

1 **Comparison of computed tomographic angiography and intraoperative mesenteric**  
2 **portovenography for extrahepatic portosystemic shunts**

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12 **SUMMARY**

13 **Objectives:** Comparison of intraoperative mesenteric portovenography and computed tomographic  
14 angiography for the documentation of the portal vasculature in patients with single extrahepatic  
15 portosystemic shunts.

16 **Methods:** Retrospective study of patients with extrahepatic portosystemic shunts that underwent pre-  
17 operative computed tomographic angiography and intra-operative mesenteric portography. Studies  
18 were compared for identification of the intra- and extrahepatic portal vasculature.

19 **Results:** Computed tomographic angiography demonstrated all four portal vein tributaries and sub-  
20 tributaries. Intra-operative mesenteric portography demonstrated the cranial mesenteric vein but  
21 inconsistently, the gastroduodenal vein (12/49 dogs, 0/10 cats), splenic vein (46/49 dogs, 8/10 cats)  
22 and caudal mesenteric vein (3/49 dogs, 2/10 cats). Computed tomographic angiography showed the  
23 intrahepatic portal vein with shunts emanating from the left gastric vein, splenocaval shunts or shunts  
24 involving the left colic vein. It showed intrahepatic portal branching in 5/12 patients with shunts  
25 involving the right gastric vein. Intra-operative mesenteric portography showed the intrahepatic portal  
26 vein in 29/59 patients and was outperformed by computed tomographic angiography in all cases  
27 except those patients with a shunt involving the right gastric vein.

28 **Clinical significance:** In cases that have undergone diagnostic pre-operative computed tomographic  
29 angiography there is no indication for diagnostic pre-ligation intra-operative mesenteric

30 portovenography. On the contrary, portovenography performed following the temporary full ligation  
31 of the shunt provides clinical useful information and might be considered an integral investigation  
32 during shunt attenuation surgery.

33

34 **Keywords: Intraoperative mesenteric portovenography, computed tomographic angiography,**  
35 **portosystemic shunt**

36

37 **INTRODUCTION:**

38

39 There are numerous reports describing imaging modalities that can be used to evaluate and describe  
40 the anatomy of congenital portosystemic shunts in small animals. These include ultrasonography  
41 (Lamb 1996, Szatmári & Rothuizen 2006), magnetic resonance angiography (MRA) (Sequin *et al.*  
42 1999, Bruehschwein *et al.* 2010, Mai & Weisse 2011), findings on intra-operative mesenteric  
43 portovenography (IOMP) (White *et al.* 2003, White & Parry 2013, 2015, 2016a, 2016b), and direct  
44 gross observations at surgery (White & Parry 2013, 2015, 2016a, 2016b). In addition to these,  
45 computed tomographic angiography (CTA) has been shown to be a highly detailed and accurate  
46 method of evaluating the portal vasculature and it is often used to replace or augment the other  
47 techniques described (Frank *et al.* 2003, Zwingenberger & Schwarz 2004, Zwingenberger *et al.* 2005,  
48 Echandi *et al.* 2007, Nelson & Nelson 2011, White & Parry 2013, Fukushima *et al.* 2014, White &  
49 Parry 2015, 2016a, 2016b).

50

51 In a recent study, the morphology of the normal extrahepatic portal vein was compared using IOMP  
52 and CTA. It was concluded that CTA consistently showed more detail of the extrahepatic portal vein  
53 and its tributaries (Parry & White 2015).

54

55 The purpose of this study was to compare the findings of IOMP and CTA for the identification of both  
56 the extrahepatic and intrahepatic portal venous system in dogs and cats with a single congenital  
57 extrahepatic portosystemic shunt (EHPSS), and to assess whether CTA can replace IOMP for shunt  
58 characterisation.

59

## 60 **METHODS:**

61 This retrospective study reviewed dogs and cats seen by the authors between 2009 and 2015 for the  
62 investigation and management of congenital PSS. The inclusion criteria were that all cases must have  
63 a congenital PSS, have undergone recorded IOMP and preoperative CTA.

64

65 Data on breed, signalment (age, sex, neutering status), imaging investigation, type of portosystemic  
66 shunt and gross surgical findings were collected and reviewed.

67

68 Computed tomography angiography was performed under anaesthesia using a 16 slice multidetector  
69 unit (Brightspeed, General Electric Medical Systems, Milwaukee) as described previously (White and  
70 Parry 2016a, 2016b). Briefly, images were acquired using a 0.625 mm or 1.25 mm slice collimation,  
71 depending on the size of the animal, 120 kVp and variable mAs. Patients were positioned in sternal  
72 recumbency. Scanned field of view (SFOV) and displayed field of view (DFOV) were selected  
73 according to the size of the animal. The collimator pitch was 0.938. Pre- and post-intravenous contrast  
74 (600mg I/kg, Iopromide, Ultravist, Bayer PLC, Berkshire) images were obtained using a standard  
75 algorithm (medium frequency reconstruction kernel) and a 512 x 512 matrix, and viewed using a  
76 window and level optimised for soft tissue (window 400HU, level 50HU). Contrast was injected at a  
77 speed of 2.0 - 3.0 ml/s (depending on the size of the animal and consequently the size of intravenous  
78 catheter placed) using a pressure injector (Medrad Stellant CT injection system, Bayer Healthcare  
79 Medical Care Indianola, PA). To optimise contrast enhancement, a transverse slice over the mid-  
80 abdomen was selected and repetitively examined whilst contrast injection was performed. At the onset

81 of opacification of the portal vessels, a complete abdominal dual phase CTA examination was  
82 performed using proprietary bolus tracking software with an automated trigger threshold of 120HU to  
83 start the scan. The trigger region of interest was positioned over the portal vein at the level of the porta  
84 hepatis in all dogs and cats, in the central aspect of the vessel to allow for respiratory motion. A  
85 further tissue pool phase was then performed without using bolus tracking. Studies were assessed in  
86 their native format, using multiplanar reformatting (MPR) and surface shaded volume rendering.  
87 Vascular maps were obtained and post processing was limited to removal of arterial vessels and  
88 unnecessary portions of the caudal vena cava (CVC) from the maps. All CTA studies were reviewed  
89 by both authors.

90

91 For IOMP, the jejunal vein was cannulated with a large bore catheter (20 or 22 gauge) and the  
92 mesenteric venous pressure was measured using a saline filled central venous manometer. IOMP was  
93 carried out using a mobile image intensification unit (OEC Fluorostar 7900, General Electric Medical  
94 Systems, Milwaukee) to obtain ventrodorsal images of the cranial abdomen (White *et al.* 1996, White  
95 *et al.* 1998). Patients were positioned in dorsal recumbency. A bolus of non-ionic iodinated contrast  
96 agent (iohexol (Omnipaque, GE Healthcare) or iopromide) was injected into the jejunal vein for each  
97 portovenogram. The total dose of iodine did not exceed 600 mg I/kg. The contrast was injected by  
98 hand using a 10 or 20 ml syringe. A mask was applied to create a digital subtraction angiogram.  
99 Angiograms were recorded digitally and were reviewed by both authors as video loops.

100

101 The CTA and IOMP images were evaluated by both authors, using a method adapted from those  
102 described previously (Parry & White 2015, Macdonald *et al.* 2002, Zwingenberger & Schwarz 2004,  
103 Lee *et al.* 2006). Extrahepatic portal vein arborisation was assessed for the presence or absence of the  
104 extrahepatic portal vein and its tributaries. The vessels were named by comparison with the published  
105 descriptions (Evans & de Lahunta 2010, Wolschrijn 2010, Bezuidenhout 2013). Intrahepatic portal  
106 vein arborisation was assessed for the presence or absence of a portal vein entering the liver; principal

107 right and left portal branches; branching of the principal portal branches; primary, secondary and  
108 tertiary branching of the principal branches; and opacification of the right and left lobes of the liver  
109 (Macdonald *et al.* 2002). The IOMP and CTA data were reviewed in a random order using simple  
110 randomisation of the data.

## 111 112 **RESULTS:**

113 Forty-nine dogs and 10 cats met the inclusion criteria. Twenty-six dogs had a shunt emanating from  
114 the left gastric vein, of which 22 had a left gastrophrenic shunt, 2 had a left gastrocaval shunt, and 2  
115 had a left gastroazygos shunt (White & Parry 2013). Twelve dogs had a shunt involving the right  
116 gastric vein, of which 1 dog had a type Ai, 9 dogs had a type Aii and 2 dogs had a type Aiii (no dogs  
117 had a type B shunt) (White & Parry 2015). Eight dogs had a splenocaval shunt (White & Parry  
118 2016a). Three dogs had a shunt involving the left colic vein, of which 2 dogs had a shunt entering the  
119 caudal vena cava and 1 dog had a shunt entering the cranial rectal vein (White & Parry 2016b). Of the  
120 10 cats, 7 had a left gastrophrenic shunt, 1 cat had a splenocaval shunt, and 2 cats had a shunt  
121 involving the left colic vein (of which one inserted into the caudal vena cava and one inserted in to the  
122 common iliac vein). Vascular shunt anatomy was depicted equally well using both CTA and IOMP  
123 and, as such, shunt classification was the same for both imaging modalities. The age, breed and sex  
124 distribution of the patients with various different shunt types were consistent with previous studies.

## 125 126 **Findings on CTA - extrahepatic portal venous system:**

127  
128 In all cases CTA showed the anomalous shunt vessel and the principal vessels associated with it. CTA  
129 documented the extrahepatic portal vein and all four of its main tributaries (the caudal mesenteric  
130 vein, the cranial mesenteric vein, the splenic vein and the gastroduodenal vein) in all cases. In  
131 addition, CTA allowed for the further subdivision of the four main venous tributaries. Identification of  
132 this subdivision was not affected by shunt type.

133

134 The cranial pancreaticoduodenal vein was identified in all dogs and cats. The right gastroepiploic vein  
135 was identified in 41/49 dogs and 9/10 cats and the right gastric vein was identified in 42/49 dogs and  
136 8/10 cats. These tributaries formed the gastroduodenal vein.

137

138 CTA documented the left gastric vein in all dogs and cats, the left gastroepiploic vein in 44/49 dogs  
139 and 9/10 cats and the pancreatic branches in 38/49 dogs and 7/10 cats. These tributaries formed the  
140 splenic vein.

141

142 CTA documented the jejunal veins (49/49 dogs and 10/10 cats), the iliocolic vein (39/49 dogs and  
143 8/10 cats) and the caudal pancreaticoduodenal vein in all dogs and cats. These tributaries formed the  
144 cranial mesenteric vein.

145

146 Lastly CTA documented the left colic vein (46/49 dogs and 9/10 cats), the right colic vein in 38/49  
147 dogs and 6/10 cats, the cranial rectal vein in 40/49 dogs and 7/10 cats and the middle colic vein in  
148 29/49 dogs and 4/10 cats. These tributaries formed the caudal mesenteric vein. Findings are visible on  
149 figure 1, 2 and 3 and table 2.

150

151 **Findings on CTA - intrahepatic portal venous system:**

152

153 In all cases, CTA documented the presence of a portal vein entering the liver (figure 1). There was  
154 however variation in appearance of intrahepatic arborisation according to shunt type. In all left  
155 gastrophrenic, left gastrocaval, left gastroazygos, splenocaval shunts and shunts involving the left  
156 colic vein, CTA documented the presence of the portal vein entering the liver, the principal right and  
157 left portal branches, the primary, secondary and tertiary branching of the principal branches and the  
158 opacification of the right and left lobes of the liver (figure 2). In those shunts involving the right

159 gastric vein, CTA documented the presence of the portal vein entering the liver and opacification of  
160 the left and right lobes of the liver in all cases, whereas, the principal right and left portal branches  
161 were only identified in 5/12 dogs and the primary, secondary and tertiary branching of the principal  
162 branches in 3/12 dogs. This data is summarised in table 2.

163  
164 **Findings on IOMP - extrahepatic portal system:**

165  
166 IOMP showed the anomalous shunt vessel and the principal vessels associated with it, but no other  
167 extrahepatic vasculature (figure 1, 2 and 3). This information is summarised in table 1.

168  
169 **Findings on IOMP - intrahepatic portal venous system:**

170  
171 There was a degree of heterogeneity in the appearance of the intrahepatic portal vasculature. Shunts  
172 involving the right gastric vein were associated with excellent intrahepatic portal opacification, with  
173 documentation of the presence of the portal vein entering the liver, the principal right and left portal  
174 branches, the primary, secondary and tertiary branching of the principal branches and the  
175 opacification of the right and left lobes of the liver (figure 3). For splenocaval shunts and shunts  
176 involving the left colic vein, there was invariably no contrast enhancement of the intrahepatic portal  
177 vasculature (figure 1). For shunts emanating from the left gastric vein (left gastrophrenic, left  
178 gastrocaval and left gastroazygos shunts) the results were more variable (figure 2). Opacification of  
179 the portal vein at the porta hepatis was present in 17/33 cases, while in the remaining 16 cases no  
180 contrast could be observed reaching the liver. Of the 17 cases with contrast reaching the liver, 15  
181 cases showed opacification of the principal right and left portal branches, and of these 15, 5 cases had  
182 opacification of both the left and right lobes of the liver, with documentation of primary, secondary  
183 and tertiary branches of the portal vein. In the remaining 10 studies, only the right primary, secondary

184 and tertiary branches of the portal branches underwent opacification. As a consequence, in these 10  
185 cases, only the right liver lobe underwent opacification.

186  
187 This data is summarised in table 2.

## 188 189 **DISCUSSION:**

190  
191 CTA and IOMP were equally able to depict the vascular anatomy of the shunt and agreed in all  
192 classifications. There was however variation in the appearance of both the intrahepatic and  
193 extrahepatic portal vasculature when the two methods of imaging were compared. With reference to  
194 the extrahepatic portal vasculature, the results are similar to a recent study comparing the two  
195 modalities in patients with normal portal anatomy, which concluded that CTA documented  
196 extrahepatic portal vasculature more completely than IOMP (Parry & White 2015).

197  
198 The selective versus non-selective methods of angiography differ in the mechanism by which portal  
199 vascular opacification is achieved. CTA is a method of non-selective angiography; the contrast agent  
200 is injected into a peripheral systemic vein passing multiple capillary networks before reaching the  
201 portal venous system. By this time, the contrast is likely to be present within the entire portal system.  
202 During CTA, contrast detection will depend on the degree of contrast dilution, the sensitivity of the  
203 scanner's ability to detect the contrast and the timing of the acquisition of the scans relative to contrast  
204 injection. IOMP is a selective angiography technique involving the detection of contrast injected  
205 directly into a mesenteric vein. IOMP will delineate the flow of contrast from its injection site to the  
206 hepatic capillary network and subsequently the post hepatic caudal vena cava. The documentation of  
207 the portal vasculature is dependent on the tributary vein selection for administration of contrast agent.  
208 Typically, a jejunal vein is selected, as this vein can be sacrificed on termination of the technique  
209 without any ill effects. As a consequence, due to normal venous flow, the cranial mesenteric vein and



210 extrahepatic portal vein will be identified consistently without filling of other portal tributaries (Parry  
211 and White 2015). Whilst every effort was made to standardise the technique of IOMP in this study,  
212 variation in patient size, catheter size and size of syringe (10ml or 20ml) will have some effect on the  
213 speed of injection of contrast in to the selected jejunal vein. This limitation of the study cannot be  
214 avoided given the retrospective nature of the study.

215

216 There was considerable variation in the appearance of the intrahepatic portal vasculature. All  
217 intrahepatic portal branches were identified using CTA for all shunt types described except those  
218 involving the right gastric vein. In this shunt type, documentation of smaller intrahepatic portal  
219 vessels was less consistent than with other shunt types. Proposed reasons for this variation are as  
220 follows. Firstly, whilst contrast enhancement of vessels was good in all cases, there was some  
221 variation between patients and it would be reasonable to postulate that in those patients showing less  
222 overall contrast enhancement of the portal vascular system there would be a corresponding reduction  
223 in visibility of the smaller vessels both within and outside the liver. Secondly, the scanned field of  
224 view (SFOV) and displayed field of view (DFOV) was different in each case as it varied according to  
225 the size of patient, despite a consistent 512 x 512 reconstruction matrix. As such, spatial resolution of  
226 each case would vary to a certain extent, and consequently smaller intrahepatic and extrahepatic  
227 branches might be inconsistently identified. Thirdly, surface shaded volume rendered images use a  
228 process called segmentation to build detailed vascular maps. Segmentation applies edge enhancement,  
229 noise reduction and regional enhancement through the discrimination of relevant density values,  
230 contour refinement and three-dimensional reconstruction using a set of partial differential equations.  
231 This process is automated and used to build the vascular maps. Applying such automated windowing  
232 and levelling techniques can alter which density values that are included in the maps and thereby  
233 might allow for errors in interpretation of the surface shaded volume rendered images generated. For  
234 this reason, native (transverse), multiplanar reconstruction images and volume rendered images were  
235 included in the study. Another potential source of interpretation error might be associated with

236 movement blur caused by breathing during scan acquisition. Although no specific scan acquisition  
237 protocols were used to protect against movement blur from breathing, examination confirmed that in  
238 no cases was scan interpretation affected by this issue in this study. Lastly, in patients with a  
239 portosystemic shunt a proportion of the portal blood will bypass the liver entering directly into a  
240 systemic vein. In cases where the 'shunting' proportion of blood is high there will be a comparative  
241 reduction in intrahepatic portal blood flow. It would not be surprising, therefore, that in patients with  
242 an EHPSS there would be a reduction in the documentation of the intrahepatic portal vasculature for  
243 both CTA and IOMP.

244

245 Variation between the two modalities may in part be due to patient positioning, which will have an  
246 effect on intra-abdominal and intra-thoracic pressure. For CTA examination, patients were always  
247 positioned in sternal recumbency, and for IOMP, patients were invariably positioned in dorsal  
248 recumbency. Whether this alteration in position has a profound effect on contrast enhancement of the  
249 portal system is yet to be established.

250

251 Another potential cause of variation between the two modalities is the unusual blood supply of the  
252 liver. The liver receives approximately 80% of its blood supply from the portal vein and 20% from the  
253 hepatic arteries (Evans & de Lahunta 2013). Opacification of the liver during IOMP will entirely be  
254 due to the portal vascular supply. On the other hand, CTA will combine arterial and portal supply and  
255 will likely lead to a higher concentration of contrast agent in the interstitial space compared to IOMP.

256

257 Interestingly, CTA showed a reduction in intrahepatic contrast enhancement in cases where shunts  
258 involved the right gastric vein, whereas patients with this shunt type consistently had good  
259 intrahepatic vascular enhancement on IOMP. Preferential flow of contrast might be an explanation for  
260 this anomaly. With IOMP, portal blood (and hence contrast agent) will flow from a region of  
261 relatively high pressure (at the point of injection into a mesenteric vein) to a region of lower pressure

262 (that is, the systemic circulation). This mechanism of preferential flow will account for the appearance  
263 of the extrahepatic portal vasculature.

264  
265 Due to the relatively high pressure across the hepatic capillary network compared to systemic venous  
266 pressure, patients with an EHPSS would be expected to have contrast moving through the shunt into  
267 the systemic venous circulation rather than passing into the intrahepatic portal vasculature (unless the  
268 anomalous shunt vessel was very small), and so, IOMP should be very inaccurate at assessing  
269 intrahepatic portal vasculature in such patients.

270  
271 It is not possible to assess whether the absence of documentation of the intrahepatic portal vasculature  
272 is due to an anatomical absence of intrahepatic portal vessels, or simply an absence of contrast  
273 enhancement due to preferential flow. Both White *et al.* (2003) and Lee *et al.* (2006) showed that  
274 intrahepatic portal vasculature is better documented after temporary shunt ligation, compared to pre-  
275 ligation, based on IOMP findings in dogs. Furthermore, Lee *et al.* (2006) confirmed that a well-  
276 developed intrahepatic portal vasculature identified on IOMP following the temporary full ligation of  
277 an EHPSS could be used as a positive prognostic indicator for clinical outcome. Lipscomb *et al.*  
278 (2009) showed similar findings in cats. Since CTA is a non-selective technique, contrast is not  
279 administered under pressure into the portal circulation as with IOMP and may be expected to  
280 underestimate the presence of portal vasculature (Zwingenberger *et al.* 2013).

281  
282 CTA did delineate intrahepatic portal vasculature better than IOMP in all cases except those patients  
283 with an EHPSS involving the right gastric vein. With IOMP, there was variation in the visibility of the  
284 intrahepatic portal vasculature, depending on shunt type. The intrahepatic portal vasculature was not  
285 identified in patients with a splenocaval shunt or shunts involving the left colic vein, but was  
286 consistently identified in those patients with a shunt involving the right gastric vein. Approximately  
287 half of those patients having a left gastrophrenic, left gastrocaval or left gastro-azygos shunt had

288 intrahepatic portal vasculature that opacified on IOMP. It is interesting that approximately one third of  
289 the patients in this latter category had contrast enhancement of the right aspect of the liver (in the  
290 territory of the right intrahepatic portal division) without opacification of the remainder of the liver.

291

292 The dynamics of the portal circulation are complex. Blood within the portal vein is not  
293 homogeneously mixed, but is streamlined in character, with discrete channels of flow permitting the  
294 liver to receive blood from discrete viscera. The blood flow through the tributaries of the portal vein  
295 has been studied in dogs with normal portal anatomy and no EHPSS (Mogicato *et al.* 2014). In the  
296 normal dog there appears to be a preferential flow of portal blood into the liver dependent on which  
297 tributary of the portal vein the blood is entering the liver from. Using IOMP, the study concluded that  
298 the cranial mesenteric, caudal mesenteric and splenic veins primarily supply the right lateral lobe and  
299 the caudate process of the caudate lobe and secondarily the left lateral lobe, left medial lobe and the  
300 quadrate lobe (Mogicato *et al.* 2014). Daniel and others (2004) noted non-uniform distribution of  
301 sodium pertechnetate during per-rectal portal scintigraphy in normal dogs and postulated that this  
302 portal streamlining may be the cause. Echandi and others (2007) showed variation in intrahepatic  
303 contrast enhancement in normal dogs after injection of contrast agent in to the splenic pulp and  
304 consequent CTA. In this latter study, contrast agent preferentially enhanced the left divisional  
305 intrahepatic branch. Whether the viscosity of the contrast agent plays a role in streamlining has, to the  
306 authors knowledge, not been investigated.

307

308 Portal streamlining has also been used to explain infection and metastases from visceral organs of the  
309 abdomen described in humans (Gates *et al.* 1971). This effect may in part account for variation in  
310 hepatic portal opacification. It is postulated that shunts involving the right gastric vein would have an  
311 increased flow of blood through the right gastric vein close to the porta hepatis, and consequently  
312 better documentation of the intrahepatic portal circulation may be expected. Similarly, those cases

313 with shunts involving the left colic vein and splenocaval shunts would be expected to have little or no  
314 intrahepatic portal vascular opacification.

315

316 With shunts involving the left gastric vein, variation in intrahepatic portal vascular opacification may  
317 be expected. Mehl and others (2005) showed that dogs with a portoazygos shunt were more likely to  
318 have smaller differences in portal pressure before and after shunt ligation than those patients with  
319 portocaval shunts. Berent and Tobias (2012) state that gastrophrenic and portoazygous shunts are  
320 often found in dogs with minimal to mild clinical signs and relatively normal blood work results. They  
321 suggested that compression of the shunts during normal respiratory movements or gastric filling may  
322 obstruct the shunt resulting in intermittent normalisation of portal blood flow. In such cases, better  
323 intrahepatic blood flow would be expected in EHPSSs that involve the left gastric vein with or  
324 without the azygos vein. Whilst CTA demonstrated good intrahepatic portal vasculature in this  
325 category, IOMP performed much less well. Assessment of such cases on CTA after temporary ligation  
326 of the EHPSS would provide significant information on this matter, but to the authors' knowledge  
327 such a study has yet to be performed.

328

329 CTA gave more information about extrahepatic portal vasculature in all cases and, in the majority of  
330 cases, more information about intrahepatic portal vasculature than IOMP. Clinically this information  
331 is valuable. It suggests that there is no logical rationale for acquisition of a pre-ligation IOMP if a pre-  
332 surgical CTA has been obtained. This allows for reduced patient morbidity due to a significant  
333 reduction in the administered dose of contrast agent and smaller reductions in both surgical and  
334 anaesthetic times in what are often very compromised patients. The authors suggest, therefore, that  
335 CTA can replace the requirement for an IOMP obtained prior to ligation of the shunt vessel in the  
336 majority of individuals with uncomplicated congenital EHPSSs.

337

338 An IOMP obtained after the temporary full ligation of the shunt, however, should still be considered a  
339 very important part of the surgery. Obtaining this IOMP will confirm both that the shunting vessel has  
340 been correctly recognised and that only one shunting vessel is present. In addition, it will provide  
341 information regarding the development of intrahepatic portal vascularity and information regarding  
342 portal venous pressure. Both of these factors are important in deciding whether a shunt should be  
343 attenuated and, if so, whether it should be fully ligated or partially closed. The degree of development  
344 of the intrahepatic portal vasculature has also been shown to influence the prognosis for the case in the  
345 longer term (White *et al.* 2003, Lee *et al.* 2006, Lipscomb *et al.* 2009).

346

347 **Conflict of interest:**

348

349 None of the authors of this article has a financial or personal relationship with other people or  
350 organisations that could inappropriately influence or bias the content of the paper.

351

352 **REFERENCES:**

353

354 Berent, A.C. & Tobias, K.M. (2012) Hepatic vascular anomalies. In: *Veterinary Surgery: Small*  
355 *Animal (Volume two)*, Ed Tobias, K.M. & Johnston, S.A. Missouri, Elsevier Saunders. p 1631

356

357 Bezuidenhout, A. J. (2013) Veins. In: *Miller's anatomy of the dog*, 4<sup>th</sup> edn. Eds Evans, H.E. and de  
358 Lahunta, A. Elsevier Saunders, St Louis. pp 519 – 520

359

360 Bruehschwein, A., Foltin, I., Flatz, K., Zoeliner, M. & Matis, U. (2010) Contrast-enhanced magnetic  
361 resonance angiography for diagnosis of portosystemic shunts in 10 dogs. *Veterinary Radiology and*  
362 *Ultrasound* **51**, 116-121

363

364 Daniel, G. B., DeNovo, R. C., Sharp, D. S., Tobias, K. & Berry, C. (2004) Portal streamlining as a  
365 cause of nonuniform hepatic distribution of sodium pertechnetate during per-rectal portal scintigraphy  
366 in the dog. *Veterinary Radiology and Ultrasound* **45**, 78 – 84  
367

368 Echandi, R. L., Morandi, F., Daniel, W. T., Paquette, J. L. & Daniel, G. B. (2007) Comparison of  
369 transplenic multidetector CT portography to multidetector CT-angiography in normal dogs.  
370 *Veterinary Radiology and Ultrasound* **48**, 38 – 44  
371

372 Evans, H. E. & de Lahunta A. (2010) Portal venous system. In: Guide to the dissection of the dog, 7<sup>th</sup>  
373 edn. W.B. Saunders Company, Philadelphia. pp 169 – 170  
374

375 Evans, H. E. & de Lahunta, A. (2013) The digestive apparatus and abdomen. In: Miller's anatomy of  
376 the dog, 4<sup>th</sup> edn. Eds Evans, H.E. and de Lahunta, A. Elsevier Saunders, St Louis. pp 331  
377

378 Frank, P. Mahaffey, M., Egger, C. et al. (2003) Helical computed tomography portography in ten  
379 normal dogs and ten dogs with a portosystemic shunt. *Veterinary Radiology and Ultrasound* **44**, 392-  
380 400  
381

382 Fukushima, K. Kanemoto, H., Ohno, K, et al. (2014) Computed tomographic morphology and clinical  
383 features of extrahepatic portosystemic shunts in 172 dogs in Japan. *Veterinary Journal* **199**, 376-381  
384

385 Gates, G. F., Dore, E.K. (1971) Portal streamlining after mesenteric vein injection with <sup>198</sup>Au colloid.  
386 *Journal of Nuclear Medicine* **12**, 357 – 358  
387

388 Lamb, C. R. (1996) Ultrasonographic diagnosis of congenital portosystemic shunts in dogs: results of  
389 a prospective study. *Veterinary Radiology and Ultrasound* **37**, 281-288

390

391 Lee, K. C., Lipscomb, V. J., Lamb, C. R., Gregory, S. P., Guitian, J. & Brockman, D. J. (2006)  
392 Association of portovenographic findings with outcome in dogs receiving surgical treatment for single  
393 congenital portosystemic shunts: 45 cases (2000-2004). *Journal of the American Veterinary Medical  
394 Association* **229**, 1122-1129

395

396 Lipscomb, V. J., Lee, K. C., Lamb, C. R. & Brockman, D. J. (2009) Association of mesenteric  
397 portovenographic findings with outcome in cats receiving surgical treatment for single congenital  
398 portosystemic shunts. *Journal of the American Veterinary Medical Association* **234**, 221-228

399

400 Macdonald N. J., Burton, C. A. & White, R. N. (2002) Comparison of visual analog and numeric  
401 scoring scales for assessing intraoperative mesenteric portovenography. *Veterinary Radiology and  
402 Ultrasound* **43**, 534-540

403

404 Mai, W. & Weisse, C. (2011) Contrast-enhanced portal magnetic resonance angiography in dogs with  
405 suspected congenital portal vascular anomalies. *Veterinary Radiology and Ultrasonography* **52**, 284-  
406 288

407

408 Mehl, M.L., Kyles, A.E., Hardie, E.M., Kass, P.H., Adin, C.A., Flynn, A.K., De Cock, H.E. &  
409 Gregory, C.R. (2005) Evaluation of ameroid ring constrictors for treatment for single extrahepatic  
410 portosystemic shunts in dogs: 168 cases (1995 – 2001). *J Am Vet Med Assoc* **226**, 2020 – 2030

411

412 Mogenicato, G., Vautravers, G., Meynaud-Collard, P., Deviers, A. & Sautet, J. (2014) Blood flows in  
413 tributaries of the portal vein: anatomical and angiographic studies in normal beagle dogs. *Anatomia  
414 Histologia Embryologia* **44**, 460-467

415



416 Nelson, N. C. & Nelson, L. L. (2011) Anatomy of extrahepatic portosystemic shunts in dogs as  
417 determined by computed tomography angiography. *Veterinary Radiology and Ultrasonography* **52**,  
418 498-506  
419

420 Parry, A. T. & White, R. N. (2015) Portal vein anatomy in the dog: comparison between computed  
421 tomographic angiography (CTA) and intraoperative mesenteric portovenography (IOMP). *Journal of*  
422 *Small Animal Practice* **56**, 657-661  
423

424 Seguin, B., Tobias, K. M., Gavin, P. R. & Tucker, R. L. (1999) Use of magnetic resonance  
425 angiography for diagnosis of portosystemic shunts in dogs. *Veterinary Radiology and Ultrasound* **40**,  
426 251-258  
427

428 Szatmári, V. & Rothuizen, J. (2006) Ultrasonographic identification and characterization of congenital  
429 portosystemic shunts and portal hypertensive disorders in dogs and cats. In: WSAVA Standards for  
430 Clinical and Histological Diagnosis of Canine and Feline Liver Disease. Saunders Elsevier,  
431 Edinburgh. pp 15-39  
432

433 White, R. N., Macdonald, N. J. & Burton, C. A. (2003) Use of intraoperative mesenteric  
434 portovenography in congenital portosystemic shunt surgery. *Veterinary Radiology and Ultrasound* **44**,  
435 514-521  
436

437 White, R. N. & Parry, A. T. (2013) Morphology of congenital portosystemic shunts emanating from  
438 the left gastric vein in dogs and cats. *Journal of Small Animal Practice* **54**, 459-467  
439

440 White, R. N. & Parry, A. T. (2015) Morphology of congenital portosystemic shunts involving the  
441 right gastric vein in dogs. *Journal of Small Animal Practice* **55**, 430-440

442

443 White, R.N. and Parry, A.T. (2016a) Morphology of splenocaval congenital portosystemic shunts in  
444 dogs and cats. *Journal of Small Animal Practice* **57**, 28 – 32

445

446 White, R. N. & Parry, A. T. (2016b) Morphology of congenital portosystemic shunts involving the left  
447 colic vein in dogs. *Journal of Small Animal Practice* **57**, 247 – 254

448

449 Wolschrijn, C. F. (2010) The abdomen of the dog and cat. In: Textbook of veterinary anatomy. 4<sup>th</sup>  
450 edn. Eds Dyce, K.M., Sack, W.O. and Wensing, C.J.G. Saunders Elsevier, St. Louis. p 450

451

452 Zwingenberger, A. L., Daniel, L., Steffey, M. A., Mayhew, P. D., Mayhew, K. N., Culp, W. T. N.,  
453 Hunt, G. B., (2013) Correlation between liver volume, portal vascular anatomy, and hepatic perfusion  
454 in dogs with congenital portosystemic shunt before and after placement of ameroid constrictors.  
455 *Veterinary Surgery* **43**, 926 – 934

456

457 Zwingenberger, A L. & Schwarz, T. (2004) Dual-phase CT angiography of the normal canine portal  
458 and hepatic vasculature. *Veterinary Radiology and Ultrasound* **45**, 117 – 124

459

460 Zwingenberger, A L., Schwarz, T. & Saunders, H.M. (2005) Helical computed tomographic  
461 angiography of canine portosystemic shunts. *Veterinary Radiology and Ultrasound* **46**, 27-32

462

463 **Figure Legends:**

464 Figure 1: CTA and IOMP from a patient with a splenocaval shunt. a. The CTA shows the intrahepatic  
465 and extrahepatic portal vasculature. b. The IOMP shows the anomalous vessel and the principal  
466 vessels associated with it. The intrahepatic portal vasculature is not identified.

467 Figure 2: CTA and IOMP from a patient with a left gastrocaval shunt. a. The CTA shows the  
468 intrahepatic and extrahepatic vasculature. b. In this patient the contrast allows identification of the  
469 right divisional branch of the intrahepatic portal vein much more completely than the left.

470

471 Figure 3: IOMP of a patient with a right gastrocaval shunt (type Ai). There is excellent visualisation  
472 of the intrahepatic portal vasculature.

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