Classification of portosystemic shunts entering the caudal vena cava at the omental foramen in dogs

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STRUCTURED SUMMARY

Objective: To re-evaluate the anatomy and classification of congenital extrahepatic portosystemic shunts entering the caudal vena cava at the level of the omental foramen.

Material and Methods: A retrospective review of a consecutive series of dogs undergoing computed tomography angiography as part of the diagnostic work-up for a congenital extrahepatic portosystemic shunt.

Results: In total, 53 dogs met the inclusion criteria revealing four anatomically distinct omental foramen shunt types; one of which (32/53 dogs) showed no shunting blood flow through the right gastric vein and three of which (21/53 dogs) involved shunting flow through this vessel. The anatomy of these four distinct shunt types, as defined by computed tomography angiography, was found to be highly consistent. In all cases, regardless of the tributary vessels, the left gastric vein was the final vessel that communicated with the caudal vena cava. Using these findings, a more accurate naming classification for congenital portosystemic shunts entering the caudal vena cava at the level of the omental foramen was proposed.

Clinical Significance: A precise pre-treatment anatomical classification of congenital extrahepatic portosystemic shunts entering the caudal vena cava at the level of the omental foramen is important for a more complete understanding of the severity of clinical signs and prognosis, and for the better communication between clinicians and researchers in this clinical field.

KEYWORDS – portosystemic shunt-dog-insertion

INTRODUCTION

By using techniques such as computed tomography angiography (CTA), intra-operative mesenteric portovenography (IOMP) and gross visual findings, the anatomy of congenital extrahepatic portosystemic shunts (EHPSSs) have been described previously (Nelson & Nelson 2011, Kraun *et al.* 2014, Fukushima *et al.* 2014, Or *et al.* 2016, White & Parry 2013, 2015, 2016a,b). In a further recent study in which a comprehensive literature review of congenital EHPSS anatomy was performed, it was concluded that in dogs four consistent shunt types (spleno-caval, left gastro-phrenic, left gastro-azygos and those involving the right gastric vein (the so-called "right gastro-caval"), were responsible for 94% of extrahepatic shunts reported in the species (White *et al.* 2018). These four most common EHPSSs have been shown to communicate at consistent sites with a number of systemic veins including the caudal vena cava (CVC) and the azygos and left phrenic veins (Nelson & Nelson 2011, Kraun *et al.* 2014, Fukushima *et al.* 2014, Or *et al.* 2016, White & Parry 2013, 2015, 2016a, White *et al.* 2018). Specifically, for two shunt types, the spleno-caval and the right gastro-caval, the site of shunt communication was with the CVC at the level of the omental (epiploic) foramen (White *et al.* 2018). In addition, it has also been proposed that the overall anatomy of a shunt type is dependent on the presence of preferential portal blood flow related to the site of communication between the anomalous shunting vessel (for example, the left gastric vein) and the systemic vein (White *et al.* 2017).

When comparing the use of CTA and IOMP to image the portal vasculature in both normal dogs and in dogs suffering from congenital EHPSSs, it has been shown that there is a large difference between the ability of the two techniques to delineate the portal vasculature (Parry & White 2015, 2017). CTA consistently visualised the extrahepatic portal vasculature

more completely than IOMP and, as such, might be considered the modality of choice for imaging the portal vasculature in clinical cases (Bertolini *et al.* 2006, Parry & White 2015, 2017, Bertolini 2019).

The naming of shunts has shown wide variation, with naming conventions not always being clear or specific (Berent & Tobias 2012). This is especially true with the naming of shunts communicating with the CVC at the level of the omental foramen where shunt blood flow might involve the left gastric vein, the right gastric vein and the splenic vein.

The purpose of this study was to re-evaluate the anatomy and classification of such congenital EHPSSs in the dog.

MATERIALS AND METHODS

A retrospective study reviewed CTAs obtained from consecutive series of dogs suffering from congenital portosystemic shunts between 2012 and 2019 for the investigation of congenital EHPSSs. The main inclusion criteria were that all cases must have undergone preoperative CTA and have a congenital EHPSS that communicated with the CVC at the level of the omental foramen.

CTA had been performed using 16-slice multidetector units (Brightspeed, General Electric Medical Systems, Milwaukee or Siemens Somatom Emotion 16, Siemens GmBH, Erlangen) as described previously (White & Parry 2013, 2015). Studies were assessed in their native format and using multiplanar reconstruction. All CTA studies were reviewed by two board certified radiologists. On the basis of this data, the anatomy of shunts entering the CVC at the level of the omental foramen was described. Anatomical landmarks that were used to define the position of the omental foramen included the CVC (dorsally), the portal vein and hepatic artery (ventrally), the caudate lobe of the liver (cranially) and the coeliac artery

(caudally). The data was also used to suggest a developmental pathway and classification system for these shunts in dogs.

RESULTS

In total, 53 dogs met the inclusion criteria. Affected breeds were crossbred (9), pug (6), shih-tzu (5), Yorkshire terrier (5), bichon frise (4), West Highland white terrier (4), Border terrier (3), Norfolk terrier (3), Jack Russell terrier (2), miniature schnauzer (2), papillon (2), beagle (1), Cairn terrier (1), Coton de Tulear (1), English springer spaniel (1), Gordon setter (1), Irish setter (1), Lhasa apso (1), Staffordshire bull terrier (1). The median age of dogs presenting with an EHPSS entering the caudal vena cava at the level of the epiploic foramen was 14 months (range 3 to 96 months). Of these dogs, 35 were male and 18 were female.

Supplementary video 1 shows a representative post contrast multiplanar reconstruction (MPR) CTA of the normal portal vasculature in the dog for reference.

The CTA studies showed that, in all cases, the anomalous shunting vessel that communicated with the CVC at the level of the omental foramen was a continuation of the left gastric vein. Shunts could broadly be further classified into those that showed no blood flow through the right gastric vein and those that did show blood flow through this portal tributary. Using our proposed naming system, the shunt subtypes observed were as follows:

Shunts with no blood flow through the right gastric vein (RGV)

Left gastro-caval subtype RGV(-) – The following description was based on the findings of CTA and modified from a previous description by White and Parry (2016). There was a normally located communication between the left gastric vein and the splenic vein

leading to formation of a normal gastro-splenic vein (Evans 1993). The gastro-splenic vein subsequently showed a normally located communication with the portal vein (Evans 1993). The anomalous vessel arose from an enlarged segment of the left gastric vein at a level adjacent to the angular notch (incisura angularis) on the dorsal wall of the pyloric region of the stomach. Subjectively, other portal tributaries including the right gastric vein showed no evidence of abnormal distension. The enlarged left gastric vein continued as the anomalous vessel travelling in a dorso-medial direction towards the prehepatic CVC where it entered the cava on the left side at a level adjacent to the origin of the coeliac artery from the aorta (omental foramen). Supplementary video 2 shows a representative post contrast MPR CTA of this shunt type. There was very little variation in the anatomy of the shunting vessel, although there was some variation in the relative lengths of the gastro-splenic vein, the tributary left gastric vein and its continuation as the anomalous shunting vessel. The left gastro-caval subtype RGV(-) shunt type was the most common and was seen in 32 dogs; crossbred (8), pug (6), shih-tzu (4), Yorkshire terrier (4), West Highland white terrier (3), Norfolk terrier (2), and one each of Cairn terrier, English springer spaniel, Gordon setter, Lhasa apso and Staffordshire bull terrier.

Shunts with blood flow through the right gastric vein

Shunts communicating with the CVC at the level of the omental foramen with blood flow through the right gastric vein could be further classified into three consistent sub-divisions. The following descriptions were based on the findings of CTA and modified from a previous description by White and Parry (2015).

Left gastro-caval subtype RGV(i) – Shunts which showed no communication between the left gastric vein and the splenic vein; the left gastric vein continued as the anomalous vessel

and inserted directly into the prehepatic CVC, and the splenic vein (rather than the normal gastro-splenic vein) showed a normal communication with the portal vein.

An enlarged right gastric vein was located along the lesser curvature of the stomach (pyloric part) before joining with the left gastric vein at the level of the angular notch (incisura angularis). The enlarged left gastric vein continued as the anomalous vessel in a dorso-medial direction towards the prehepatic CVC, where it entered the cava on the left side at a level adjacent to the origin of the coeliac artery from the aorta (omental foramen). There was no evidence of a connection between any portion of the left gastric vein and the splenic vein, although the splenic vein was seen to join the portal vein at a normal location. Supplementary video 3 shows a representative post contrast MPR CTA of this shunt type. This shunt type was seen in three dogs; two Border terriers and one bichon frise.

Left gastro-caval subtype RGV(ii) – Shunts which showed an anomalous communication between the left gastric vein and the splenic vein with the splenic vein (rather than the normal gastro-splenic vein) joining with the portal vein in the normal anatomical position; the left gastric vein also formed the anomalous vessel prior to its entrance into the prehepatic CVC.

An enlarged right gastric vein was located along the lesser curvature of the stomach (pyloric part) before joining with an enlarged left gastric vein at the level of the angular notch. The left gastric vein continued in a dorso-caudal direction prior to joining with the splenic vein. The splenic vein then continued in a medial direction before joining with the portal vein at a normal anatomical position. Dorsal to the pylorus, approximately equidistant between the joining of the right gastric and left gastric veins, and the joining of the left gastric vein with the splenic vein, the anomalous vessel emerged from the enlarged left gastric vein travelling in a dorso-medial direction towards the prehepatic CVC, where it entered the cava on the left side at a level adjacent to the origin of the coeliac artery from the aorta (omental foramen).

Supplementary video 4a shows a representative post contrast MPR CTA of this shunt type. This shunt type was seen in 12 dogs; three bichon frise and one each of crossbred, Irish setter, Jack Russell terrier, miniature schnauzer, Norfolk terrier, papillon, shih-tzu, West Highland white terrier and Yorkshire terrier.

A single variation of this shunt type was observed in which there were two separate communications between the left gastric vein and the splenic vein. There was a normal communication between the left gastric vein and the splenic vein leading to formation of a normal gastro-splenic vein. The gastro-splenic vein subsequently showed a normal communication with the portal vein. In addition, there was a further anomalous communication between the left gastric and splenic veins similar to that seen in the majority of dogs in this group. The remaining anatomy of this variant was the same as the others in this group; the left gastric vein forming the anomalous vessel (shunt) prior to its entrance into the prehepatic CVC. Supplementary video 4b shows a post contrast MPR CTA of this shunt type. This variation was seen in a single dog (papillon).

Left gastro-caval subtype RGV(iii) – Shunts which showed an anomalous communication between the left gastric vein and splenic vein (similar to that observed in subtype RGV(ii)), with the splenic vein showing no normal direct communication with the portal vein; the left gastric vein formed the anomalous vessel (shunt) prior to its entrance into the prehepatic CVC.

An enlarged right gastric vein was located along the lesser curvature of the stomach before joining with an enlarged left gastric vein at the level of the angular notch. The enlarged left gastric vein continued in a dorso-medial direction where it was joined by the splenic vein before entering the prehepatic CVC on the left side at a level adjacent to the origin of the coeliac artery from the aorta (omental foramen). There was no evidence of a normal connection between the left gastric vein and splenic vein, and the portal vein. Supplementary video 5 shows

a representative post contrast MPR CTA of this shunt type. This shunt type was seen in five dogs; one each of beagle, Border terrier, Coton de Tulear, miniature schnauzer and Jack Russell terrier.

Our classification naming solution of the shunt types entering the CVC at the level of the omental foramen (with comparison is summarized in Table 1. The table includes the various current names for these shunt types for comparison.

Postulated role of preferential flow in the development of congenital EHPSSs communicating with the CVC at the level of the omental foramen

The following diagrams show our postulated role of preferential venous flow within the portal system in the development of congenital EHPSSs communicating with the prehepatic CVC at the level of the omental foramen. Figure 1 shows a diagram of a normal portal vasculature with normal hepatopetal blood flow for cross-reference.

The left gastro-caval subtype RGV(-)

Figure 2A shows the communication (shunt) between the left gastric vein and the CVC at the level of the omental foramen. Figure 2B and C shows the effect that the development of one, specific preferential hepatofugal blood flow might have, leading to the resultant formation of the classic left gastro-caval subtype RGV(-) shunt, which shows no shunting blood flow through the right gastric vein.

The left gastro-caval – subtype RGV(i)

Figure 3A shows the communication (shunt) between the left gastric vein and the CVC at the level of the omental foramen. Figure 3B and C shows the effect that the development of a different, specific preferential hepatofugal blood flow might have, leading to the resultant formation of the classic left gastro-caval subtype RGV(i) shunt, which shows shunting blood flow through the right gastric vein but no communication between the left gastric vein and the splenic vein.

The left gastro-caval – subtype RGV(ii)

Figure 4A shows the communication (shunt) between the left gastric vein and the CVC at the level of the omental foramen. Figure 4B and C shows the effect that the development of a further different, specific preferential hepatofugal blood flow might have leading to the resultant formation of the classic left gastro-caval subtype RGV(ii) shunt, which shows shunting blood flow through the right gastric vein and communication between the left gastric vein and the splenic vein prior to the splenic vein joining with the portal vein in a normal manner.

Figure 5A to C shows the effect that a further different, specific preferential blood flow might have leading to the resultant formation of the single variant of this shunt subtype in which there were two separate communications between the left gastric vein and the splenic vein.

The left gastro-caval – subtype RGV(iii)

Figure 6A shows the communication (shunt) between the left gastric vein and the CVC at the level of the omental foramen. Figure 6B and C shows the effect that the development of

another different, specific preferential hepatofugal blood flow might have, leading to the resultant formation of the classic left gastro-caval subtype RGV(iii) shunt, which shows shunting blood flow through the right gastric vein and communication between the left gastric vein and the splenic vein but with the splenic vein showing no normal direct communication with the portal vein.

DISCUSSION

This study has shown that all commonly observed congenital EHPSSs entering the CVC at the level of the omental foramen do so via a single, consistent portal vessel; that is, a continuation of the left gastric vein. This finding further supports the previous suggestion that, embryologically, it is the development of the left gastric vein that is critical in the formation of EHPSSs that communicate with the CVC at the level of the omental foramen (White & Parry 2015, 2016a).

The naming of congenital EHPSSs shows wide variation with the continued use of unclear and non-specific naming conventions (Berent & Tobias 2012). Currently, there appears to be a lack of consistency in the naming of congenital portosystemic shunts that communicate with the CVC at the level of the omental foramen (see Table 1). Naming of those that show no involvement of the right gastric vein has included "splenic-caval" (Szatmári *et al.* 2004), "spleno-caval" (Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016, White & Parry 2016, White *et al.* 2018) or "left gastro-caval" (White & Parry 2016). Naming those congenital shunts showing involvement of the right gastric vein has included the term "right gastric-caval" to embrace all three subtypes (Szatmári *et al.* 2004) and the use of "right gastric-caval" to describe two out of the three subtypes and "right gastric-caval with a caudal loop" to describe the third (Nelson & Nelson 2011, Fukushima *et al.* 2014,

Kraun *et al.* 2014, Nelson & Nelson 2016). Only two studies have made any attempt to name the three subtypes individually (White & Parry 2015, White *et al.* 2018), with only one confirming their involvement of the left gastric vein (White & Parry 2015). The findings of this study confirmed that there are four anatomically distinct omental foramen shunt types; one of which showed no abnormal, hepatofugal blood flow through the right gastric vein and three of which involved abnormal, hepatofugal portal blood flow through this vessel. The anatomy of these four distinct shunt types, as defined by CTA, was found to be highly consistent. Using our current findings, and those of previous studies investigating the anatomy of congenital EHPSSs, we have proposed a new method of naming congenital EHPSSs entering the CVC at the level of the omental foramen. This system was based broadly on that devised by White and Parry (2015, 2016a) and White and others (2018). Unlike previous descriptions, which have only included shunts involving the right gastric vein, our new system incorporates all commonly observed congenital EHPSSs that enter the CVC at the level of the omental foramen.

Findings of this current study support and compliment those of White and Parry (2016a) who described the anatomy of the spleno-caval EHPSS using IOMP, CTA and gross findings at surgery. They concluded that the previously named spleno-caval shunt represented a consistent EHPSS which involved a distended splenic vein that communicated, via an anomalous left gastric vein, with the CVC at the level of the omental foramen (White & Parry 2016a). Although data for IOMP and gross findings at surgery were available for 98 dogs in this study, the data for CTA was only available for 7 of these (White & Parry 2016a). Previous studies have concluded that as a modality for imaging the portal vasculature and congenital EHPSSs, CTA consistently outperformed IOMP and could be considered the imaging modality of choice in clinically affected cases (Parry & White 2015, 2017, Bertolini 2019). Our current study includes a further 32 dogs in which CTA was used to assess the portal vasculature,

representing the largest number of consecutive cases in which this preferred imaging modality was used to define the anatomy of this specific shunt type. By anatomical convention, portosystemic shunts are most commonly named using the name of the portal vessel from which the shunt emanates and the name of the systemic vein to which it joins (Payne *et al.* 1990). By using this convention, in conjunction with the CTA findings of this current study, it is clear that the previously named spleno-caval shunt would be more accurately named a left gastro-caval shunt. The fact that this study also highlighted the presence of more than one type of left gastro-caval shunt – those with and those without shunting blood flow through the right gastric vein – suggests that this particular shunt would be better named a "left gastro-caval shunt with no shunting of blood through the right gastric vein" or, more briefly, a "left gastro-caval subtype RGV(-)".

The findings of this current study were also compared to those of White and Parry (2015) who described the anatomy of congenital portosystemic shunts involving the right gastric vein using IOMP, CTA and gross findings at surgery. In a similar manner, this previous study only had CTA data available for 10 out of the 22 dogs investigated, whereas, this current study has consecutive CTA data available for a total of 21 further cases. Findings from our current study and that of White and Parry (2015), indicate the existence of three distinct subtypes of left gastro-caval shunts which show blood flow through the right gastric vein and enter the CVC at the level of the omental foramen. In both studies, the gross anatomical findings of these three subtypes were the same. The combined period of consecutive case recruitment for both studies was approximately 21 years (1997 to 2018); a length of study duration considered likely to include a typical representation of shunt types involving the right gastric vein in the dog. It seems probable, therefore, that these three subtypes are representative of the common congenital EHPSSs involving the right gastric vein and entering the CVC at the level of the omental foramen.

The anatomy of the three shunt subtypes is interesting because in two of the three, the shunt appears to demonstrate not only the presence of an abnormal communication (shunt) between the left gastric vein and the CVC, but also the presence of abnormal anatomy within the tributary veins of the portal vasculature. In one, the left gastro-caval subtype RGV(i), there was no communication between the left gastric vein and the splenic vein; in the second, the left gastro-caval subtype RGV(iii), the splenic vein showed no communication with the portal vein. For both these shunt types, it remains unclear if the normal anatomical communication existed initially only to regress and become functionless later in development, or, whether, in fact, the communication never developed or existed at all.

The findings of CTA confirmed that all congenital EHPSSs involving the right gastric vein and entering the CVC at the level of the omental foramen showed a vascular communication between the right and left gastric veins on the lesser curvature of the stomach at the level of the angular notch. This venous anastomosis between the right and left gastric veins is considered a normal finding in many species including the dog (Schaller 1992, Evans 1993). Although the flow of portal blood from the right gastric vein to the left gastric vein might not be considered a 'normal' physiological finding, the potential for such blood flow cannot be considered the result of an abnormal communication between these two vessels. Interestingly, in two of the subtypes seen (RGVii and RGViii), the communication between the splenic vein and left gastric vein was not considered 'normal' in its anatomically position. The anomalous communication appeared more peripherally positioned (nearer the spleen) within the left gastric and splenic vein tributary vessels than in dogs with a normal portal vascular system (Evans 1993). To the best of our knowledge, this anomalous communication between the left gastric vein and splenic vein has not been described previously. Seventeen of the 18 dogs with the RGVii or RGViii subtypes showed no evidence of a more normally positioned left gastric to splenic vein communication (Evans 1993). In one single dog, a

papillon with a subtype RGVii variation, there was evidence of both the normally positioned left gastric to splenic vein communication in addition to the anomalous, peripherally positioned communication that was seen consistently in all remaining RGVii and RGViii subtypes. It remains unclear how best to name this anomalous communication; does it represent a normal variation between the left gastric vein and splenic vein, or, does it represent an anomalous communication between the splenic vein and the left gastric vein via a vessel such as the short gastric vein? Anatomical studies of the portal venous drainage of the stomach and spleen in normal dogs are required to further investigate this issue of nomenclature.

The cause for the development of different preferential blood flows through the developing portal venous system remains unclear. The potential role of venous valves in the development of preferential venous blood flow within the portal system of the dog has been hypothesized and well-described (White *et al.* 2017). Despite evidence for the presence of venous valves within the portal system of dogs (Dawson *et al.* 1988), there remains scant evidence for the presence of valves within the portal tributary vessels forming congenital EHPSSs communicating with the CVC at the level of the omental foramen (Schummer *et al.* 1981, Dyce *et al.* 2010). The presence of venous valves within the tributary vessels forming congenital EHPSSs represents only one potential mechanism by which preferential venous blood flow might develop and a lack of such valves does not in any way eliminate preferential blood flow as the mechanism for the development of the four shunt types described in our current study. Blood flow is a result of differences in blood pressure resulting in flow within vessels from a site of higher pressure to a site of lower pressure along the path of greatest conductance and least resistance (Levick 2010). There are numerous physical variables that can affect such a flow. The most obvious of these are the radius and length of the vessel through which the fluid is flowing; in general, the resistance to flow will be less the shorter the tube and the greater its diameter (Poiseuille's law). There are many other factors than might

influence blood flow including fluid viscosity, fluid volume, dilation or constriction of the vessel wall, changes in the pressure gradient and the presence of turbulence and eddies (Pappano 2010). If the system through which the fluid is flowing has more than one choice of the vessel through which it can flow, as we have postulated is the case in the portal venous system of the cases described in this study, then one or more of these factors will have an important influence on which available portal vessels the portal blood preferentially flows through. If an anomalous communication (shunt) forms between the developing portal and systemic venous systems, at a consistent site near a part of the portal venous system where there are both tributary vessel anastomoses and potential for both hepatopetal and hepatofugal blood flow (for example, the right and left gastric veins), it might be possible that a resultant preferential blood flow could result in growth and development of certain portal tributaries while others might show regression and atrophy. Such a process could result in the development of a number of specific shunt types with differing, but consistent vascular anatomies, such as those described in our current study. Such a mode of shunt development might support the lack of a role for venous valves as a means for the development of preferential portal blood flow. One further factor should be considered when discussing the use of CTA and the development of preferential flow. Although CTA is considered the modality of choice for imaging the portal vasculature (Bertolini *et al.* 2006, Parry & White 2015, 2017, Bertolini 2019), it is a method of non-selective angiography and, as such, does not define the direction of flow; in this instance, whether the venous portal blood flow is hepatopetal or hepatofugal in nature. Direction of flow can be assessed more fully by using selective angiographic techniques; for example, intraoperative mesenteric portography (Parry and White 2015, 2017).

This novel naming system not only provides a more accurate classification for congenital portosystemic shunts entering the CVC at the level of the omental foramen but also

provides a potential framework for an all-encompassing classification system for other common congenital EHPSSs. For example, congenital EHPSSs communicating with the azygos vein do so via the left gastric vein with or without involvement of the blood flow through the right gastric vein (Nelson & Nelson 2011, White & Parry 2013, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016, Or *et al.* 2016). In such documented shunts that show involvement of the right gastric vein, the published anatomical findings suggest that those presently termed "right gastric-azygos with caudal loop" shunt (Nelson & Nelson 2011, 2016, Or *et al.* 2016) might be better named "left gastro-azygos subtype RGV(ii)". Similarly, in such documented shunts showing no involvement of the right gastric vein, the presently termed "spleno-azygos" shunt (Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016, Or *et al.* 2016) might be better named "left gastro-azygos subtype RGV(-)". Likewise, there would be an indication to use this novel naming system for congenital EHPSSs communicating with the phrenic vein; for example, the presently termed "right gastric-phrenic" shunt described by Fukushima and others (2014) might be better named "left gastro-phrenic subtype RGV(i)".

In conclusion, in the dog, four consistent shunt types entering the CVC at the level of the omental foramen were described. The anatomy of each shunt type described appears to be a result of the abnormal communication between the left gastric vein and the prehepatic CVC, the presence or absence of an abnormal communication between the splenic, left gastric and portal vein, and the subsequent development of preferential blood flow (hepatopetal or hepatofugal) through essentially normal portal vessels within the portal venous system.

Conflict of interest

No conflicts of interest have been declared.

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Shunt types entering the CVC at the level of the omental foramen					
With no blood flow through the right gastric vein			**With blood flow through the right gastric vein**		
Proposed name	**Existing name with reference**		**Proposed name**	**Existing name with reference**	
LGV – subtype RGV(-)	Splenic-caval Spleno-caval L gastro-caval	Szatmári *et al.* 2004 Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016, White & Parry 2016, White *et al.* 2018 White & Parry 2016	LGV – subtype RGV(i)	Right gastric-caval Type Ai	Szatmári *et al.* 2004, Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016 White & Parry 2015, White *et al.* 2018
			LGV – subtype RGV(ii)	Right gastric-caval Right gastric-caval with a caudal loop Type Aii	Szatmári *et al.* 2004 Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016 White & Parry 2015, White *et al.* 2018
			LGV – subtype RGV(iii)	Right gastric-caval Type Aiii	Szatmári *et al.* 2004, Nelson & Nelson 2011, Fukushima *et al.* 2014, Kraun *et al.* 2014, Nelson & Nelson 2016 White & Parry 2015, White *et al.* 2018

Table 1. Classification of shunt types entering the caudal vena cava (CVC) at the level of the omental foramen. L, left; LGV, left gastric vein; RGV, right gastric vein

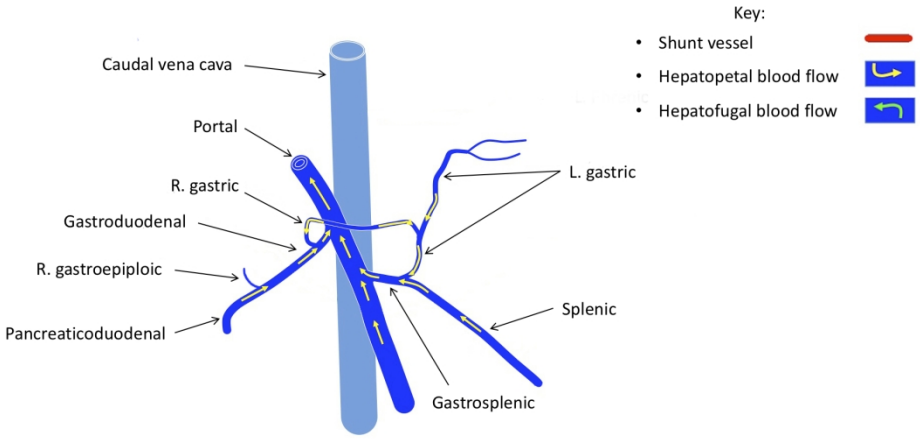

FIG 1. The normal portal vasculature and normal hepatopetal portal blood flow (modified from Evans 1993). Key for Figs 1 to 6. L, left; R, Right

338x190mm (150 x 150 DPI)

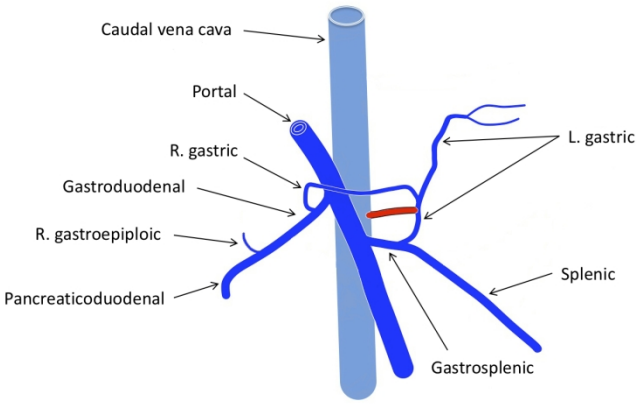

FIG 2. (A) The communication (shunt) between the left gastric vein and the prehepatic CVC at the level of the epiploic foramen. L, left; R, right

338x190mm (150 x 150 DPI)

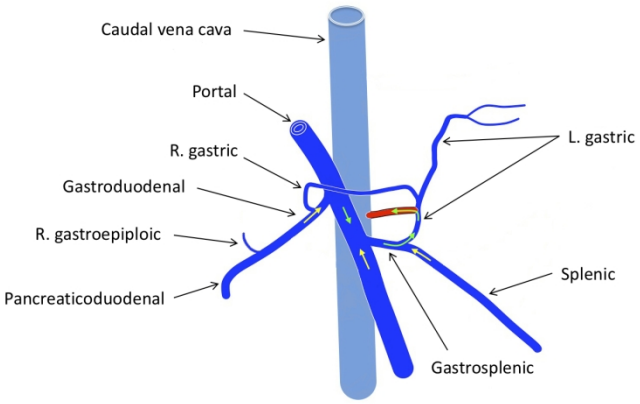

FIG 2. (B) Shows the impact that the presence of such a shunt and the development of preferential blood flow might have on hepatopetal and hepatofugal blood flows within the portal tributary vessels.

338x190mm (150 x 150 DPI)

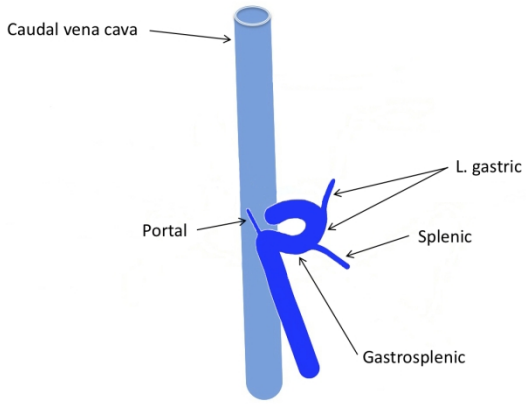

FIG 2. (C) The resultant left gastro-caval subtype RGV(-) produced by such preferential blood flow.

338x190mm (150 x 150 DPI)

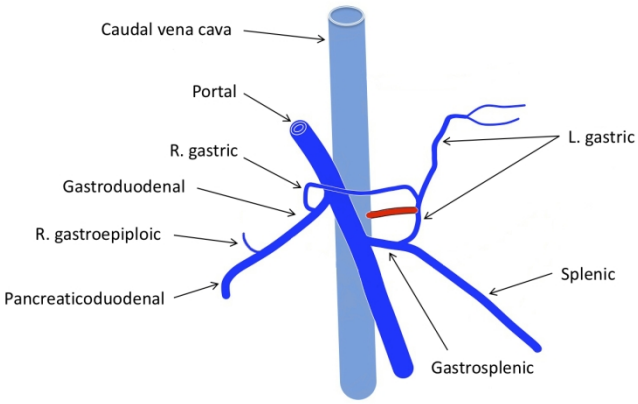

FIG 3. (A) The communication (shunt) between the left gastric vein and the prehepatic CVC at the level of the epiploic foramen. L, left; R, right

338x190mm (150 x 150 DPI)

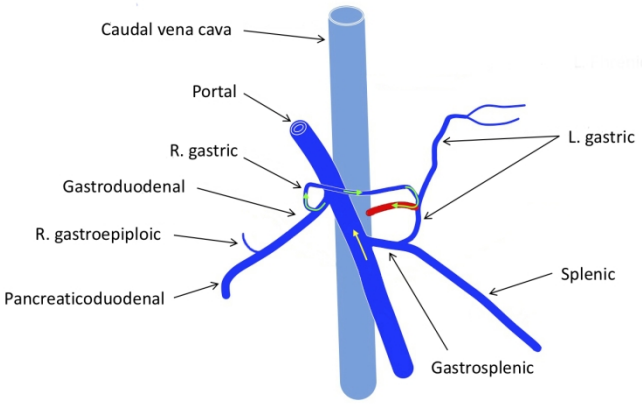

FIG 3. (B) Shows the impact that the presence of such a shunt and the development of preferential blood flow might have on hepatopetal and hepatofugal blood flows within the portal tributary vessels.

338x190mm (150 x 150 DPI)

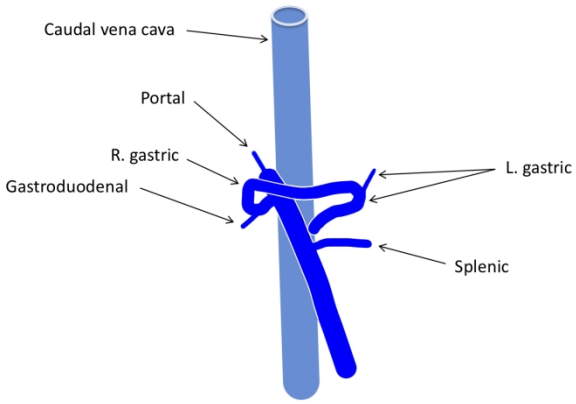

FIG 3. (C) The resultant left gastro-caval subtype RGV(i) produced by such preferential blood flow (we postulate that the communication between the left gastric vein and the splenic vein regresses and atrophies in response to the preferential flow).

338x190mm (150 x 150 DPI)

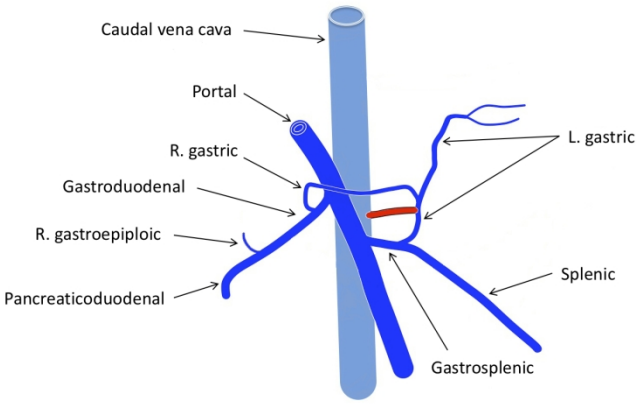

FIG 4. (A) The communication (shunt) between the left gastric vein and the prehepatic CVC at the level of the epiploic foramen. L, left; R, right

338x190mm (150 x 150 DPI)

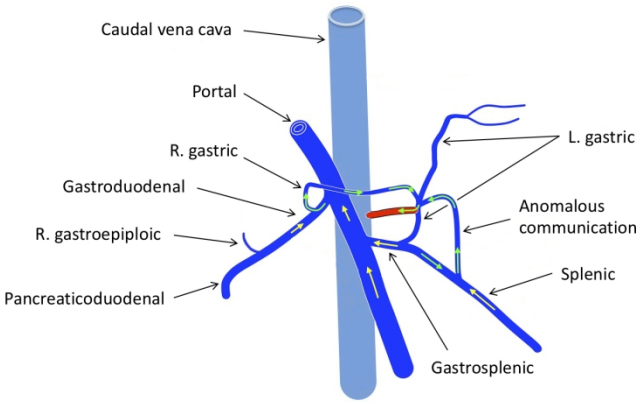

FIG 4 (B) Shows the impact that the presence of such a shunt and the development of preferential blood flow might have on hepatopetal and hepatofugal blood flows within the portal tributary vessels.

338x190mm (150 x 150 DPI)

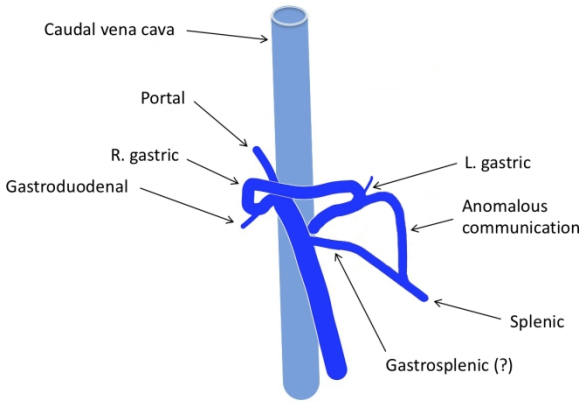

FIG 4. (C) The resultant left gastro-caval subtype RGV(ii) produced by such preferential blood flow (we postulate that the 'normal' communication between the left gastric vein and the splenic vein regresses and atrophies in response to the preferential flow).

338x190mm (150 x 150 DPI)

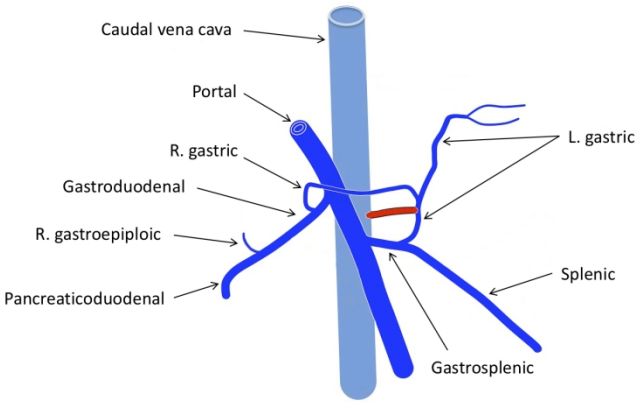

FIG 5. (A) The communication (shunt) between the left gastric vein and the prehepatic CVC at the level of the epiploic foramen. L, left; R, right

338x190mm (150 x 150 DPI)

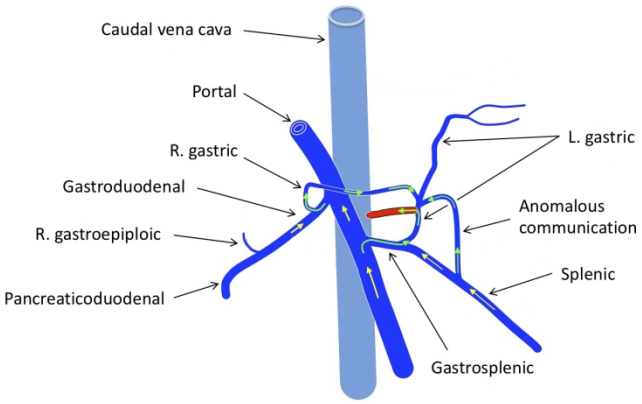

FIG 5. (B) Shows the impact that the presence of such a shunt and the development of preferential blood flow might have on hepatopetal and hepatofugal blood flows within the portal tributary vessels.

338x190mm (150 x 150 DPI)

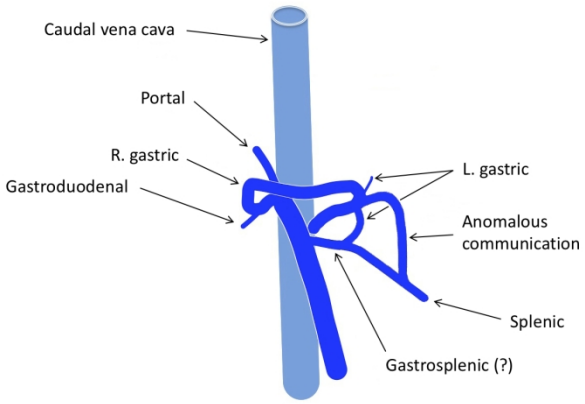

FIG 5. (C) The resultant single variant left gastro-caval subtype RGV(ii) produced by such preferential blood flow.

338x190mm (150 x 150 DPI)

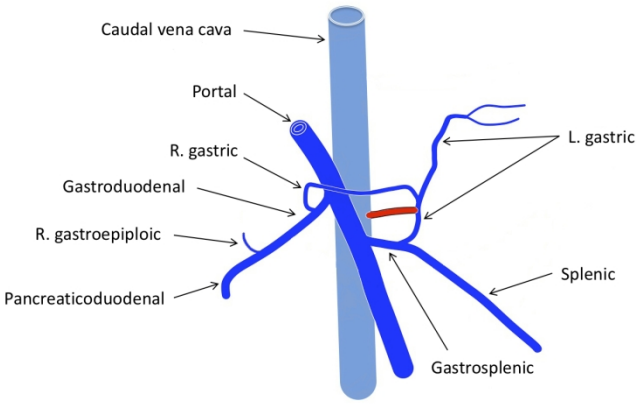

FIG 6. (A) The communication (shunt) between the left gastric vein and the prehepatic CVC at the level of the epiploic foramen. L, left; R, right

338x190mm (150 x 150 DPI)

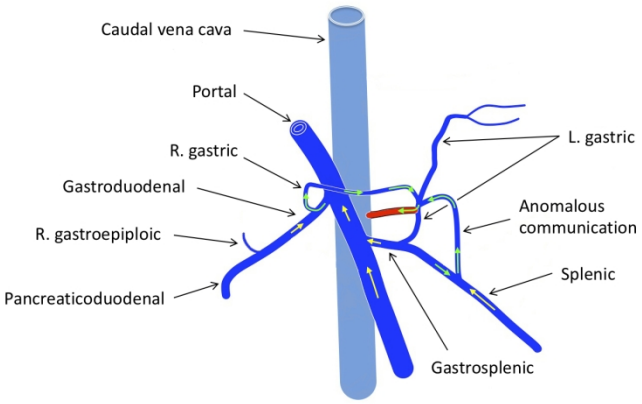

FIG 6. (B) Shows the impact that the presence of such a shunt and the development of preferential blood flow might have on hepatopetal and hepatofugal blood flows within the portal tributary vessels.

338x190mm (150 x 150 DPI)

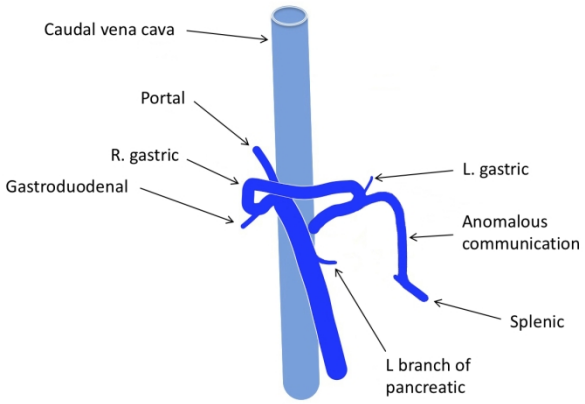

FIG 6. (C) The resultant left gastro-caval subtype RGV(iii) produced by such preferential blood flow (we postulate that in this shunt type the communication between the splenic vein and portal vein, and the 'normal' communication between the splenic vein and left gastric vein, both regress and atrophy in response to the preferential flow).

338x190mm (150 x 150 DPI)