivation.

Pigs with hemoperitoneum due to hepatic rupture presented focal or multifocal ruptures, mainly in the left and right medial lobes. This condition often showed comorbidities, being pneumonia (10/14), PDNS and bacterial pericarditis (2/14 each) the most frequently observed. In addition to the areas of rupture of the capsule and parenchyma, neither macroscopic nor microscopic lesions were observed in the liver of these pigs.

In the group of bone fractures, six pigs presented fracture of the spine (mean of 152 days of age), three exhibited epiphysiolisis (159 days), and one, a humerus fracture. No histological lesions of osteometabolic disease were observed in these cases. Enterocolitis comprised four cases of acute *Salmonella* sp. infection (4/9); three cases of rectum stenosis due to chronic salmonellosis (3/9); and two cases of proliferative enteropathy by *L. intracellularis* (2/9). The culture of *Salmonella* sp. was possible in only one case. Intestinal samples of both pigs with proliferative enteropathy were positive in Warthin-Starry technique.

The group "others" was composed by less frequent diagnoses (19/601). They were fibrocartilaginous thromboembolism, diaphragmatic hernia, eosinophilic granulomatous myocarditis, rectum prolapse, vaccine reaction, mediastinal lymphoma, penile urethra necrosis, bacterial peritonitis and congenital heart defects.

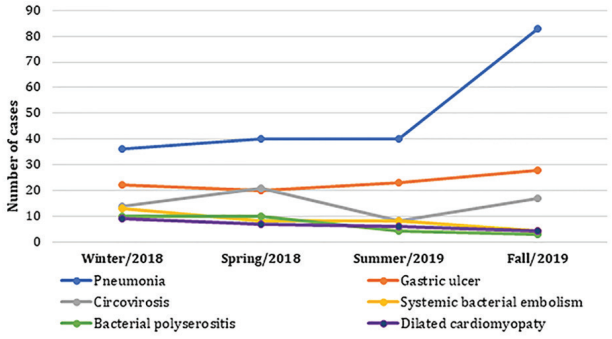

Fig.10. Distribution of the main causes of death of growing-finishing pigs diagnosed throughout the four seasons.

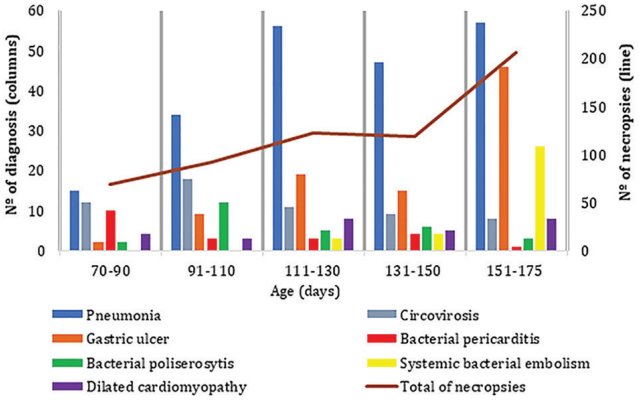

Fig.11. Distribution of the main causes of death of growing-finishing pigs diagnosed according to age and number of necropsies performed at each age.

DISCUSSION

The technified production of pigs is characterized by the confinement of large groups of animals, and this intensification generates an environment favorable to the transmission of infectious agents that clinically affect pigs (Maes et al. 2001). In addition, changes of the epidemiological profile of pig diseases can be observed today (Thrusfield 2013). Several studies show that infectious diseases are the most frequent in the growth and finishing phases, and these can represent up to 75% of the diagnoses (Wilson 1970, Lippke et al. 2007, Sobestiansky et al. 2012, Brum et al. 2013, Konradt et al. 2020). Similarly, in the present study, infectious diseases were the most frequent. However, the large number of non-infectious diseases stood out (35.6% of conclusive diagnoses). Performing necropsies *in loco* provided an adequate sampling, essential to reach the final diagnosis, and allowed the observation of the gross appearance of non-infectious conditions that are frequently and easily diagnosed, such as gastric ulcer and torsions. These are usually sporadic diseases that do not justify the submission of samples for laboratorial diagnosis, making them underrepresented in the laboratories routine, and consequently in retrospective studies.

The most frequent diseases of this study did not present apparent seasonality, however a significant increase in the number of cases of pneumonia was observed in the fall. This increase was justified by a failure to include antibiotics in the ration of Farm A in the month of visit. Regarding the mortality rate, it was evident that the number of deaths increased throughout the life of pigs, peaking in the final weeks, near the time of slaughter, as also highlighted in a previous work (Straw et al. 1983).

Pneumonias represented the group of greatest importance in this work. The term "swine respiratory disease complex" is used to refer to the interaction of many infectious agents with risk factors for the development of pneumonia in pigs (Fonseca et al. 2015). In the present study, this interaction was evident and was considered for the establishment of diagnoses. In Brazil, swine influenza became important after the entry of the pandemic influenza A H1N1 virus in 2009 (Schaefer et al. 2011). After 2013, the virus became endemic in the swine population, causing mild and less lethal lesions (Konradt et al. 2020). Although there are few studies about influenza virus infection dynamics, Nirmala et al. (2019) demonstrated that influenza A viruses isolated from the same batch at different times were genetically different, with multiple genotypes co-circulating throughout winter and summer. This suggests that Influenza virus has the potential to reinfect animals, causing year-round disease in pigs of different ages. Further studies

infer that there is cross-immunity only for homologous strains of the virus, which allows the pig to become constantly infected by heterologous strains (Everett et al. 2019). In the present study, 80.4% of the pigs that died of pneumonia presented histological lesions suggestive of influenza, demonstrating the great importance of this pathogen in finishing herds, in which mortality is influenced by its presence. The results of the present study also demonstrated that in 75% of the lungs tested (60/80) there was involvement of *Mycoplasma hyopneumoniae* in the lesions. Thus, the importance of influenza A virus and *M. hyopneumoniae* as the main primary respiratory agents of pigs in the growth and finishing phases is emphasized, in agreement with other studies (Morés et al. 2015, Rech et al. 2018).

In association with Influenza and *M. hyopneumoniae*, *Pasteurella multocida* was also an important respiratory pathogen for pigs in this study, which is in accordance with other studies on pneumonia in pigs (Choi et al. 2003, Oliveira Filho et al. 2015, Morés et al. 2015). Previously, *P. multocida* was highlighted as a secondary and opportunistic bacterium of the respiratory tract of pigs, mainly related to co-infection with *M. hyopneumoniae* (Pijoan & Fuentes 1987, Hansen et al. 2010). Currently, *P. multocida* has been also associated with primary lesions of pneumonia and septicemia in pigs (Cappuccio et al. 2004, Kich et al. 2007, Pors et al. 2011, Oliveira Filho et al. 2015, Paladino et al. 2017), and it is known to produce suppurative, necrosuppurative and necrohemorrhagic bronchopneumonias, as well as pleurites, especially when there is the involvement of strains of high pathogenicity (Paladino et al. 2017, Oliveira Filho et al. 2018). In this study, bacterial isolation was possible in 61.30% of bacterial pneumonia cases. The absence of growth or presence of contaminant microorganisms in the remaining samples may have occurred due to some factors, such as frequent use of antibiotics in water or feed, parenteral treatment of sick animals, chronicity of lesions, varying degree of autolysis, as well as the logistics of shipping samples to the laboratory.

Gastric ulcer was the second most frequent diagnosis in this study, and this condition presents great importance in mortality and decreased performance of pigs. The prevalence of death from gastric ulcer ranges from 2 to 27% in confined herds (Deen 1993, Melnichouk 2002), and its observation in slaughterhouses can reach frequencies close to 20% (Gottardo et al. 2017). It is a condition with multifactorial etiology, associated with factors such as management practices, environment, feed granulometry, fasting, genetics and stress, which may be associated (Almeida et al. 2006, Thomson & Friendship 2012). In the present study, deaths from gastric ulcers were more frequent at the end of the finishing phase, possibly related to the exacerbation of predisposing factors, such as overcrowding. Usually, these triggering factors are related, and it is difficult to determine the main cause of ulceration, especially in large herds (Gottardo et al. 2017).

Among viral diseases, circovirosis is one of the most important diseases diagnosed in pigs in Brazil (Brum et al. 2013, Konradt et al. 2020), which corroborates with our results, in which it was the third leading cause of death. Detected in the country since 1999, the porcine circovirus type 2 (PCV2) has become endemic, and it is controlled with the use of vaccines, which provide a significant reduction in the losses caused by the disease (Guedes 2012). In the present study, circovirosis was of great importance, especially in the clinical form of PDNS. This was also observed in another study, in which many cases of PDNS were noted, but without the observation of PMWS (Thomson et al. 2002). As demonstrated by Wellenberg et al. (2004), extremely high titers of antibodies against PCV-2 could contribute to the development of the syndrome. In another study, the authors argue that viral load is not a decisive factor in the development of PDNS (Olvera et al. 2004). In this work, it was not possible to determine the origin of the trigger of this condition, however, the advanced age of involvement of these pigs may be a predisposing factor, since finishing pigs are antigenically exposed for a longer period of time, which may favor the more frequent appearance of PDNS.

Although most herds are vaccinated and PCV2 is endemic, the disease has reemerged in recent years, mainly due to vaccine management failures (Konradt et al. 2018), in addition to the interference of other concomitant diseases

Table 2. Main causes of death of growing-finishing pigs from two farms in Southern Brazil

Diagnosis	Total (%)	Sex (male/female)	Age range (days)	Mean age (median)
Pneumonia	199 (33)	112/87	75-190	135 (140)
Gastric ulcer	93 (15.4)	62/31	75-190	149 (152)
Circovirosis	60 (9.9)	24/36	80-190	117 (108)
Systemic bacterial embolism	33 (5.4)	24/9	120-190	171 (180)
Bacterial polyserositis	27 (4.4)	17/11	91-150	116 (100)
Dilated cardiomyopathy	26 (4.3)	12/14	80-190	124 (117)
Torsion of organs of the abdominal cavity	26 (4.3)	11/15	78-175	102 (125)
Bacterial pericarditis	21 (3.4)	9/12	75-150	98 (93)
Meningoencephalomyelitis	15 (2.4)	9/6	70-170	112 (100)
Hemoperitoneum due to liver rupture	14 (2.2)	8/6	75-150	128 (135)
Bone fracture	10 (1.5)	5/5	90-190	159 (170)
Intestinal incarceration/rupture associated with hernia	10 (1.5)	7/3	75-181	157 (145)
Bacterial enterocolitis	9 (1.4)	4/5	80-190	142 (155)
Cardiorespiratory insufficiency associated with fighting	8 (1.2)	3/5	90-190	156 (160)
Others	19 (3.1)	7/12	75-190	148 (155)
Inconclusive	31 (5.0)	13/18	76-190	128(130)
TOTAL	601			

in the vaccination phase; use of vaccines outside the ideal age; and possible insufficiency of vaccine immunity in the protection against viral variants (Segalés 2015). Because it is an immunosuppressive disease, especially when it comes to PMWS, circovirosis makes pigs more vulnerable to secondary bacterial infections (Morés et al. 2015). Valvular endocarditis, pneumonia and bacterial meningoencephalitis were the most frequent concomitant lesions in pigs with circovirosis in the present study.

Systemic bacterial embolisms are caused by opportunistic bacterial infections, which spread hematogenously from a primary lesion and can cause suppurative and abscedative lesions in several organs. The main association of primary lesion in this study was tail biting lesions, as previously observed in pigs with embolic lesions during the slaughter process (Braga et al. 2006, Marques et al. 2012). Males were more frequently affected by this condition, which may indicate a predisposition to caudophagy (Walker & Bilkei 2006, Kritas & Morrison 2007). Other factors that may predispose to this condition are related to stress, such as overcrowding, competition for food, nutritional factors, humidity, temperature, gas level (CO2 or NH3), age and weight gain (Schroder-Petersen & Simonsen 2001, Moinard et al. 2003, Sobestiansky & Zanella 2007). In the farms evaluated, the females selected for reproductive replacement left the farm earlier than the males. Males also tended to be housed in overstocked stalls when compared with females, and these two factors may have contributed to the higher proportion of males with tail biting lesions and systemic bacterial embolism in this study. Cannibalism is also a concern in pig production due to the condemnation of carcasses affected by secondary embolic lesions (Braga et al. 2006, Kritas & Morrison et al. 2007, Marques et al. 2012). In addition to its importance as a cause of carcass condemnation in the slaughterhouse, the present study highlights the group of embolic diseases as an important cause of death of growing and finishing pigs, especially in older animals.

Bacterial polyserositis was the fifth most prevalent diagnosis in this study and was mainly associated with *P. multocida* infection. As already addressed, highly pathogenic strains of *P. multocida* have potential to produce primary lesions of necrohemorrhagic pneumonia, pleuritis, and fibrinous pericarditis (Cappuccio et al. 2004, Oliveira Filho et al. 2015). In the present study, polyserositis lesions with isolation of *P. multocida* were observed in 17 cases (62.9% of polyserositis), sometimes also associated with pneumonia (Paladino et al. 2017, Oliveira Filho et al, 2018). Thus, it is suggested that strains of high pathogenicity of *P. multocida* may be circulating in Brazilian herds, causing mortality and possibly chronic injuries, which can lead to condemnations in slaughterhouses. Therefore, studies on pathogenicity and virulence factors of super pathogenic strains of *P. multocida* become important.

In this research, cardiopathies represented one of the main diagnoses of causes of death of non-infectious origin in pigs, and the most frequent presentation was dilated cardiomyopathy. This condition is a myocardial disorder characterized by reduced contractility and ventricular dilation (Miller & Gal 2017) that may progress to chronic congestive heart failure and death. In pigs there are reports of this disease associated with gossypol and fumonisin poisoning, besides cardiomyopathies of undefined cause (Loynachan 2012, Sobestiansky 2012, Collins et al. 2015), as found in this study. Recently, this disease has been described in Brazil and experimentally reproduced in nursery pigs; in the referred study a nutritional etiology was suggested (Cruz et al. 2019). In the present study, although macroscopic and histopathological lesions were similar to those observed by Cruz et al. (2019), the disease affected pigs sporadically during the growth and finishing phases, in two farms with distinct genetics and nutritional practices, and not as outbreaks, what does not allow us to associate these cases with any epidemiological factor.

Torsions of abdominal organs are common in pigs, especially in the finishing phase (Thomson 2007). The prevalence of mesentery torsion in finishing pig herds can range from 8 to 12% (Melnichouk 2002) and can reach up to 19.3% (Desrosiers 2008). The etiology is not fully elucidated, but it is believed that feed and eating habits are risk factors (Buddle & Twomey 2002, Hollis 2006, Martineau 2008). When compared to younger pigs, finishing pigs eat fewer times a day and consume a larger amount of feed per meal, which may predispose to excessive intestinal gas production, consequently predisposing to twisting at a fixed point (Buddle & Twomey 2002, Thomson 2007, Martineau 2008).

Liver lobe torsion is considered uncommon in production animals (Hamir 1980, Schwartz et al. 2006). However, Schwertz et al. (2018) found that this change was an important cause of death of sows. Generally, twists tend to affect the left lateral lobe, because it is the largest hepatic lobe in the swine species. This lobe is connected to the left medial lobe by a narrow band of tissue, making it predisposed to twists (Hamir 1980, Schwartz et al. 2006). In addition to the displacement of abdominal organs, hepatic rupture with secondary hemoperitoneum was observed in 14 pigs in this study. However, it was not possible to determine the primary cause of the rupture, since no microscopic lesions were found in the ruptured livers, as well as no evidence of blunt trauma.

Bacterial pericarditis represented a small proportion of diagnoses in this study. They usually result from the hematogenous spread of bacterial agents from inflammatory processes in adjacent tissues, such as the lung (Robinson& Robinson 2016). In the present study, pleuritis and pleuropneumonias associated with cases of fibrinous pericarditis were found, and bacterial culture of *P. multocida* occurred in 10 samples. Pulmonary and pleural lesions associated with isolation of *P. multocida* from the pericardial sac were observed by Coelho et al. (2014) in a study on bacterial pericarditis in a slaughterhouse. As the lesions are strongly related to pneumonia and pleuritis, pulmonary agents of greater importance, such as *P. multocida* and *S. suis,* also affect the pericardium more frequently. In general, clinical detection of cases of pericarditis in pigs is difficult in the final stages of the finishing phase, because they are chronic or subclinical conditions, and chronic lesions are usually identified in the slaughterhouse (Sorensen et al. 2006). The chronicity of these lesions also contributes to the difficulty of bacterial isolation from these samples. Another important factor that indicated the chronic course of the disease in the cases diagnosed here was the development of congestive heart failure, in addition to thickening of the pericardium due to intense proliferation of fibrous connective tissue (fibrosis).

Fights are an important stressful factor for pigs. On these moments, when the stress response is exacerbated, there is

activation of the autonomic sympathetic system and simultaneous release of cortisol and catecholamines, especially adrenaline and norepinephrine by the adrenal glands (Maria et al. 2013). This hormonal discharge rapidly increases the heart and respiratory rates, as well as promotes systemic vasoconstriction, redirecting blood flow to the brain, heart and skeletal muscle (Pereira & Ribeiro 2012). This defense mechanism is known as "fight or flight", described by Cannon (1927). Deaths of dogs after manipulation in veterinary establishments and, consequently, reaction to stressful situations, are described by Maria et al. (2013), where 93.8% of the dogs evaluated exhibited edema and marked pulmonary congestion, similar to those described in the pigs of this study. Another fact that contributes to the clinical evolution is the inefficiency of the swine species of losing heat. In these cases of thermal stress, peripheral vasodilation and increased cardiac output occur. When these compensatory mechanisms are overloaded, cardiorespiratory failure and death occur (Krum & Osborne 1977, Johnson 1982). Pigs also present, in general, low heart weight and cardiac volume when compared to other domestic species, and this promotes greater sensitivity of the myocardium to hypoxia. In stressful situations, such as fights, farrowing, loading, and transportation (D'Allaire et al. 1991, Drolet et al. 1992) circulatory system overload and acute heart failure may occur (Thielscher 1987). These mechanisms triggered by stress justify the pulmonary edema and congestion observed in pigs with history of fight in this work.

Enteric diseases represented a small portion of the causes of death of pigs in the farms evaluated. According to Thomson & Friendship (2012), in the growing-finishing phase the main enteric diseases are swine dysentery, swine proliferative enteropathy, salmonellosis, and spirochaetal colitis. However, in the present study, enteritis was sporadic and found in both herds, represented by salmonellosis and the hemorrhagic form of swine proliferative enteropathy. In cases of salmonellosis, bacterial growth was possible in only one case, isolated in bile and spleen. This may be associated with the intermittent excretion of the bacteria through the intestine (Van Winsen et al. 2001), as well as the use of antibiotics in the treatment of affected animals.

CONCLUSIONS

Infectious diseases were the most common cause of death in growing-finishing pigs, especially pneumonia and circovirosis. Non-infectious diseases accounted for 35.6% of diagnoses, with emphasis on gastric ulcer, dilated cardiomyopathy and torsion of abdominal organs. There was an increase in pig mortality in older pigs compared with recently housed pigs.

The most frequent disease was pneumonia, with emphasis on the association among influenza A, *Mycoplasma hyopneumoniae,* and *Pasteurella multocida* as the main etiological agents involved. It was also observed that in addition to being frequently associated with other agents as a cause of pneumonia, *P. multocida* can also cause atypical lesions such as polyserositis.

Circovirosis, even in vaccinated herds, presented a high frequency, especially in the clinical form of porcine dermatitis and nephropathy syndrome. Tail biting was considered an important cause of bacterial thromboembolism in the two farms evaluated, mainly in males. Enteric diseases were not very common causes of death of pigs in this study.

A wide variety of conditions were diagnosed as the cause of death of growing and finishing pigs, most of which were easily diagnosed through necropsy, histopathological examination, and complementary bacteriological and molecular examinations.

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