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Use of smartphone messaging applications to increase diagnostic efficiency in veterinary diagnostic laboratories[1]

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ABSTRACT.- Lemos R.A.A., Guizelini C.C., Silva T.X., Souza L.L., Fonseca H.C.F., Bonato G.C., Gomes D.C. & Pupin R.C. 2023. **Use of smartphone messaging applications to increase diagnostic efficiency in veterinary diagnostic laboratories**. *Pesquisa Veterinária Brasileira 43:e07226, 2023*. Laboratório de Anatomia Patológica, Faculdade de Medicina Veterinária e Zootecnia, Universidade Federal de Mato Grosso do Sul, Av. Sen. Filinto Müler 2443, Campo Grande, MS 79070-900, Brazil. E-mail: ricardo.lemos@ufms.br

Many inconclusive diagnoses have been reported in studies carried out in veterinary diagnostic laboratories (VDLs). These inconclusive diagnoses are often associated with field veterinarians sending tissue samples and carcasses for histopathological examination. The use of social media in care has the potential as a tool for improvements in animal health. We evaluated the improvement in the rate of conclusive diagnoses in the VDL when using a messaging application for smartphones as a guidance tool for field veterinarians to refer animals and sample tissues for necropsy and histopathology. Veterinarians contacted the VDL team via a messaging app and forwarded videos, images, and clinical-epidemiological history. Based on this information, guidelines were created in real-time for contacting professionals about methods for collecting samples during necropsy and making diagnoses and scheduling visits to properties. The data obtained showed that smartphone messaging applications could be useful tools to expand the performance of VDLs and improve their diagnostic efficiency, especially when sending samples of animals that died is impossible due to certain sanitary conditions.

INDEX TERMS: Smartphone messaging applications, diagnostic laboratories, animal production, veterinary pathology.

RESUMO.- [Uso de aplicativos de mensagens de smartphones para aumentar a eficiência diagnóstica em laboratórios de diagnóstico veterinário.] Muitos diagnósticos inconclusivos têm sido relatados em estudos realizados em laboratórios de diagnóstico veterinário (LDVs). Esses diagnósticos inconclusivos são frequentemente associados a veterinários de campo que enviam amostras de tecidos e carcaças para exame histopatológico. O uso das mídias sociais com cuidado tem potencial como ferramenta para melhorias na saúde animal. Avaliamos a melhora na taxa de diagnósticos conclusivos no LDV ao utilizar um aplicativo de mensagens para smartphones como ferramenta de orientação para veterinários de campo encaminharem animais e amostras de tecidos para necropsia e histopatologia. Os veterinários entraram em contato com a equipe do L por meio de um aplicativo de mensagens e encaminharam vídeos, imagens e histórico clínico-epidemiológico. Com base nessas informações, foram criadas orientações em tempo real para contato dos profissionais sobre métodos de coleta de amostras durante a necropsia e realização de diagnósticos, além do agendamento de visitas às propriedades. Os dados obtidos mostraram que os aplicativos de mensagens para smartphones podem ser ferramentas úteis para ampliar o desempenho dos VDLs e melhorar sua eficiência diagnóstica, principalmente quando o envio de amostras de animais que morreram é impossível devido a determinadas condições sanitárias.

TERMOS DE INDEXAÇÃO: Aplicativos de mensagem, laboratórios de diagnóstico, produção animal, patologia veterinária.

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INTRODUCTION

Veterinary diagnostic laboratories (VDLs) are a fundamental part of the integrated diagnostic system in animal health, as they work in the diagnosis, prevention, control, and treatment of diseases, in addition to contributing to the development and improvement of diagnostic techniques. This set of actions results in an important economic impact on livestock activity by reducing losses caused by diseases (Schulz et al. 2018).

Retrospective studies carried out by these VDLs in Brazil (Lucena et al. 2010, Sprenger et al. 2015, Mello et al. 2017, Rondelli et al. 2017, Pupin et al. 2019, Molossi et al. 2021) indicate that 72.9% to 89.94% of inconclusive diagnoses are obtained from samples sent by field veterinarians. The main reasons for this are the sending of tissues in insufficient quantity or an advanced stage of autolysis, the non-referral of organs possibly associated with the reported clinical signs, and the lack of epidemiological and clinicopathological information.

Therefore, to reduce the number of inconclusive diagnoses resulting from failures in forwarding materials to the VDLs, it is necessary to implement measures to minimize these problems. The use of social media for teaching and improving the speed of diagnoses in Veterinary Medicine (Bernardo et al. 2013, Tenhaven et al. 2013, Mekaru & Brownstein 2014, Haustein et al. 2015, Kedrowicz et al. 2016, Englar 2017, Ober 2019, Saadeh et al. 2021, Sellers et al. 2021, Trittmacher et al. 2021, Woodard et al. 2021) and telemedicine (Farahani & Pantanowitz 2015, Bertram & Klopfleisch 2017) grows exponentially. The use of smartphones and media during visits to rural properties and in the guidance to veterinarians on the procedures necessary for sending samples to the VDLs, respectively, showed the potential to stimulate improvements in animal health (Karimuribo et al. 2016, Miltenburg et al. 2021). However, we could find no specific reports addressing the role of messaging applications designed for smartphones as a tool to aid field veterinarians in the elaboration of diagnoses.

This study aimed to evaluate the efficiency of smartphone messaging applications as a tool to guide and direct field veterinarians during the collection and sending of samples to assess whether there is an improvement in the rate of conclusive diagnoses in VDLs.

MATERIALS AND METHODS

For data collection, the team from the "Laboratório de Anatomia Patológica" of the "Universidade Federal de Mato Grosso do Sul" (LAP-UFMS) provided veterinarians with a cell phone number registered in a messaging application, asking them to share this number with other veterinarians. From January 2020 to November 2021, all clients who referred clinical cases via text or audio messages, images, and videos on this digital platform were considered in the study.

The messages received were cataloged and evaluated in terms of the municipality where the clinical cases occurred, the quality of the images and videos referring to the clinical cases and lesions found during the necropsy of the animals, if there was a referral at LAP-UFMS of carcasses or tissues samples from animals necropsied, and their respective number of conclusive and inconclusive diagnoses.

For the evaluation of image quality, only those sent via the messaging application by field veterinarians were considered. The images were classified into three groups: a) poor quality: there was no concrete visualization of clinical signs and/or macroscopic lesions from the images; b) good quality: it was possible, with some graphic difficulty, to determine the clinical signs and/or the macroscopic lesions present in the images and classify them in a diagnostic category (e.g., neurological syndromes, myopathies, and hepatotoxic or cardiovascular diseases); and c) high quality: when the images made it possible to accurately identify the clinical signs and macroscopic lesions (e.g., jaundice, pneumonia, and myonecrosis).

The conclusive diagnoses were based on identifying the etiologic agent in tissue and fluid samples from the necropsied animals, either by histopathological examination or other complementary exams. When the images associated with the epidemiological and clinical history were sufficient to determine the cause of death of the animal, the diagnosis was also conclusive. When macroscopic lesions were sufficient to cause clinical signs and/or death, but the etiological agent was not determined, the morphologic diagnosis was instituted as the final diagnosis. Diagnoses were considered inconclusive when it was not possible to identify lesions that could be associated with the clinicopathological aspects.

RESULTS

During the period evaluated, 411 samples of cattle, 80 horses, 16 sheep, 11 pigs, and two goats were sent to the LAP-UFMS; of this total, 88 (21.4%) were included in this study. The farms of the assisted animals are located in the states of Mato Grosso do Sul (31 municipalities), Mato Grosso, Goiás, Bahia and Pará (Table 1) and have minimum and maximum distances to the physical headquarters of the LAP-UFMS of 58.5km and 2,890km, respectively.

A total of 95 veterinarians contacted the cell phone number provided; of these, 35 (36.84%) sent carcasses to the LAP-UFMS for a necropsy by the specialized team, and 25 (26.31%) performed the necropsy directly in the field, sending organ samples for histopathological exam and other complementary tests, such as microbiological culture. The remaining 35 (36.84%) did not send tissue samples or carcasses but recorded images of clinical signs and provided some epidemiological information about the case. Among the veterinarians who forwarded tissue samples from animals or cadavers to the LAP-UFMS (60), 34 used this service for the first time and made new shipments later.

The LAP-UFMS team performed 45 necropsies, 32 (71.11%) of which had a conclusive diagnosis, two (4.44%) had a suggestive diagnosis, and 11 (24.44%) had inconclusive diagnoses. In addition to frequently diagnosed conditions (Table 2), this study included – with a frequency of 3.12% (1/32) of each disease – nutritional myopathy, poisoning by *Enterolobium contortisiliquum*, urea and ionophore antibiotics, bacterial discospondylitis, malnutrition, hypovolemic shock secondary to severe anemia due to high tick infestation, traumatic reticulopericarditis, and co-infection between *Anaplasma* sp. and *Salmonella* sp.

There were 39 samples collected in necropsies performed by field veterinarians, of which 81.4% (31), 16.3% (7), and 2.3% (1) had a conclusive diagnosis (Table 1), inconclusive and suggestive of some condition, respectively. Regarding the 63 contacts who did not send tissue samples or cadavers but sent images and videos, the inconclusive diagnosis predominated and totaled 68.25% (43/63), mainly due to the non-performance of necropsies or the not sending samples for histopathology.

The conclusive diagnoses in this category were associated with diseases whose macroscopic lesions and clinical history

were sufficient, such as urethral obstruction and intestinal torsion. One of these situations resulted in a visit by the LAP-UFMS team to the property to collect fecal samples for bacterial culture; in 14 other cases (22.22%), the macroscopic images or clinical-epidemiological information allowed the narrowing of the differential diagnoses, such as the suspicion of polioencephalomalacia after treatment with dexamethasone and vitamin B1. Based on the information presented by the veterinarians, other possible diagnoses were poisoning by *Brachiaria* spp. and *Brachiaria radicans* (Figs.1-4) and *Stryphnodendron fissuratum* (Figs.5-7), hypothermia, sodium deficiency, and ruminal acidosis (Figs.8-9). Sporadically diagnosed diseases included suppurative discospondylitis, bovine herpesvirus (BoHV) encephalitis, ionophore antibiotic poisoning, and dermatophilosis.

Table 1. Municipalities and states assisted by the LAP-UFMS and their total cases included in this study

Municipality/State		Total (%)
Mato Grosso do Sul	Dois Irmãos do Buriti	14 (9.65%)
	Terenos	14 (9.65%)
	Campo Grande	13 (9%)
	Água Clara	12 (8.3%)
	Paraíso	8 (5.51%)
	Aquidauana	7 (4.8%)
	Corumbá	6 (4.13%)
	Jaraguari	6 (4.13%)
	Nioaque	6 (4.13%)
	Coxim	5 (3.44%)
	Miranda	5 (3.44%)
	Naviraí	5 (3.44%)
	Paranaíba	4 (2.75%)
	Dourados	3 (2.06%)
	Eldorado	3 (2.06%)
	Jardim	3 (2.06%)
	Maracaju	3 (2.06%)
	Rio Brilhante	3 (2.06%)
	Rio Negro	3 (2.06%)
	Bataguassu	2 (1.4%)
	Camapuã	2 (1.4%)
	Bandeirantes	1 (0.7%)
	Bodoquena	1 (0.7%)
	Caracol	1 (0.7%)
	Cassilândia	1 (0.7%)
	Chapadão do Sul	1 (0.7%)
	Costa Rica	1 (0.7%)
	Nova Andradina	1 (0.7%)
	Rochedo	1 (0.7%)
	Santa Rita do Pardo	1 (0.7%)
	São Gabriel D'Oeste	1 (0.7%)
Pará		4 (2.75%)
Bahia		2 (1.4%)
Goiás		1 (0.7%)
Mato Grosso		1 (0.7%)

Regarding the carcasses sent for a necropsy to the LAP-UFMS, the inconclusive diagnoses were obtained from severe autolysis (2/10), absence of macroscopic and histological lesions (3/10), and diseases of the reproductive tract (abortions and malformations), in which the etiologic agent could not be identified or there were no macroscopic and microscopic changes (5/10). The organ and tissue samples sent by field veterinarians to the LAP-UFMS that were inconclusive were autolyzed (1/7), suggestive of botulism, but it was not possible to detect botulinum toxin (1/7); there were no macroscopic and microscopic lesions (3/7) or resulted from incomplete sending of samples necessary for diagnoses, such as the absence of brain and spinal cord in situations where neurological diseases were suspected (2/7).

Clinical-pathological suspicions of field veterinarians who referred cadavers or samples of organs from necropsied animals corresponded to the conclusive diagnosis in approximately 26.7% and 40% of the cases, respectively. When only images and epidemiological information were sent, the contact's suspicion was correct in 9.8% of the cases.

Regarding the quality of images and videos sent by contacting veterinarians, most were classified as good quality (46.42%), followed by poor (44.64%), and high (8.92%). There were situations in which, even with poor quality, the images were decisive for the diagnosis.

DISCUSSION

The data obtained demonstrate that smartphone messaging applications can be useful tools to expand the performance of VDLs and improve their diagnostic efficiency (Karimuribo et al. 2016, Miltenburg et al. 2021), especially when sending samples of animals that died due to a certain condition is not possible.

Approximately 21.5% of the diagnoses in production animals performed by the LAP-UFMS team resulted from contacting veterinarians via messaging application. The

Table 2. Main conclusive diagnoses in farm animals diagnosed by the LAP-UFMS through necropsy performed by the LAP team or by field veterinarians in 2020 and 2021

Necropsy performed by LAP-UFMS team		Necropsy performed by field veterinarian	
Diagnosis	Frequency	Diagnosis	Frequency
Rabies	21.87% (7/32)	Rabies	42.85% (15/35)
Botulism	9.37% (3/32)	Bovine respiratory disease	5.71% (2/35)
Bovine respiratory disease	6.25% (2/32)	Polioencephalomalacia of unknown cause	5.71% (2/35)
Escherichia coli and *Cryptosporidium* sp. enteritis	6.25% (2/32)		
Brachiaria sp. poisoning	6.25% (2/32)		
Polioencephalomalacia	6.25% (2/32)		
Bovine herpesvirus encephalitis	6.25% (2/32)		

replacement of telephone contact with electronic means, such as e-mail, creates a certain distance between the user and the VDL. The tool used in this study provided direct and personal communication between the VDL and the contacting veterinarian, making it possible to make new contacts and schedule visits to the properties. This was demonstrated by the present study, in which users who did not send animals for necropsy or tissue samples for histopathology in the first contact did so later, in addition to scheduling visits to the properties where the problem occurred. Sending cadavers to the VDL for necropsy was considered an important factor in reducing the number of inconclusive diagnoses, as this procedure is performed by veterinarians trained for this practice (Pupin et al. 2019)

The contact made by field veterinarians located outside the LAP-UFMS area of operation, such as in the states of Mato Grosso, Goiás, Bahia and Pará, reinforces the usefulness of this remote tool for solving health problems since the rapid exchange of information and images from this means of communication help professionals to take certain actions for the definitive diagnosis, avoiding the loss of other animals due to diseases that can be controlled. The initial contact with VDLs located far from the property in question allows the team to indicate VDLs close to where the contacting veterinarian works.

The percentage of conclusive diagnoses in the necropsies performed at the LAP-UFMS was 71.11%. This percentage is higher than previous studies, which accounted for 62.9%

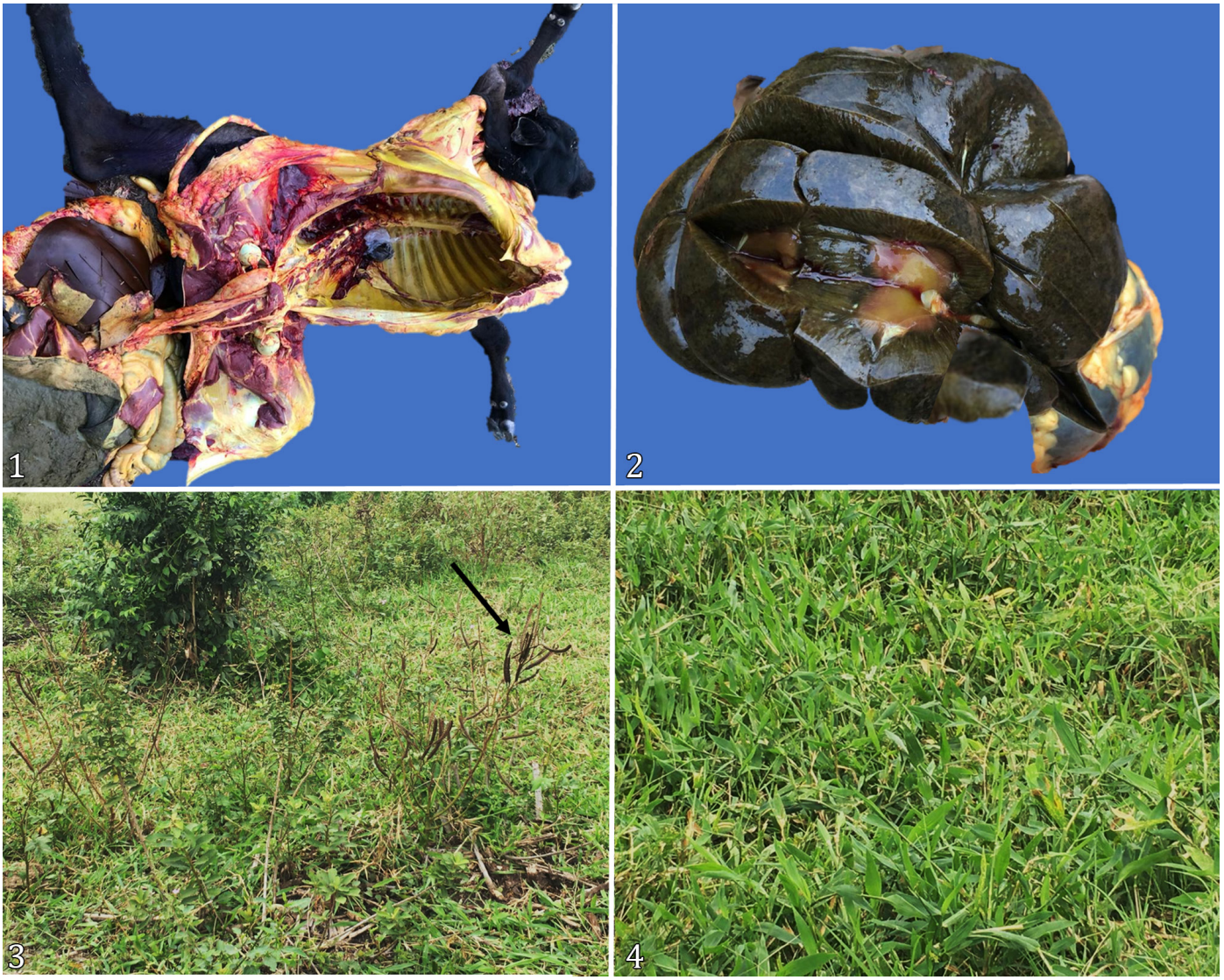

Fig.1-4. Poisoning by *Brachiaria radicans* in cattle. (**1**) Good quality. Diffusely icteric carcass. The liver is diffusely dark brown. (**2**) High quality. The kidney is diffusely black, with a pelvis moderately yellowish. (**3**) Good quality. In the pasture, there are specimens of *Senna occidentalis* (arrow). (**4**) High quality. In the pasture, *B. radicans* predominates. The necropsy findings were compatible with intravascular hemolysis, and the absence of muscle necrosis made it possible to exclude *S. occidentalis* intoxication from the differential diagnosis. The absence of hemoparasites in the complementary exams and the spontaneous recovery of the cattle after the removal of the paddock infested by *B. radicans* was the criterion for excluding the suspicion of babesiosis. Copper toxicosis was excluded, as the cattle were raised extensively and received only mineral salt formulated for the affected animal category. Images provided by veterinarian Pedro Henrique Pereira de Jesus.

(Lucena et al. 2010) and 46.21% (Pupin et al. 2019), and in cases where veterinarians sent samples for histopathology. Although the number of samples and the time interval evaluated in previous studies are higher than those considered in this paper, this improvement in the diagnostic process can be attributed to the possibility of guiding veterinarians in real time on the procedures to be adopted in the collection of samples during the necropsy, according to the different clinical suspicions. This is reinforced by the good percentage of conclusive diagnoses in samples sent by field veterinarians (79.5%), even when, in most cases (60%), the initial clinical suspicion did not coincide with the final diagnosis. Even with a

Fig.5-7. Poisoning by *Stryphnodendron fissuratum* in cattle raised extensively. (**5**) Good quality. Increased volume in the dewlap region and skin dryness in the axillary and neck regions. (**6**) High quality. Subcutaneous in the dewlap region is thickened by yellowish gelatinous material (edema). (**7**) High quality. *S. fissuratum* fruit was found in the pasture where the cattle lived. In the smaller image, there are seeds of this plant, which were found in the rumen content of the necropsied bovine. The images are compatible with this intoxication despite not sending tissue samples for histopathological examination. Images provided by veterinarian Fernando Arévalo Batista.

mistaken initial suspicion, the exchange of information in real-time with members of the VDL team allowed the collection of information and samples necessary for a conclusive diagnosis. Failure to send epidemiological data and anatomical portions of organs essential for diagnosis and failures in packaging and conservation of samples were the main reasons for inconclusive diagnoses.

An important example is the absence of spinal cord or brain samples for diagnosing rabies, the main cause of death in cattle in this study and Mato Grosso do Sul (Ribas et al. 2013, Pupin et al. 2019). As the correction of this failure represents an increase in conclusive diagnoses, communication between the VDL team and the field veterinarian via a mobile application becomes important, as it is a fast way that allows directing the professional in the collection of specific tissue samples according to clinical suspicion, and acts as a gateway for sending animals to the VDL for necropsy performed by the specialized team.

These guidelines were fundamental for the efficiency of the diagnosis in this study since, in most cases, the initial suspicion did not correspond to the final diagnosis.

This remote means of communication proved to be very useful in diseases that do not cause mortality, such as outbreaks of dewlap edema in cattle (Fig.10), a reaction possibly associated with hypersensitivity after drops in ambient temperature but can be confused with outbreaks of poisoning by toxic plants, such as *Brachiaria* sp. (Souza et al. 2010), *Enterolobium contortisiliquum* (Pupin et al. 2019) and *Stryphnodendron fissuratum* (Guizelini et al. 2021). In these situations, as tissue samples are often not sent to the VDL, the referral of images and clinical-epidemiological information is essential for the diagnosis.

Regarding the images that illustrate clinical signs and necropsy findings, the main limitation was a large number of images with poor quality, which reduced the chances of assistance to the veterinarian by the VDL team in the orientation for the accomplishment of the final diagnosis. Although the quality of the images was not ideal in many cases, the set of images and the clinical and epidemiological information provided helped formulate the conduct for the conclusive diagnosis. For this reason, the criterion adopted in the present study, which considered a conclusive diagnosis only in cases in which materials are sent for laboratory tests, is subject to review since, in several situations observed, the images associated with the history were sufficient for the formulation of the diagnosis.

Fig.8-9. Ruminal acidosis in feedlot cattle. (**8**) High quality. Rumen with extensive reddish areas and mucosal detachment. (**9**) Good quality. Rumen with extensive reddish areas. Although this organ was not referred for histopathological examination, the macroscopic diagnosis made it possible to take measures to contain the outbreak. In this case, there was no specific initial suspicion, but based on the clinical and epidemiological history, guidelines were developed on the conduct to be adopted during the necropsy. Images provided by veterinarian Helton Martins.

Fig.10. Edema in the dewlap region in cattle. High quality. The condition occurs as outbreaks in several rural properties and affects many cattle, usually after an intense cold. Recovery is spontaneous, but this condition must be distinguished from hepatogenous photosensitization caused by intoxication by *Brachiaria* spp., *Enterolobium contortisiliquum*, and *Stryphnodendron fissuratum*, in addition to heart failure and its causes. The initial suspicion of intoxication by *Brachiaria* sp. was ruled out based on clinical course and condition, with spontaneous recovery and without photodermatitis. Serum levels of the enzyme gamma-glutamyl transferase (GGT) and aspartate aminotransferase (AST) were within physiological values and were considered complementary diagnostic criteria. Image provided by the veterinarian Guilherme Dutra, Rodrigo Spengler and Luiz Carlos Louzada Ferreira.

Messaging applications for smartphones are useful tools to optimize and improve the efficiency of diagnosis in the region where the VDLs operate, and, in this study, it helped to increase the number of conclusive diagnoses in the LAP-UFMS due to the direct contact with field veterinarians during the investigation of causes of death in farm animals. Results superior to those observed by our team can be achieved if users of this type of service are trained for this purpose since the improvement in the quality of the images and the clinical-epidemiological history help in the conclusion of the diagnosis at a distance, even when samples are not forwarded to the VDL. Considering that flaws in the methodology for collecting and sending tissue samples and pathological, clinical, and epidemiological data to the VDLs still exist, it is necessary to develop training that approaches these aspects for field veterinarians. This approach may not apply to countries that have a broad network of VDLs (Derscheid et al. 2021, Trevisan et al. 2021). However, in countries with large territorial areas of animal production but do not have a sufficiently broad network of VDLs, the search for alternatives that facilitate access to these VDLs is feasible to increase the diagnosis of cattle diseases.

CONCLUSION

Messaging applications for smartphones can improve the efficiency of diagnoses made by veterinary diagnostic laboratories (VDLs) and help field veterinarians in real time when collecting and sending samples.

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