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Pattern recognition and feature extraction of canine celiac and cranial mesenteric arterial waveforms: Normal versus chronic enteropathy – A pilot study

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Abstract

In this pilot study, we hypothesize that waveform patterns of the celiac and cranial mesenteric arteries differ pre- and post-prandially in normal dogs compared to those with chronic enteropathy. We further suggest that it is possible to classify these findings according to the type of disease present.

Eleven dogs with chronic enteropathy and eight normal dogs were examined. Doppler examinations were performed at times 0 (fasted), and at 20, 40, 60 and 90 min post-prandially. The waveform shapes were described and the following features were extracted: resistive and pulsatility index, mean maximum velocity, mean diastolic velocity, peak systolic velocity, early diastolic notch ratio and the deceleration time interval. Dogs with inflammatory bowel disease had either lower or absent flow at fasting in early diastole compared to the other groups. Resistive and pulsatility indices decreased during digestion in all groups except those with protein losing enteropathy. The increase in mean diastolic flow during digestion in affected dogs was either lacking (protein-losing enteropathy) or significantly lower (inflammatory bowel disease, $P < 0.05$) compared to normal dogs. Dogs with chronic enteropathies had abnormal arterial waveform shapes and suboptimal increases in diastolic blood flow during digestion and these findings worsened with the severity of the histological lesions present. Doppler ultrasound of the celiac and mesenteric arteries has great potential to enhance our understanding of intestinal disease in conscious dogs.

Keywords: Doppler ultrasound; Celiac artery; Cranial mesenteric artery; Gastrointestinal blood flow; Inflammatory bowel disease

1. Introduction

The investigation of gastrointestinal blood flow with Doppler ultrasound is in its infancy in veterinary medicine. A few veterinary investigators have described the spectral waveforms of the celiac and cranial mesenteric arteries in normal dogs as being of moderately high resistance (Finn-Bodner and Hudson, 1998; Kircher et al., 2003; Riesen et al., 2002; Spaulding, 1997). Reference values for resistive index (RI), pulsatility index (PI) and peak systolic and diastolic velocity estimations in normal dogs, both pre- and post-prandially, have only recently been made available (Kircher et al., 2003; Riesen et al., 2002). It has also been shown that post-prandial RI and PI values of the celiac and cranial mesenteric arteries are dependent on which dietary components predominate (Kircher et al., 2003).

Although the haemodynamic physiology of the canine gastrointestinal tract has been described, the haemodynamics of dogs clinically affected with chronic enteropathies have not been investigated. Additionally, attempts to recognize altered gastrointestinal haemodynamics in dogs other than by calculating RI and PI values have not been reported.

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Food intake was one of the first physiological stimuli applied to test mesenteric artery responses by means of Doppler ultrasound in humans (Jager et al., 1986; Moneta et al., 1988). Furthermore, Doppler ultrasound has been applied to the diagnosis of disease processes in the gastrointestinal tract and to monitor disease activity in humans, mainly in inflammatory bowel disease (IBD) (Britton et al., 1998; Van Oostayen and Wasser, 2002). Chronic enteropathies in dogs are most commonly due to IBD, food allergies, bacterial overgrowth and parasitism. IBD is common in both dogs and humans (Guilford, 1996; Hall and Simpson, 2000; Jergens, 1999; Marteau, 2000; Sicherer, 2002) and is a collective term describing a group of chronic enteropathies having histological evidence of inflammation. In dogs, the nomenclature of the grouping reflects the type of mucosal infiltrate found histologically (Jergens, 1999). The aetiology of IBD in humans is unclear despite extensive investigations into Crohn's disease, celiac disease and ulcerative colitis (Jergens et al., 1992; Marteau, 2000). Similarly, the cause of canine IBD remains unclear (Guilford, 1996; Jergens et al., 1992).

Doppler shifts obtained from arteries may be processed to produce either a flow velocity waveform or a Doppler power spectrum (Evans and Mcdicken, 2000). Pattern recognition involves interpreting waveform shape and making a decision based on that shape whether or not disease is present. The objective of pattern recognition is to detect waveforms that are abnormal even if the details of why a particular physiological or pathological change gives rise to a particular change in shape is not fully understood (Evans and Mcdicken, 2000). Pattern recognition consists of three stages: transduction, feature extraction and classification (Baykal et al., 1996; Evans and Mcdicken, 2000). *Transduction* derives a pattern vector from the blood flow in the artery. An example is the velocity waveform for an artery. *Feature extraction* deals with extracting and combining features of the pattern into a feature vector such as calculating an index from specific points of the waveform. *Classification* is used to decide whether the vector is normal or abnormal and even possibly by employing the use of a grading system.

In this pilot study, we examined waveform patterns of the celiac and cranial mesenteric arteries pre- and post-prandially in normal dogs and compared our findings with those in dogs with chronic enteropathy. We then explored whether these patterns may be further classified according to the type of disease present through a process of pattern recognition and feature extraction.

2. Materials and methods

The investigation was a precursor to a larger, multidisciplinary study on dogs with chronic diarrhoea in order to test previously established methods of investigating gastrointestinal blood flow in normal dogs on those with chronic enteropathy.

The local ethics committee and the Swiss animal welfare authorities authorized the procedures carried out in this study.

2.1. Study population

The first 11 dogs with chronic enteropathies that presented for evaluation by our gastroenterology research group were examined (Table 1). Eight normal healthy dogs that were part of a previous study were included to compare with the affected animals (Kircher et al., 2003). Only the RI and PI values of the celiac and cranial mesenteric arterial waveforms of those dogs were previously reported and their waveforms were used for additional analysis and comparison with dogs clinically affected with diarrhoea.

Affected dogs were included in the study based on the following protocol: those with a history of diarrhoea of more than three weeks duration where infestation with intestinal parasites and pancreatic, liver and metabolic disorders were ruled out (based on clinical examination and laboratory findings, i.e., parasitology, haematology and chemistry profiles).

After the initial clinical work-up, dogs that were enrolled in the study underwent two-dimensional greyscale abdominal ultrasonography, Doppler analysis of the celiac and cranial mesenteric arteries pre- and post-prandially, gastroduodenoscopy and intestinal mucosal biopsy sampling. The ultrasound examination was performed two to three days prior to the endoscopic procedures. No therapy was initiated until after all examinations were carried out.

2.2. Doppler ultrasound

The celiac (CA) and cranial mesenteric arteries (CMA) of each dog were examined with Doppler ultrasound pre- and post-prandially as previously described (Kircher et al., 2003). The dogs were fasted for at least 12 h prior to examination and water was withheld in the morning; the stomach was confirmed as being empty with two-dimensional ultrasound prior to Doppler investigation.

Doppler examinations were performed at times 0 (fasted), and at 20, 40, 60 and 90 min post-prandially. The affected dogs were fed their regular diet for the post-prandial measurements. All were commercially available diets with the following component ranges: carbohydrate (12.0–15.8 g/100 g), protein (3.8–5.8 g/100 g) and fat (2.7–3.9 g/100 g). Caloric density ranged between 243 and 383 kcal/225 mL. No diet was high in fat and the compositions were similar to the diets fed to the normal dogs: 12.5 g/100 g carbohydrate, 6 g/100 g protein and