White, Robert N. and Parry, A.T. (2016) Morphology of congenital portosystemic shunts involving the left colic vein in dogs and cats. Journal of Small Animal Practice, 57 (5). pp. 247-254. ISSN 1748-5827

Morphology of congenital portosystemic shunts involving the left colic vein in dogs and cats

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SUMMARY

Objectives: To describe the anatomy of congenital portosystemic shunts involving the left colic vein in dogs and cats.

Methods: A retrospective review of a consecutive series of dogs and cats managed for congenital portosystemic shunts.

Results: Six dogs and three cats met the inclusion criteria of a congenital portosystemic shunt involving the left colic vein plus recorded intraoperative mesenteric portovenography, computed tomography angiography and gross observations at surgery. All cases had a shunt which involved a distended left colic vein. The final communication with a systemic vein was variable; in seven cases (5 dogs, 2 cats) it was via the caudal vena cava, in one cat it was via the common iliac vein and in the remaining dog it was via the internal iliac vein. In addition, two cats showed caudal vena cava duplication.

Clinical Significance: The morphology of the shunt type described appeared to be a result of an abnormal communication between either the left colic vein or the cranial rectal vein and a pelvic systemic vein (caudal vena cava, common iliac vein or internal iliac vein). This information may help with surgical planning in cases undergoing shunt closure surgery.

Keywords: Soft Tissue-Cardiovascular, Imaging-CT

INTRODUCTION

Congenital portosystemic shunts (PSS) are broadly classified as either intrahepatic or extrahepatic (Payne *et al.* 1990, Martin 1993, Levy *et al.* 1995, Lamb & White 1998, Tillson & Winkler 2002, Hunt 2004) with further sub-classification of extrahepatic portosystemic shunts (EHPSSs) commonly being restricted to either porto-caval or porto-azygos (Szatmári *et al.* 2004). Methods used for shunt classification include ultrasonography (Lamb 1996, Szatmári & Rothuizen 2006), magnetic resonance angiography (MRA) (Sequin *et al.* 1999, Bruehschwein *et al.* 2010, Mai & Weisse 2011), computed tomography angiography (CTA) (Frank *et al.* 2003, Zwingenberger *et al.* 2005, Nelson & Nelson 2011, White & Parry 2013), findings on intra-operative mesenteric portovenography (IOMP) (White *et al.* 2003, White & Parry 2013), direct gross observations at surgery (White & Parry 2013, White & Parry 2015) and the examination of corrosion casts made post mortem from individuals suffering from an extrahepatic portosystemic shunt (Szatmári & Rothuizen 2006).

Recently, congenital EHPSSs involving the left phrenic vein and right gastric vein were independently described in detail using a combination of CTA, IOMP and gross anatomical findings (White & Parry 2013, White & Parry 2015). These studies concluded that the left gastric vein commonly represented the anomalous vessel (shunt) communicating with the systemic vein. In addition, the morphology of each shunt type described was shown to be the result of the development of preferential blood flow through essentially normal portal vessels within the portal venous system.

The purpose of this study was to define the morphology of congenital EHPSSs emanating from the left colic vein in both dogs and cats using a combination of CTA, IOMP and gross anatomical findings of a series of consecutive clinical cases.

MATERIALS AND METHODS

This retrospective study reviewed dogs and cats seen by the authors between 1997 and 2014 for the investigation and management of congenital PSS. The main inclusion criterion was that all cases must have a congenital PSS that emanated from the left colic vein. In addition, all cases must have undergone either preoperative CTA (only available after 2009) or recorded IOMP and direct gross observations at the time of surgery.

Data on breed, signalment (age, sex), imaging investigation, type of portosystemic shunt and gross surgical findings were collected and reviewed. Shunts that emanated from the left colic vein were separated and reviewed from the main body of shunts collected.

Computed tomography angiography was performed under anaesthesia using a 16 slice multidetector unit (Brightspeed, General Electric Medical Systems, Milwaukee) as described previously (White & Parry 2013, White & Parry 2015). Briefly, images were acquired using a 0.625 mm or 1.25 mm slice collimation, depending on the size of the animal, 120 kVp and variable mAs. Scanned field of view (SFOV) and displayed field of view (DFOV) were selected according to the size of the animal. The pitch was 0.938. Pre- and post intravenous contrast (600mg I/kg, Iopromide, Ultravist, Bayer PLC, Berkshire) images were obtained using a standard algorithm (medium frequency reconstruction kernel) and a 512 x 512 matrix, and viewed using a window and level optimised for soft tissue (window 400HU, level 50HU). Contrast was injected at a speed of 2.0 ml/s using a pressure injector. To optimise contrast enhancement, a transverse slice over the mid-abdomen was selected and repetitively examined whilst contrast injection was performed. At the onset of opacification of the portal vessels, a complete abdominal CTA examination was performed using proprietary bolus tracking software with an automated trigger threshold of 120HU to start the scan. The trigger region of interest was positioned over the portal vein at the level of the porta hepatis in all dogs, in the central aspect of the vessel to allow for respiratory motion. Studies were assessed in their native format, using multiplanar reformatting (MPR) and using surface shaded volume rendering. Vascular maps were obtained and post processing was limited to removal of arterial vessels and unnecessary portions of the caudal vena cava (CVC) from the maps.

All CTA studies were reviewed by both authors. In addition, a number of normal CTA studies in dogs and cats were reviewed for the purposes of cross-reference. IOMP was carried out during surgery by using a mobile image intensification unit obtaining ventrodorsal images of the abdomen (White *et al.* 2003, White & Parry 2015). Images were obtained before the manipulation of the shunt and during the temporary full ligation of the shunting vessel. Angiograms were recorded and reviewed by both authors.

The gross anatomy of the shunt was recorded in the surgical report for each case. Information recorded included the course of the distended vasculature, any obvious tributary vessels and its entrance into the CVC or associated systemic vein. In addition, at the request of the owners, one cat was euthanased at the time of surgery and with their permission this individual was made available for a post mortem examination of its gross shunt anatomy.

Using the combined data of IOMP, gross findings during surgery and CTA, the morphology of EHPSSs emanating from the left colic vein was compared. On the basis of this combined data, the anatomy of this shunt type was described and evaluated in the dog and the cat.

RESULTS

In total, six dogs and three cats met the inclusion criteria. The median age of dogs that met the inclusion criteria was 18 months (range 8-84 months). Of these dogs, five were male and one was female. Affected breeds were Yorkshire terrier (n=5) and standard poodle (n=1).

The median age of the three cats that met the inclusion criteria was 45 months (range 6-72 months). Of the three cats, two were male domestic shorthair and one was a female domestic longhair.

Although IOMP was performed in all cases (including a description of the IOMP findings for each case in the respective clinical notes), it was only available for review in three dogs and in none of the cats. In addition to IOMP, CTA was performed in three dogs and two cats. The morphology of shunts emanating from the left colic vein showed variability in cases in which it was identified. The following descriptions were based on the findings of CTA, IOMP and gross findings at the time of surgery (and post mortem in one cat). Data on breed, signalment (age, sex), imaging investigation and type of portosystemic shunt are presented in Table 1. Figure 1 shows a diagram of a normal portal vasculature for cross-reference.

There was initial anatomical consistency, with all cases showing an enlarged but normally sited caudal mesenteric vein draining into the portal vein at a level just caudal to the left limb of the pancreas. Again in all cases, the enlarged caudal mesenteric vein was observed to be a continuation of an enlarged but essentially normally positioned tributary left colic vein within the mesentery of the descending colon (Fig 2). From this point onwards there was variation in the anatomy observed. The most common variation was observed in four dogs (cases 2, 3, 4 & 8) and one cat (case 9). This consistent variation was characterized by the presence of a distended left colic vein that curved craniodorsally and to the right, at the level of the 6th or 7th lumbar vertebra, making a 180 degree turn before entering the left side of the CVC at the level of the 5th or 6th lumbar vertebra (Fig 3A, B & C).

In the remaining two dogs and two cats, the anatomical variations were as follows. In one dog (case 5), the distended left colic vein communicated with a distended cranial rectal vein prior to this vessel's connection with the right internal iliac vein (Fig 4). In another dog (case 6), the distended left colic vein was observed to continue as an anomalous vessel that crossed from left to right before joining the left side of the CVC at the level of the deep circumflex veins (Fig 5). In two cats, there was evidence of CVC duplication. In both, the subsequent two vessels appeared symmetrical but the left was larger than the right. In one cat (case 7), the distended left colic vein communicated with the left common iliac vein (at the level of L6) before this in turn communicated with the left segment of the CVC duplication (Fig 6). In the second cat (case 1), the distended left colic vein curved craniodorsally at the level of the 6th lumbar vertebra, making a 180 degree turn before entering the left segment of the CVC duplication at the level of the 5th lumbar vertebra (Fig 7).

DISCUSSION

The results of this study revealed shunts involving the left colic vein showed some consistency with regard to their course and site of connection with a systemic vein. In six of the nine cases (four dogs and two cats) the shunt anatomy was consistent; a normal but distended left colic vein, passing within the mesentery of the descending colon, which subsequently curved craniodorsally making a 180 degree turn before entering the CVC at the level of the 5th or 6th lumbar vertebra. In one dog, the shunt entered the CVC at a more caudal location at the level of confluence of the deep circumflex veins and the CVC. In the remaining two cases, the distended left colic vein was observed to communicate with the cranial rectal vein prior to entering the common iliac vein and the internal iliac vein, respectively. The overall findings of IOMP, CTA and gross findings at surgery (and at post mortem in one case) were consistent allowing the anatomical description of these shunts in all cases. In addition, the findings from all three investigations were never contradictory.

There was some lack of uniformity in the investigations used to image the EHPSSs involving the left colic vein in this current study. Despite this variation, the investigations performed allowed the vascular anatomy to be accurately determined in all of the cases described. Although IOMPs were only available for retrospective review in three dogs, all nine cases underwent IOMP at the time of surgery with the findings of these studies being both recorded in the clinical case notes and available for review in each case. In addition, gross observations at the time of surgery were also recorded and available for review for all nine individuals. There were, therefore, six cases (1, 2, 5, 6, 7 & 9) in which IOMPs were unavailable for retrospective review. Of these six cases, in four (5, 6, 7 & 9) preoperative CTAs were available for retrospective review. The use of CTA has been shown to be highly accurate in the description of both normal portal vasculature (Zwingenberger & Schwarz 2004, Parry & White 2015) and for the imaging of congenital portosystemic shunts (Frank et al. 2003, Zwingenberger et al. 2005, Nelson & Nelson 2011, White & Parry 2013, White & Parry 2015). It has been argued that the use of CTA will, in fact, provide more information than that provided by an IOMP. An IOMP will only delineate the flow of contrast from its site of injection along the path of venous blood flow and in doing so will fail to show the presence of many portal tributaries (Parry & White 2015). On the contrary, the CTA being a method of non-selective angiography will, if performed correctly, delineate the majority of the portal venous vasculature including the majority of the portal tributary vessels. In one of the remaining two cases, a cat (case 1), an accurate shunt description was achieved via a post mortem examination following the intra-operative euthanasia of the individual. There was therefore only one case, a dog (case 2), in which the evaluation of the shunt anatomy relied solely on the information recorded in the clinical case notes regarding both IOMP and gross observations at the time of surgery. The description of these findings in this particular case were clear and entirely consistent with most common variation in shunt morphology in which the distended left colic vein curved craniodorsally and to the right, at the level of the 6th or 7th lumbar vertebra, making a 180 degree turn before entering the left side of the CVC at the level of the 5th (in this case) lumbar vertebra.

In all cases, although distended, the anatomy of the caudal mesenteric and the left colic veins were considered essentially normal. Visual examination at the time of surgery and the results of the IOMP studies confirmed that the blood flow through these two essentially normal portal vessels was hepatofugal (abnormal blood flow away from the liver) rather than hepatopetal (normal blood flow towards the liver). As described previously, the direction of blood flow is governed by the venous pressure gradient between the splanchnic and hepatic capillary networks (White & Parry 2015). The presence of a congenital EHPSS between the left colic or cranial rectal veins and a systemic vein significantly alters the normal venous pressure gradients in the portal venous system leading to the possibility of hepatofugal and hepatopetal blood flows. A lack of vein valves within the caudal mesenteric and left colic veins would allow for the development of preferential hepatofugal blood flow through what are essentially normal portal vessels. This, in turn, would dictate the characteristic findings observed on IOMP in the cases described. There appears to be no published information regarding the presence or absence of venous valves in either the caudal mesenteric or left colic veins in both the normal dog and cat. Certainly, in this study, the presence of hepatofugal blood flow on IOMP appeared to confirm a complete lack of venous valves within both the caudal mesenteric and left colic veins in all the cases described. What remains unclear is whether a lack of venous valves within these two vessels might, in some part, have had a role to play in the development of this particular shunt type in these cases. Further studies are required to determine whether venous valves are present or absent within the portal venous system of both dogs and cats, and what role their presence or absence might have in the development of congenital PSSs in these species.

In the dog and the cat the rectum is drained via the cranial, middle and caudal rectal veins (Miller 1964, Schaller 1992). The cranial rectal vein is a tributary of the portal system; it is a continuation of the left colic vein which, in turn, is a continuation of the caudal mesenteric vein which drains into the portal vein (Miller 1964, Schaller 1992). On the contrary, the middle and caudal rectal veins are tributary veins of the systemic venous system draining via the internal iliac vein before entering the CVC (Miller 1964, Schaller 1992). Although not well-described, in both the dog and cat, there is a poorly developed rectal venous plexus (plexus venosus rectalis) which unites the systemic middle and caudal rectal veins with the portal cranial rectal vein (Miller 1964, Schaller 1992, Zahner & Wille 1996). This suggests that, in theory at least, there already exists the potential for portosystemic shunting of blood at this site. In eight of the cases described, the shunt appeared to have no involvement with the cranial rectal vein but, in one (case 5), there was a direct communication between this vein and the internal iliac vein. It is unlikely, therefore, that the presence of potential portosystemic shunting of blood at the level of the rectal venous plexus had any involvement in development of this shunt type in at least eight of the cases described. In this single dog (case 5), where the shunting portal cranial rectal vein was observed to have a direct communication with the systemic internal iliac vein there remains a possibility that the abnormal development of the rectal venous plexus might have resulted in the development of this dog's EHPSS.

The embryological development of congenital EHPSSs involving the left colic vein remains unclear. The pre-hepatic portal system develops entirely from the vitelline venous system while the majority of the CVC and common and internal iliac veins develop from the cardinal venous system (Noden & de Lahunta 1985, Payne *et* *al.* 1990). Embryologically, the vitelline vein forms the trans-hepatic portion of the CVC. To produce the complete abdominal CVC this vitelline derived portion of the CVC must fuse with the developing pre-hepatic portion of the CVC, which itself is formed from the cardinal vein. Pre-hepatically, there should be no other functional embryologic communications between the vitelline and cardinal venous systems with the cardinal system only contributing to the development of non-portal veins (Payne *et al.* 1990). The formation of congenital EHPSSs involving the left colic vein are likely to represent a developmental error in which there are functional communications between veins of cardinal vein (CVC, common iliac and internal iliac veins) and vitelline vein (left colic and cranial rectal veins) origin.

Anatomical variation of the caudal vena cava is a well-recognised condition in the cat (Huntington & McClure 1920, Butler *et al.* 1946, Hare 1951). Recently, an association with caval duplication and circumcaval ureter has also been described (Bélanger *et al.* 2014, Castelyn *et al.* 2015). In their series of domestic cat cadavers obtained from an animal shelter, Bélanger and others (2014) described 21 (7%) as having a double CVC and (35.2%) as having either unilateral or bilateral circumcaval ureter. In this current study, the two cats with caval duplication showed no evidence of circumcaval ureter.

It is interesting that the left colo-caval shunt type observed in this study was observed in five Yorkshire terriers; the only other dog in the series being a standard poodle with a shunt involving the cranial rectal vein and the right internal iliac vein. As far as the authors are aware, none of these Yorkshire terriers were related. Although congenital PSSs are known to be inherited including in the Yorkshire terrier, the low numbers of dogs in this current study cannot be used to make any meaningful conclusion in regard to the prevalence of this shunt type in this breed of dog (Tobias 2003, van Staten *et al.* 2005, van Steenbeck *et al.* 2012).

In conclusion, in both the dog and the cat a shunt involving essentially normal caudal mesenteric and left colic veins was described. The shunt was similar and consistent in 4/6 dogs and 2/3 cats; in these the shunt emanated from the left colic vein and entered the CVC at the level of the 5th or 6th lumbar vertebra. There was variation in the remaining three cases; in one dog the shunt entered the CVC at the level of the deep circumflex vein via the left colic vein and in the remaining two cases the shunt entered either the common iliac vein (cat) or the internal iliac vein (dog) via the cranial rectal vein.

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Table 1. Species, breed representation, gender, age, imaging investigation and shunt type of a consecutive series of dogs and cats with congenital extrahepatic portosystemic shunts involving the left colic vein.

Case No.	Species	Breed	Gender	Age (months)	CTA	IOMP	IOMP available for review	Gross observations at surgery	Shunt type
1	cat	DSH	M(N)	6		●		●*	CVC duplication - left colic vein enters left branch of CVC at level of L5
2	dog	Yorkshire terrier	M(E)	16		●		●	Left colic vein enters CVC (left side) at level of L5
3	dog	Yorkshire terrier	M(N)	18		●	●	●	Left colic vein enters CVC (left side) at level of L6
4	dog	Yorkshire terrier	M(E)	18		●	●	●	Left colic vein enters CVC (left side) at level of L6
5	dog	Standard poodle	M(E)	8	●	●		●	Cranial rectal vein communicates with right internal iliac vein
6	dog	Yorkshire terrier	M(N)	84	●	●		●	Left colic vein joins CVC (left side) at the level of the deep circumflex veins
7	cat	DLH	F(N)	72	●	●		●	CVC duplication – left colic vein communicates with left common iliac vein at level of L6
8	dog	Yorkshire terrier	F(N)	24	●	●	●	●	Left colic vein enters CVC (left side) at level of L5
9	cat	DSH	M(N)	45	●	●		●	Left colic vein enters CVC (left side) at level of L5

CTA computed tomography angiography, CVC caudal vena cava, DSH domestic short hair, DLH domestic long hair, F(N) female neutered, IOMP intra-operative mesenteric portovenography, L5 5th lumbar vertebra, L6 6th lumbar vertebra, M(E) male entire, M(N) male neutered, * observations were also made *post mortem*