Original Article

Variations in the branching pattern of the canine coeliac trunk in Thailand: an anatomical study

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Abstract

Although the major dog population in Thailand is the Thai native dog, its anatomy has rarely been studied. This study aimed to investigate anatomical variations of the canine coeliac trunk (CT) in Thailand by observing 62 cadavers including 46 Thai native dogs and 16 non-Thai native dogs. All cadavers were preserved in formalin solution, and the arteries were illustrated by injection of red coloured latex. Variations of CT were initially classified into 2 main types and 7 subtypes (type 1a-e and 2a-b) based on the previous reports. Type 1 was described as CT separated from the cranial mesenteric artery (CMA) while type 2, CT fused with CMA and called the coeliacomesenteric trunk (CMT). In this study, only 5 of 7 patterns were found (1a-c and 2a), but a new variation was identified as type 2c. The common patterns were type 1a (CT bifurcated into the gastrosplenic and hepatic arteries; 53.2%) and type 1b (CT trifurcated into the hepatic, left gastric and splenic arteries; 40.3%). The CMT was observed only at 3.2% while two types (1d-e) were not observed in this study. The male and female were different in the most common patterns (1b and 1a, respectively). Thai native dogs showed similar result to all dog results. To the authors' knowledge, this is the first study concerning anatomical variations of the canine coeliac trunk of dogs in Thailand. This study is useful for facilitating imaging diagnosis and surgical treatment and also provides important knowledge for understanding the pathogenesis of the coeliac trunk related diseases.

Keywords: Branching pattern, Coeliac trunk, Coeliacomesenteric trunk, Thai native dogs

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Introduction

Knowledge of anatomical variations is essential to understanding canine physiology and pathology. It is also useful for imaging diagnosis, medicine and surgical operations. However, there are only few reports related to the pattern of anatomical variations of canine vessels compared to human studies (Abidu-Figueiredo *et al.*, 2005, Avedillo *et al.*, 2016).

The present study focused on the branching pattern of the coeliac trunk (CT) (also known as the coeliac artery) and its anatomical relation to the cranial mesenteric artery (CMA). The CT and CMA are the first and second visceral branches originating from the abdominal aorta, respectively. The CT is the second largest branch of the abdominal aorta, its terminal branches are the hepatic, splenic, and left gastric arteries supplying blood to the liver, spleen, and stomach, respectively. The CMA is the largest visceral branch of the canine aorta. It passes through the mesentery and supplies blood to intestines (Evan & Lahunta, 2013). The CT and CMA also attach to the coeliac and mesenteric nerve plexuses, the largest nerve network in the abdomen that controls the function of abdominal visceral organs (Evan & Lahunta, 2013). The anatomy of the CT and CMA is important for surgery and medicine. An occlusion or compressing of these vessels may cause visceral ischaemia and neurological disorders (Kazan *et al.*, 2013, Loukas *et al.*, 2007). The location and pattern of the coeliac trunk can be used to locate the coeliac and mesenteric plexuses for the treatment of severe abdominal pain and for postoperative ileus resolution (Ravasio et al, 2015).

A previous study demonstrates that the coeliac trunk in some dogs (9%) has been compressed by median arcuate ligament of diaphragm (Le Pommellet *et al.*, 2018). In humans, the compression of the CT is clinically important because it can affect the blood circulation and nerve function resulting in abdominal pain and weight loss (Kazan *et al.*, 2013, Loukas *et al.*, 2007). However, the relation of the compression of the coeliac trunk to clinical problems in dogs is still inconclusive and requires more study (Le Pommellet *et al.*, 2018). Some abnormalities of CMA can be found in dogs, for example, canine mesenteric artery ischaemia (also known as cranial mesentery block). This abnormality is caused by thromboembolism (Sakaguchi *et al.*, 2002) or rotation of the root of mesentery (Junius *et al.*, 2004) causing the death of dogs. Notably, the study of the CT and the cranial mesenteric artery is not only essential for dogs but is also being used as a model for visceral ischaemia in human (Bonakdarpour *et al.*, 1975, Mandarry *et al.*, 2010, Romano *et al.*, 2011).

A few studies of the anatomical variation of the canine CT and CMA have been done, and six branching patterns have been found (Kennedy & Smith, 1930, Roza *et al.*, 2012, Schmidt & Schoenau, 2007) but a summary of branching patterns has never been reported. In human studies, the coeliac trunk variation can be found in more than fifteen patterns (De Martino, 2015, Yi *et al.*, 2007).

The present study investigated the variation of canine coeliac trunks in Thailand. The majority of dogs in Thailand are Thai native dogs which are unique and ancient with regard to genetics, archaeology and biogeography studies from years ago (Boonyaprakob *et al.*, 2017, Larson *et al.*, 2012, Pilot *et al.*, 2015, Wang *et al.*, 2016). Most Thai native dogs are free-breeding and considered to be mongrels except for the Thai Ridgeback breed that is registered by the world dog organisation (Federation Cynologique Internationale, 2004), and their anatomies have not been recorded.

The aim of the study was to reveal the branching patterns of CT of dogs in Thailand and compare them to those of previous studies.

Materials and Methods

Cadavers: All canine cadavers in this study had naturally died from non-infectious diseases and were donated to the Faculties of Veterinary Science (Mahidol and Chulalongkorn Universities) for being used in teaching veterinary gross anatomy.

This study was performed on dissected cadavers previously used for gross anatomy learning by veterinary students. This research project was approved by the Animal Care and Use Committee, Faculty of Veterinary Science, Mahidol University.

Forty-six cadavers of Thai native dogs (none were Ridgebacks) were observed (26 males/ 20 females) and sixteen non-Thai native dogs (4 golden retrievers, 3 beagles, 3 Labrador retrievers, 1 Dalmatian, 1 French bulldog, 2 Siberians huskies, and 2 poodles) were also included in the study (8 males/ 8 females). In total, the number of male dogs was 34 and females 28. The dogs' ages were approximately 8 to 12 years old and their body weight was between 5 and 15 kg.

Cadaver preparation: After donation, the cadavers were kept either in 4 ºC (1 to 3 days at Chulalongkorn University) or -20 ºC freezer (1 to 2 weeks at Mahidol University) until embalming. Thereafter, the cadavers were thawed at room temperature for a day and then a preservative chemical solution (a mixture of formaldehyde, glycerine, and phenol) was injected into the left common carotid artery of the specimens until an excess amount of solution leaked out from their noses and the body (abdomen) of the cadavers began to swell. A day later, approximately 500 mL of red coloured latex was injected by a pressure pump into the left common carotid artery to clearly illustrate arterial vessels. The cadavers were then kept at room temperature for a day before they were immersed in diluted formalin solution for long-term storage.

Most of the dogs in the present study were Thai native dogs. Their body weight was about 10-15 kg and they had short hair with colours that were white, brown, black, grey or mixed (Figure 1).

Classification of branching patterns: The classification of the CT patterns was based on our observation and previous reports (Abidu-Figueiredo *et al.*, 2005, Araujo Netoand & Campos, 2015, Awal *et al.*, 2001, Kennedy & Smith, 1930, Le Pommellet *et al.*, 2018, Ricciardi *et al.*, 2013, Roza *et al.*, 2012, Schmidt & Schoenau, 2007). According to the information from previous studies, we categorised branching patterns into two major groups (Figure 2): type 1, the CT and CMA arose separately from the abdominal aorta while type 2, the CT and CMA shared common trunk called coeliacomesenteric trunk (CMT) before branching. Seven subtypes were subsequently identified and named type 1a, 1b, 1c, 1d, 1e, 2a, and 2b as shown in Figure 2.

Type 1a was described as the CT bifurcated to the hepatic artery and gastrosplenic trunk which later branched into the left gastric and splenic arteries. In Type 1b, the CT trifurcated into the hepatic, left gastric and splenic arteries. Type 1c, the CT had a bifurcation of hepatic and left gastric arteries while the splenic artery branched off as the first branch of the CMA. In Type 1d, the CT trifurcated into the splenic artery, the gastroduodenal artery and the gastrohepatic trunk which branched into the left gastric and hepatic arteries. In Type 1e, the CT branched into the two-left gastric, splenic, and hepatic arteries.

In type 2a, the CMA and CT branched off from the CMT, after that, the CT trifurcated into the hepatic, left gastric and splenic arteries whereas in type 2b, the first two branches of the CMT were the hepatic and left gastric arteries followed by the bifurcation of the splenic artery and the CMA.

Figure 1 The appearance of the Thai native dog.

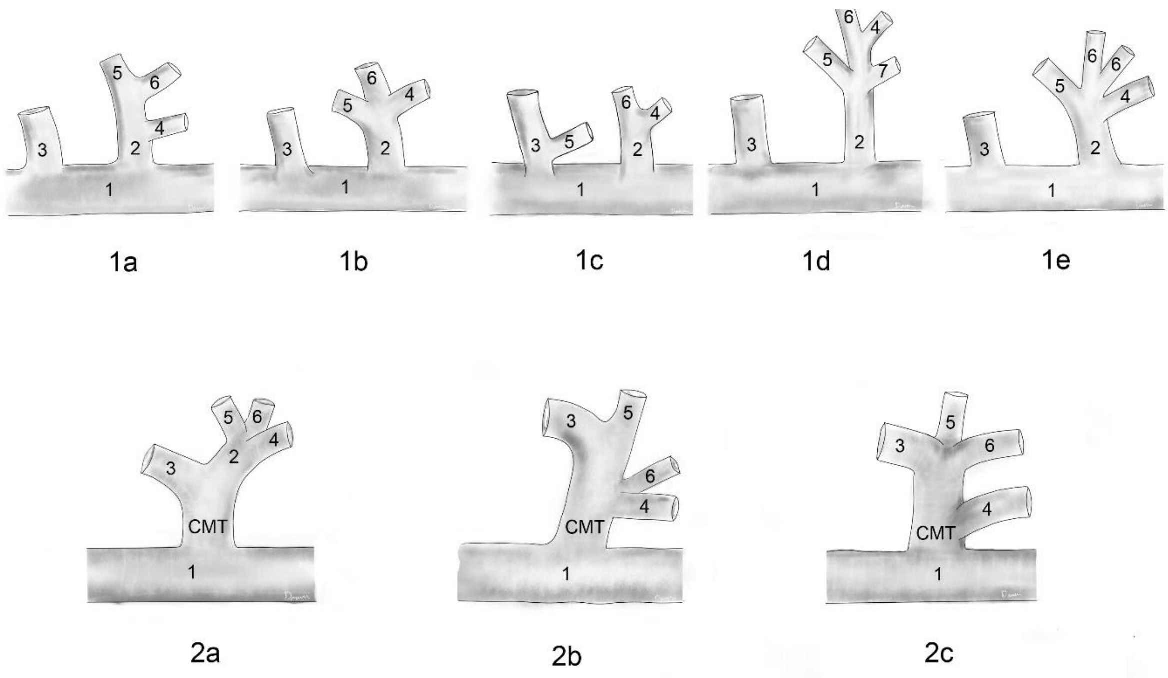

Figure 2 Branching patterns of the coeliac trunk that can be found in our study and previous studies. 1= the abdominal aorta, 2 = the coeliac trunk (CT), 3 = the cranial mesenteric artery (CMA), 4 = the hepatic artery, 5 = the splenic artery, 6 = the left gastric artery, 7 = the gastroduodenal artery and the CMT = the coeliacomesenteric trunk.

Results

The occurrence of each branching pattern in all dogs is summarised in Table 1, and the occurrence in Thai native dogs is shown in Table 2. From observation, 93.5% of all specimens were type 1a and 1b (53.2% and 40.3%, respectively). These common patterns were also observed in Thai native dogs (95.6%) in which type 1a was 45.3% and type 1b was 41.3%.

In the present study, we found a new pattern of the coeliac trunk in a Labrador retriever and placed it into type 2c (Figure 2 and 3). This pattern was described by the CMT gave the hepatic artery as a first branch, and then trifurcation of the CMA, splenic and left gastric arteries. Two subtypes (type 1d and 1e) were not found in this study. Moreover, types 1c, 2a, 2b, and 2c were rarely found (6.4%) and each type was only found in one dog. Type 2a and 2b were identified in Thai native dogs, and type 1c was found in a Golden retriever.

A comparison between male and female dogs revealed that the most common branching pattern of male dogs was type 1b (50.0%) which was slightly higher than type 1a (47.1%) (Table 1). On the other hand, type 1a was the most common pattern found in female dogs, and the occurrence was clearly different from type 1b (60.7% Vs 28.6%). A difference in the most common pattern between male and female dogs was also observed in Thai native dogs (Table 2), the most common pattern in the male Thai native dogs was type 1b (50.0%) while in the female, it was type 1a (65.0%).

Table 1 The occurrence of branching patterns of the coeliac trunk in all dogs.

Type	**Sub Type**	**Comparison by sex**		
		All n (%)	**Males n (%)**	**Females n (%)**
1	**1a**	33 (53.2)	16 (47.1)	17 (60.7)
	1b	25 (40.3)	17 (50.0)	8 (28.6)
	1c	1 (1.6)	0 (0.0)	1 (3.6)
	1d	0 (0.0)	0 (0.0)	0 (0.0)
	1e	0 (0.0)	0 (0.0)	0 (0.0)
	Sub Total	59 (95.2)	33 (97.1)	26 (92.9)
2	**2a**	1 (1.6)	1 (2.9)	0 (0.0)
	2b	1 (1.6)	0 (0.0)	1 (3.6)
	2c	1 (1.6)	0 (0.0)	1 (3.6)
	Sub Total	3 (4.8)	1 (2.9)	2 (7.1)
	Total	62 (100)	34 (100)	28 (100)

Table 2 The occurrence of branching patterns of the coeliac trunk found in Thai native dogs.

Type	**Sub type**	**Comparison by sex**		
		All n (%)	**Males n (%)**	**Females n (%)**
1	**1a**	25 (45.3)	12 (46.2)	13 (65.0)
	1b	19 (41.3)	13 (50.0)	6 (30.0)
	1c	0 (0.0)	0 (0.0)	0 (0.0)
	1d	0 (0.0)	0 (0.0)	0 (0.0)
	1e	0 (0.0)	0 (0.0)	0 (0.0)
	Sub total	44 (95.6)	26 (96.2)	19 (95.0)
2	**2a**	1 (2.2)	1 (3.8)	0 (0.0)
	2b	1 (2.2)	0 (0.0)	1 (5.0)
	Sub total	2 (4.4)	1 (3.8)	1 (5.0)
	Total	46 (100)	26 (56.5)	20 (43.5)

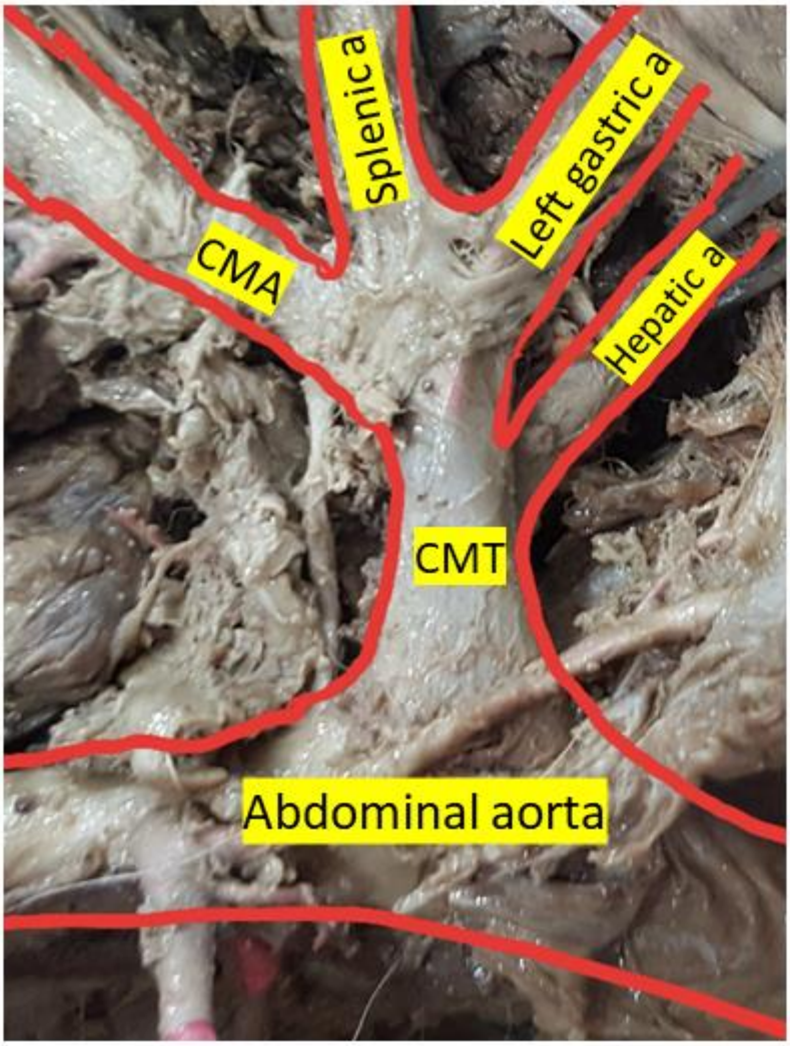

Figure 3 Type 2c, the new type found in this study. This pattern was described as the CMT gave the hepatic artery as a first branch, and then trifurcation of the CMA, splenic and left gastric arteries

Discussion

In the present study, we identified six branching patterns of the coeliac trunk from the cadavers including types 1a to 1c and 2a to 2c. Notably, type 2c was the new pattern, however, two subtypes (type 1d and 1e) that had been reported in other studies (Awal *et al.*, 2001, Le Pommellet *et al.*, 2018) were not observed in this study. Additionally, the extraordinary pulmonary branch reported by Roza et al (2012) was also not found in this study.

The common patterns in the present study were types 1a and 1b which accounted for more than 90% of dogs. These two common patterns were also observed by Abidu-Figueiredo *et al.* (2005). Conversely, Le Pommellet *et al.* (2018) reported type 1a as the common pattern but type 1b was not observed, and others (Evans & de Lahunta, 2013, Dyce *et al.*, 2010) stated that type 1b was the common pattern while type 1a was rare. Notably, for the first time, the present study revealed a difference in the most common pattern of the coeliac trunk between male and female dogs (particularly Thai native dogs); this difference has never been reported in other species. A knowledge of the difference in the common pattern between sexes and breeds is useful for imaging diagnosis and surgery. It has been reported that the coeliac trunk variations increase the difficulty and risk of abdominal operations and require preoperative imaging evaluation (Huang *et al.*, 2015).

The CMT (type 2) was infrequent in dogs. It was found in 4.8% of the present study, 2.3% in the study of Le Pommellet *et al.*, (2018), and two case reports (Kennedy & Smith, 1930, Ricciardi *et al.*, 2014). In comparison to other species of mammals, the CMT was not found in rabbits (Abidu-Figueiredo *et al.*, 2008, Estruc *et al.*, 2015), cattle (Khalifa, 2013), goats (Alsafy, 2009), chinchillas (Ozdemir *et al.*, 2013) and it was extremely rare in humans (<1%) (De Martino, 2015), but a higher occurrence of the CMT was observed in cats (15%) (Le Pommellet *et al.*, 2018) and sheep (39%) (Langenfeld & Pastea, 1977). Surprisingly, the CMT was very common (nearly 100% occurrence) in some rodents such as the degus and guinea pigs (Petrenko, 2014, Bednárová Z & Malinovský, 1990, Shively & Stump, 1975) and was also the most frequently observed pattern in non-mammalian species such as bullfrogs (Ichimura *et al.*, 2001) and Pirarucu fish (Santos *et al.*, 2007).

From a clinical point of view, the CMT can cause more clinical and surgical complications, therefore a preoperative knowledge of vascular anomalies is necessary when planning a surgical approach (Sangster *et al.*, 2014). The occlusive diseases of the CMT may create more serious ischaemic consequences to the abdominal visceral organs due to no redundancy between the coeliac and mesenteric arterial circulation (Ailawadi *et al.*, 2004). From the evolution perspective, the incidence of the CMT may represent the anatomical evolution of vertebrates. The low occurrence of the CMT may represent the high development of the abdominal aorta due to the separation of the coeliac trunk and the CMA can help to compensate the blood flow when occlusion occurs in one of these vessels. The theory of blood flow compensation between the coeliac trunk and the CMA has already been shown in a previous study in dogs (Keskitalo *et al.*, 1976).

In conclusion, the present study proposed that there were eight variations of the branching pattern of the coeliac trunk in dogs in which type 1a and 1b were the most common patterns. However, the most common pattern in male dogs was type 1b while type 1a was the most common pattern in female dogs. A knowledge of anatomy of coeliac trunk is useful for teaching veterinary anatomy and can be applied surgery and imaging diagnosis.

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