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POLSKA AKADEMIA NAUK

Polish Journal of Veterinary Sciences Vol. 22, No. 3 (2019), 457–461

DOI 10.24425/pjvs.2019.129305

Original article

Accuracy of real-time shear wave elastography in the assessment of normal small intestine mucosa in dogs

J. Spużak[1], K. Kubiak[1], K. Glińska-Suchocka[1], M. Jankowski[1], P. Borusewicz[1], D. Kubiak-Nowak[2]

[1] Department of Internal Diseases with Clinic of Horses, Dogs and Cats, Faculty of Veterinary Medicine, Wroclaw University of Environmental and Life Sciences, pl. Grunwaldzki 47, 50-366 Wrocław, Poland
[2] Department and Clinic of Surgery, Faculty of Veterinary Medicine, Wroclaw University of Environmental and Life Sciences, pl. Grunwaldzki 51, 50-366 Wrocław, Poland

Abstract

The aim of the study was to assess the physiological stiffness of the normal canine jejunal mucosa based on shear wave elastography. The study was carried out on 60 dogs. In all the animals studied, the abdominal ultrasound was carried out using the SuperSonic Imagine Aixplorer system. The site of the jejunal elastography was determined using standard ultrasonography and all the measurements were carried out thrice. The stiffness of the area examined was determined during each measurement. Mean values were calculated based on the results obtained. The normal stiffness of the jejunal mucosa ranged from 1.305 kPa to 9.319 kPa (mean 5.31 ± 2.04 kPa). Based on our findings, we determined the range of normal values of the jejunal mucosal stiffness in healthy dogs. In addition, shear wave elastography was found to be safe and easy to perform. Moreover, it did not require anaesthesia or patient immobilisation for long periods.

Key words: dog, intestine, elastography

Introduction

Elastography is a modern diagnostic technique with increasing diagnostic implications in human and veterinary medicine. Elastography is a diagnostic tool which was first used in medicine at the end of the 20th century (Ophir et al. 1991). However, a dynamic development of elastography has been observed in recent years (Cosgrove et al. 2013). Static and dynamic elastography are the two main types of elastography.

Static elastography is a study that involves exerting slight pressure on the examined tissue with the ultrasound probe, leading to its displacement. The device then analyses the displacement in the studied area and provides the result in the form of a coloured map superimposed on the ultrasound image. Static elastography is subject to error as the repeatibility of the results depends on the pressure exerted by the examiner (Gennisson et al. 2013).

Dynamic elastography determines tissue elasticity

Correspondence to: J. Spużak, e-mail: jolanta.spuzak@upwr.edu.pl

based on the propagation velocity of transverse waves that pass through the tissue examined. The transverse wave propagation velocity increases in firm tissues. The most common dynamic elastography techniques include: transient elastography (TE), acoustic radiation forse impulse (ARFI) and shear wave elastography (SWE) (DeWall 2013).

In transient elastography, an external low-frequency generator is used to excite a transverse wave and wave propagation is observed using ultrasound methods. Approximately 10 measurements of tissue elasticity are collected and a mean kPa value is calculated. Acoustic radiation force impulse (ARFI) is an additional feature of some Siemens US scanners (Acuson S2000, Acuson S3000). During the elastographic study, the probe generates short ultrasound impulses at a frequency of 2.6 MHz resulting in tissue deformation. The applied technique measures the transverse wave in a specific location. The device measures the propagation velocity of the wave in m/s (Gennisson et al. 2013).

Shear-wave elastography (SWE) is one of the most recent advances in this technique. During SWE, several transverse waves are generated at different tissue depths. Through interfering with one another, they form a new cone-shaped transverse wave. In order to assess wave propagation, the data acquisition by the ultrasound transducer must be very fast to register at least 5000 frames/per second. The results obtained are reported in m/s or kPa by the unit software. Due to the fact that the data is rapidly acquired, it is not dependent on the movement of the patient or the physician. A two-dimensional colour map displays the areas of strain and is overlaid on gray-scale ultrasound images. After freezing the frame, the physician is able to measure a preferred area on a large, two-dimensional image of the chosen tissue or organ (Sarvazyan et al. 1998).

Initially, elastography was used in the diagnosis of hepatic fibrosis in humans and in the assessment of breast cancer in women (Bavu et al. 2011, Ferraioli et al. 2012). With the development of novel elastographic techniques, numerous studies have been performed on the use of elastography to assess muscle, tendon and thyroid disorders as well as neoplastic disorders (Bhatia et al. 2012). In veterinary medicine, several studies have looked into the clinical application of elastography (Kallel et al. 1999, Fernandez et al. 2017, Glińska-Suchocka et al. 2017). The results of these studies indicate that elastography may be used in the diagnosis of mammary gland, testicular, hepatic, adrenal and prostate lesions. Based on the above, we attempted to evaluate the applicability of elastography to assess canine jejunal mucosal stiffness.

The aim of the study was to assess the physiological elasticity of the normal canine jejunal mucosa based on shear wave elastography.

Materials and Methods

The study was performed on 60 dogs of various breeds (15 Beagles, 4 German shepherds, 5 Labrador retrievers, 2 Maltese, 1 Boxer, 6 American Staffordshire bullterriers, 27 mixed-breed dogs) and both sexes (26 males, 34 females), aged 2 - 8 years (median = 6). Based on the data provided by the dog owners, none of the animals showed signs of digestive tract disease, such as vomiting or diarrhoea, in six months preceding the study. All the animals were dewormed every three months. The animals were deemed healthy based on the clinical examination and the complete blood count. The complete blood count and serum biochemistry (AST, ALT, ALP, lipase, amylase, TLI, B_{12}, folic acid, urea, creatinine, total protein, albumin, glucose, Na, K, Cl) analyses were within the reference range. In all the dogs, the abdominal ultrasound was performed using a SuperSonic Imagine Aixplorer scanner and a SL15-4 linear probe with a frequency range from 4 to 15 MHz. Next, B-mode ultrasound imaging was carried out to determine the optimal site of the jejunal elastography. Jejunal elastography was repeated thrice. The examination site was clipped, and the measurements were collected by a clinician, who was trained by the device manufacturer. The site was coated with a thick layer of ultrasound gel (approximately 1.5 cm thick), which minimised the pressure exerted by the probe. An SWE box (the site of elastography) was placed within the site of the jejunal mucosa. The measurement site (Q-box) had a diameter of 1-2 mm and was positioned in the middle of the SWE-box. The mean stiffness of the area was determined. All the means were calculated from the obtained measurements.

The normality of the jejunal mucosal elastographic data distribution was analysed based on the χ^2 test (Statsoft Inc. 2014, USA, Statistica, version 12).

Results

The results of the jejunal mucosa elastography passed the normality test (p=0.053). In order to exclude 5% of the most extreme values, a critical region was calculated: $<\mu-1{,}96*\sigma; \mu+1{,}96*\sigma>$ (where μ and σ are the mean and standard deviation, respectively) that delimited 95% of the area under the curve and contained values ranging from 1.305 to 9.319 (Fig.1). Therefore, it may be assumed that 5% of the extreme values were below 1.305 and above 9.319. The mean stiffness of the normal jejunal mucosa was 5.31 ± 2.04 kPa. The images obtained during the elastography are presented in Fig. 2.

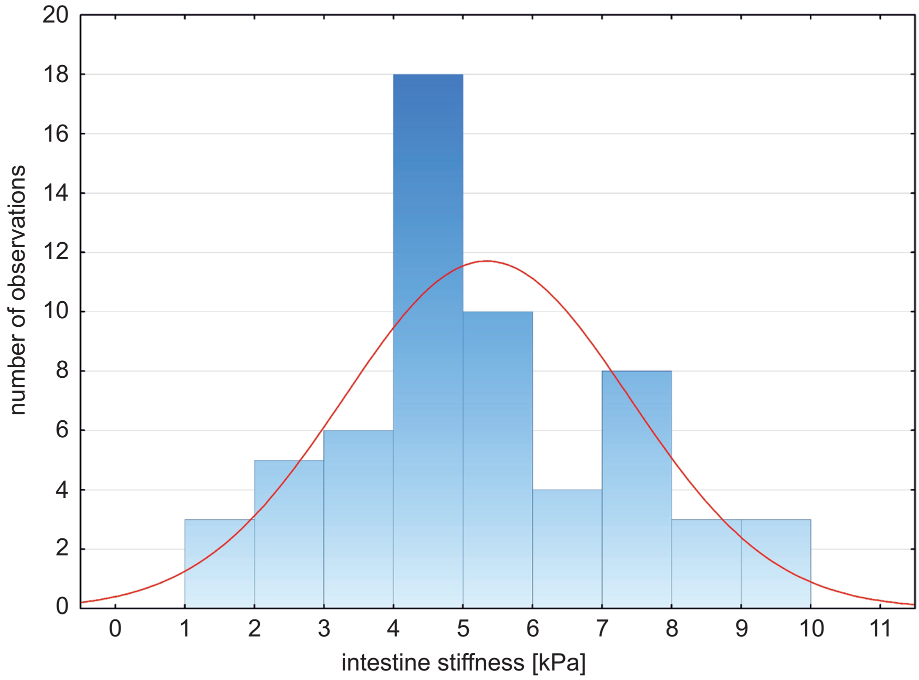

Fig. 1. The graph presents the distribution of stiffness obtained using elastography of the normal small intestinal mucosa in dogs.

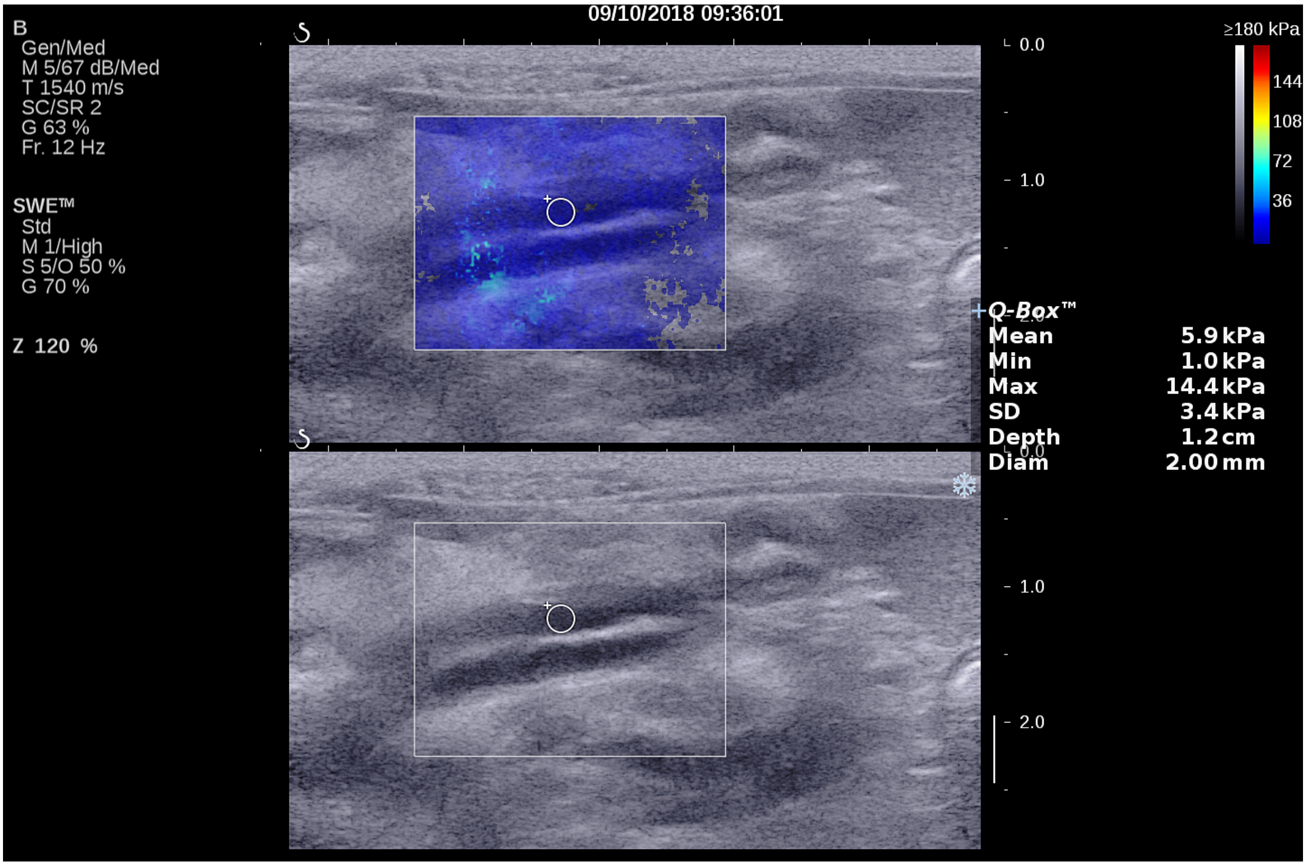

Fig. 2. An elasticity map of the small intestinal mucosa obtained using shear wave ultrasonographic elastography. The elasticity score was 5.9 kPa.

Discussion

In human and veterinary medicine, the accurate diagnosis of the lesions developing in individual organs and/or systems is crucial for their correct treatment. This is particularly important in gastroenterology, where an ideal imaging technique of the intestinal wall allowing simple, minimally invasive diagnosis of disease and differentiating inflammation and fibrosis is still sought, despite the availability of numerous diagnostic tools. Intestinal lesions most commonly develop in the mucosa and may occur as mucosal thickening, obliteration of the mucosal layers, ulceration and enlargement of lymphatic vessels. These lesions are often accompanied by enlarged mesenteric lymph nodes.

Studies carried out in humans have shown that sonoelastography enables differentiating pathological lesions in organs and tissues based on their stiffness (Itoh et al. 2006, Athanasiou et al. 2010, Dillman et al. 2014, Ferraioli et al. 2014). In human medicine, this imaging technique has also been used in the diagnostics of intestinal disease, especially in children, as they have a thin abdominal wall. Hence, the assessed structures are close to the transducer and may be visualised clearly (Darge et al. 2010, Anupindi et al. 2015). Similarly, in dogs and cats, the abdominal wall thickness is small. There are several studies assessing the use of elastography in the diagnosis of intestinal disease in humans. The authors of these studies found that the elasticity of the intestinal wall in Leśniowski-Crohn disease or intestinal adenocarcinoma is slightly increased compared to that of the normal intestinal wall (Havre et al. 2014, Higgins et al. 2014, Fufezan et al. 2015). In veterinary medicine, there are currently two studies available describing intestinal sonoelastography in a rat experimental model (Stidham et al. 2011, Dillman et al. 2013). The authors of these studies applied the same elastography technique as that reported by Dillman et al. (2013), who compared the stiffness of the colon in rats with an experimentally induced Leśniowski-Crohn disease. Based on the results, these authors found that the intestinal stiffness was greater in rats with colonic fibrosis than in those with colonic inflammation. Stidham et al. (2011) also performed a study on the colon in rats with experimentally induced Leśniowski--Crohn disease. The animals were divided into three groups: a control group, a group with acute inflammation and a group with fibrosis. The greatest tissue stiffness was observed in rats with fibrosis, a moderate stiffness was determined in rats with acute inflammation and the lowest stiffness was observed in the control group. It amounted to 2.75 ± 0.56 kPa, 2.16 ± 0.40 kPa and 0.30 ± 0.25 kPa, respectively. These findings support the results of the present study, where the jejunal mucosal stiffness in healthy dogs was significantly lower and ranged from 1.305 kPa to 9.319 kPa (mean 5.31 ± 2.04 kPa) compared with the stiffness of the mucosa in dogs with protein losing enteropathy, where it ranged from 14.4 kPa to 16.8 kPa (mean 15.36 ± 1.32) (unpublished data).

Studies in human medicine have shown that elastography is useful in assessing intestinal fibrosis. It is less invasive than computer tomography (CT) and magnetic resonance elastography (MRE) and does not require anaesthesia. CT additionally emits ionising radiation, while MRE requires the intravenous administration of a contrast agent, which limits its use in emergency cases.

Conclusion

The above presented results are preliminary and form the basis for further analysis of changes in intestinal mucosal stiffness in animals with various intestinal diseases.

Based on the present findings, we determined the range of normal values of the jejunal mucosal stiffness in healthy dogs, which reached 1.305 – 9.319 kPa. In addition, shear wave elastography was found to be safe, feasible and did not require anaesthesia for patient immobilisation.

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