

1 Original article

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3 Morphology of the canine omentum part 1: Arterial landmarks
4 that define the omentum

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6 **M. Doom¹, H. de Rooster², T. van Bergen³, Ingrid Gielen⁴, Kaatje Kromhout⁴, P.**
7 **Simoens¹ and P. Cornillie¹**

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9 ¹ Department of Morphology, Faculty of Veterinary Medicine, Ghent University, Ghent,
10 Belgium

11 ² Department of Medicine and Clinical Biology of Small Animals, Faculty of Veterinary
12 Medicine, Ghent University, Ghent, Belgium

13 ³ Department of Surgery and Anaesthesiology, Faculty of Veterinary Medicine, Ghent
14 University, Ghent, Belgium

15 ⁴ Department of Veterinary Medical Imaging and Small animal orthopaedics,
16 Faculty of Veterinary Medicine, Ghent University, Belgium

17

18 Corresponding author:

19 Marjan Doom, DVM
20 Marjan.Doom@UGent.be
21 Salisburylaan 133, B-9820 Merelbeke, Belgium
22 Tel : 0032(0)9/264.77.14
23 Fax : 0032(0)9/264.77.90

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28 3 Figures

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30 1 Video

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35 Summary

36 Although the omentum remains an enigmatic organ, research during the last decades has
37 revealed its fascinating functions including fat storage, fluid drainage, immune activity,
38 angiogenesis and adhesion. While clinicians both in human and veterinary medicine are
39 continuously exploring new potential omental applications, detailed anatomical data on the
40 canine omentum are currently lacking and information is often retrieved from human
41 medicine. In the present study, the topographic anatomy of the canine greater and lesser
42 omentum is explored in depth. Current nomenclature is challenged and a more detailed
43 terminology is proposed. Consistent arteries that are contained within folds of the superficial
44 omental wall are documented, described and named, as they can provide the anatomical
45 landmarks that are necessary for unambiguous scientific communication on the canine
46 omentum. In an included dissection video, the conclusions and *in situ* findings described in
47 the present study are demonstrated.

48 Key words: Anatomy – Arteries - Canine – Omentum

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50 Introduction

51 The greater and lesser omentum (Omentum majus and Omentum minus) are peritoneal sheets
52 that originate from the embryonic dorsal and ventral mesogastrium, respectively (Evans,
53 1993; McGready et al., 2006; Barone, 2009). During fetal development, the mesogastria lose
54 their initial role of anchoring the stomach to the dorsal and ventral body walls. They are
55 charged with blood vessels and lymphatics that run in fatty streaks. As the greater curvature
56 of the developing stomach topples to its final position, the dorsal mesogastrium elongates and
57 is drawn to the left. Its double layer of mesothelium reflects, lining a cavity that will become
58 the omental bursa (Bursa omentalis). From this stage of development onwards, the dorsal

59 mesogastrium consists of a superficial and a deep wall (Noden and De Lahunta, 1985;
60 McGready, 2006).

61 In dogs, the greater omentum is remarkably large and extends as a double-folded structure
62 from the stomach to the urinary bladder, covering the intestinal coils ventrally and bilaterally.
63 The greater omentum is classically subdivided into a bursal, a splenic and a veil portion
64 (Zietzschmann, 1939; Evans, 1993; Budras, 2002; Barone, 2009). The bursal and splenic
65 portions are composed of two walls, viz. a superficial wall (Paries superficialis) and a deep
66 wall (Paries profundus) (Budras, 2002). In the veil portion, however, both walls fuse during
67 embryonic development (Zietzschmann, 1939). The lesser omentum is small and relatively
68 simple. It spans the area lined by the liver, the lesser curvature of the stomach and the cranial
69 part of the duodenum (Barone, 2009). Based on the site of attachment, it is subdivided into the
70 hepatogastric ligament (Ligamentum hepatogastricum) and the hepatoduodenal ligament
71 (Ligamentum hepatoduodenale), the latter of which contains the portal vein, the hepatic artery
72 and the common bile duct (Evans, 1993; Barone, 2009).

73 After Otto Zietzschmann meticulously described the topographical anatomy of the canine
74 omentum in 1939, some nomenclature introduced in this pioneer study is no longer commonly
75 applied, and little additional research has been performed on the gross anatomy of the
76 omentum of the dog. However, there is a need for more detailed anatomical data since
77 surgical applications of the omentum are continuously being developed not only in human
78 medicine (Liebermann-Meffert, 2000) but also in small animal veterinary medicine (Valat and
79 Moissonnier, 2004). The anatomy and physiology of the omentum turn the organ into a very
80 beneficial tool for a variety of intra- and extra-abdominal surgical procedures (Fix and
81 Vasconez, 1989; Ross and Pardo, 1993; Hultman et al., 2002; Ito et al., 2010). Due to its large
82 surface area, pliability, malleable volume, generous pedicle length and extremely rich blood
83 supply, the omentum is particularly fit to treat infected, irradiated and ischemic wounds such

84 as radiation injuries of the chest wall in humans (Fix and Vasconez, 1989; Hultman et al.,
85 2002) or chronic axillary wounds in cats (Gray, 2005). In dogs, the omentum is also used as a
86 physiological drain in the surgical management of prostatic abscesses and cysts (White and
87 Williams, 1995). Moreover, the omentum is a reservoir of peritoneal immune cells and a
88 source of angiogenic and neurotrophic factors (De la Torre and Goldsmith, 1988; Zhang et al.,
89 1997; Dujovny et al., 2004). The latter may play an important role in the future treatment of
90 some neurological conditions (Goldsmith, 2010). The omentum has also been identified as a
91 source of adult stem cells, opening future prospects in the field of tissue engineering and the
92 synthesis of vascular grafts in human medicine (Collins et al., 2009). For extra-peritoneal
93 wounds, the omentum can be harvested for a microsurgical free graft, or it can be mobilized
94 as a pedicle flap (Hultman et al., 2002). Knowledge on the attachment of the omentum to
95 surrounding structures and on its vascular supply is obviously prerequisite for these surgical
96 applications. In fact, in human medicine, the refinement of anatomic knowledge and the
97 development of safe mobilization techniques have paralleled the increased use of the
98 omentum in reconstructive and cardiovascular surgery (Fix and Vasconez, 1989; Hultman et
99 al., 2002). Although dogs and cats have frequently served as research models to explore these
100 omental surgical applications in humans (Goldsmith, 1975; De la Torre and Goldsmith, 1994;
101 Hayari et al., 2004), detailed anatomical data on the canine and feline omenta and their
102 vascular supply are scarce. Consequently, the surgical techniques used in these exploratory
103 studies, as well as those subsequently applied in companion animal patients, often improperly
104 rely on human data.

105 Furthermore, in microscopic studies on the omentum of small animals, researchers have few
106 anatomical landmarks to meticulously describe the place of sampling (Owaki et al., 2013). As
107 a result, the nomenclature used in the current scientific literature on omental research in dogs

108 and cats is based on either non-detailed veterinary anatomical terminology or ill-extrapolated
109 human data.

110 The main goal of the present study was to map anatomical landmarks that will improve
111 unambiguous scientific communication on the canine omentum. In the second part of the
112 study (Part 2) the recesses of the omental cavity will be described and discussed in detail.

113 Materials and Methods

114 A total of 9 cadavers of dogs of different gender, age and breed were used (Table 1). Different
115 techniques including casting of the blood vessels, dissection of embalmed cadavers and
116 filming of a dissected fresh cadaver were implemented to illustrate observations. All animals
117 had been euthanized for reasons unrelated to this study. In 6 dogs, latex injection and vessel
118 dissections were performed. All dogs were positioned in dorsal recumbency. The thoracic
119 cavity was opened through a rectangular window (approximately 6x4 cm) in the left 4th-6th
120 intercostal space. A 20 Gauge intravenous catheter was placed in the thoracic aorta and
121 secured by an encircling ligature just caudal to the aortic arch, and a 3-way stopcock was
122 connected. Subsequently, 150-700 ml of an aqueous latex solution (Polyester Demaere©,
123 Belgium) was injected into the catheter. After curing of the latex for at least 2 hours, the
124 abdominal wall was incised along the ventral midline, and the peritoneal cavity was opened
125 from the xiphoid cartilage to the pecten of the pubic bone to explore and dissect the injected
126 blood vessels. Additionally, the abdominal cavities of 2 female embalmed dogs with injected
127 blood vessels (Carolina's Perfect Solution©, USA) were dissected to confirm previously
128 gained insights and to illustrate some anatomical features more clearly due to the rigidity of
129 the embalmed cadavers (Fig 3). Finally, to illustrate the three-dimensional topographic
130 anatomy of the greater omentum *in situ*, the omentum of a fresh cadaver was filmed while

131 being dissected via a ventral midline approach. The resulting video can be viewed by opening
132 the following URL-link: www.UGent.be/canine-omentum.

133 Results

134 In all dogs, the greater omentum was composed of a bursal, a splenic and a veil portion. The
135 former two portions consist of a superficial and a deep wall, whereas the veil portion is a
136 single peritoneal fold. The omentum contains several arteries, of which the topographic
137 anatomy provides the landmarks necessary to delineate the various omental parts.

138 Arterial landmarks

139 The omental blood vessels are either located in the fatty streaks of the omental wall or are
140 contained within folds of the superficial wall of the greater omentum, which protrude into the
141 omental bursa (video).

142 The major blood supply of the bursal portion is derived from the gastroepiploic arterial arch.
143 This anastomosis between the left and right gastroepiploic arteries (A. gastroepiploica sinistra
144 and A. gastroepiploica dextra, respectively) is located in the superficial wall of the bursal
145 portion, parallel to the greater curvature of the gastric corpus and pylorus. The left and right
146 gastroepiploic arteries have a different origin. The right gastroepiploic artery is located in the
147 pyloric region and stems from the short gastroduodenal artery (A. gastroduodenalis), which is
148 a branch from the hepatic artery (A. hepatica) (Fig. 1, video). After arising from the celiac
149 artery (A. celiaca), the hepatic artery courses cranioventrally towards the liver in a peritoneal
150 fold extending from the dorsal abdominal wall, the hepatopancreatic fold (Plica
151 hepatopancreatica) (Fig. 3C). The left gastroepiploic artery stems from the splenic artery (A.
152 lienalis), which arises from the celiac artery and is located in the deep wall of the greater
153 omentum in which it runs parallel to the left pancreatic lobe. At the level of the lateral tip of

154 this pancreatic lobe, the splenic artery gives off a large gastrosplenic branch and continues
155 towards the splenic hilus. The gastrosplenic branch gives rise to a splenic branch that supplies
156 the dorsal part of the spleen and a cranial gastric branch that curves ventrally towards the
157 fundus of the stomach and which it supplies by several short gastric arteries (Aa. gastricae
158 breves) (Fig. 1, video). The cranial gastric branch is contained within a fold of the superficial
159 wall of the greater omentum, which will be further referred to as the cranial gastrosplenic fold
160 (Fig. 2). After giving rise to the gastrosplenic branch, the splenic artery continues its course in
161 the deep wall of the greater omentum towards the middle segment of the spleen and proceeds
162 along the splenic hilus. However, before reaching the hilus the artery gives off two strong
163 branches, i.e., the left gastroepiploic artery and a second strong arterial branch that will be
164 further referred to as the caudal gastric branch and that ramifies in short gastric arteries to the
165 gastric fundus (Fig. 1, video). Occasionally, the caudal gastric branch arises directly from the
166 left gastroepiploic artery (Fig. 1). Both the left gastroepiploic artery and the caudal gastric
167 branch are contained in folds of the superficial wall of the splenic portion, designated as the
168 caudal and middle gastrosplenic fold respectively (Fig 2).

169 Omental portions

170 The bursal portion of the greater omentum covers the intestinal coils both ventrally and
171 bilaterally. Its superficial wall originates from the greater curvature of the stomach, extending
172 from the gastric fundus to the pylorus and continuing onto the proximal part of the duodenum
173 in alignment with the attachment of the lesser omentum to the duodenum (Ligamentum
174 hepatoduodenale). The superficial wall extends along the ventral abdominal wall as far as the
175 empty urinary bladder. To the right, caudally and also to the left (i.e., caudal to the spleen) the
176 superficial wall of the bursal portion reflects dorsally and continues as the deep wall. The
177 deep wall of the bursal portion proceeds cranially, attaches to the left lobe of the pancreas,

178 encompasses this pancreatic lobe and then continues craniodorsally to attach to the dorsal
179 abdominal wall (Fig 3B). The left cranial edge of the bursal portion is attached to the hilus of
180 the spleen. However, the ventral extremity of the spleen remains unattached to omentum
181 (video). The cranial border of the deep wall of the bursal portion is delineated by the splenic
182 artery (Fig. 1, video).

183 The splenic portion of the greater omentum also consists of a superficial and a deep wall. At
184 the level of the spleen, i.e., in the left cranial area of the abdomen, the superficial wall of the
185 splenic portion is continuous with the superficial wall of the bursal portion. The border
186 between the superficial walls of the bursal and splenic portions can be set at the level of the
187 caudal gastrosplenic fold containing the left gastroepiploic artery. The superficial wall of the
188 splenic portion is bordered medially by the stomach and laterally by the cranial half of the
189 splenic hilus. The splenic portion then extends further craniodorsally beyond the spleen,
190 forming a cranial protrusion consisting of a superficial and a deep wall. Both walls attach
191 medially to the cardia of the stomach and the oesophagus, and insert cranially on the
192 tendinous centre of the diaphragm, lining the left half of the oesophageal hiatus (Fig. 1,
193 video). The caudal border of the superficial wall of the cranial protrusion is delineated by the
194 cranial gastrosplenic fold, whilst the caudal border of the deep wall of this protrusion is
195 delineated by the gastrosplenic branch of the splenic artery (Fig. 1, video).

196 Between the cranial and caudal gastrosplenic folds, the superficial wall of the splenic portion
197 forms a semilunar pouch, further referred to as the caudoventral outpocketing of the splenic
198 portion (video).

199 The deep wall of the splenic portion is divided into cranial and caudal parts by the position of
200 the gastrosplenic branch of the splenic artery. The caudal part is bordered laterally by the
201 splenic hilus and both medially and caudally by the splenic artery which courses towards the

202 splenic hilus and delineates the border between the deep walls of the bursal and splenic
203 portions of the greater omentum. The caudal part of the deep wall of the splenic portion forms
204 a semilunar pouch, which is further referred to as the caudodorsal outpocketing of the splenic
205 portion (Fig. 1, video).

206 The veil portion, which was remarkably large in some dogs, is characterized by a free caudal
207 margin. Its cranial margin originates from the deep wall of the omentum at the level of the
208 splenic artery. The right lateral margin of the veil portion blends with the left side of the
209 mesocolon. The left lateral margin is attached to the ventral part of the visceral side of the
210 spleen. Perpendicular to the left lateral margin a small triangular fat-free fold splits off from
211 the dorsal surface of the veil portion and protrudes towards the spleen (Fig. 3A, video).

212 Discussion

213 The present observations of the canine omentum largely correspond to those described in the
214 literature (Evans, 1993; Barone, 2009). The subdivision of the greater omentum into bursal,
215 splenic and veil portions has been set a long time ago (Zietzschmann, 1939), but the definition
216 of the exact borders between those individual omental portions was lacking until now.
217 Moreover, some previous definitions of omental parts are ambiguous. Since research on the
218 omentum and its clinical applications is increasing, there is a need for clear definitions.

219 In the present study, we attempted to set consistent and unambiguous borders for omental
220 portions, resulting in specific definitions and a more detailed nomenclature for the canine
221 omentum. To a large extent, these margins are defined by arterial landmarks. The smaller
222 proper omental arteries run in the fatty streaks of the omental walls while some of the larger
223 arteries, supplying the omentum and the attached organs (stomach and spleen), are contained
224 within folds of the superficial wall of the greater omentum that protrude into the bursal cavity

225 of the omentum. These arteries provide some of the landmarks that are necessary to define the
226 various parts of the omentum properly.

227 The canine splenic artery presents a variable branching pattern resulting in a variety of
228 descriptions and confusing nomenclature in the literature (Gravenstein, 1938; Horst, 1941;
229 Godinho, 1964). Yet, some consistent findings were confirmed in the present study. Shortly
230 after its origin from the celiac artery, the splenic artery bifurcates into a proximal and a distal
231 branch (Gravenstein, 1938; Horst, 1941; Godinho, 1964; Barone, 1996). In all cases in the
232 present study, this bifurcation was situated at the level of the lateral tip of the left pancreatic
233 lobe. The proximal branch provides blood supply to the dorsal part of the spleen (through
234 splenic branches) and additionally to the stomach (through short gastric arteries)
235 (Gravenstein, 1938; Horst, 1941). This proximal branch corresponds to the gastrosplenic
236 branch as defined in international nomenclature in pigs (Simoens, 2012). It was previously
237 described as occasionally double and contained within a fold of the superficial wall of the
238 splenic portion (Gravenstein, 1938; Horst, 1941). We found in all cases a single gastrosplenic
239 branch, which ramified into a splenic branch and a cranial gastric branch. The latter was
240 contained within the cranial gastrosplenic fold of the superficial wall of the splenic portion.
241 The splenic artery proceeds its course towards the splenic hilus. Before reaching the hilus, it
242 gives rise to the left gastroepiploic artery, which is also contained in a fold of the superficial
243 omental wall (Gravenstein, 1938, Horst, 1941, Evans, 1993). This fold, which we named the
244 caudal gastrosplenic fold, is located in the transition zone between the superficial walls of the
245 bursal and splenic portions (Horst, 1941). Hence, it serves as a clear and consistent border
246 between both omental portions.

247 The short gastric arteries arise from the cranial gastric branch and the left gastroepiploic
248 artery, but they can also originate from an additional arterial branch, which was previously
249 described as originating directly from the splenic artery (Gravenstein, 1938) or from the left

250 gastroepiploic artery (Horst, 1941). This double origin was confirmed in the present study as
251 both were observed and we designated this branch as the caudal gastric branch. It was
252 consistently present and was contained within the middle gastrosplenic fold , serving as a
253 landmark to define the splenic portion. A variety of smaller additional branches of the splenic
254 artery have been described in the literature (Gravenstein, 1938, Horst, 1941) and were also
255 found in the present study. Given their inconsistent pattern they cannot serve as landmarks to
256 define omental portions. The same is true for smaller arteries that supplied the splenic portion
257 itself and arose from the splenic artery or from one of its major branches. Those arteries ran
258 superficially and in variable patterns in the fatty streaks of the splenic portion.

259

260 A precise delineation and definition of the gastrosplenic (Ligamentum gastrolienale),
261 gastrophrenic (Ligamentum gastrophrenicum) and phrenicosplenic (Ligamentum
262 phrenicolienale) ligaments is lacking in traditional descriptions and in official nomenclature.
263 The gastrosplenic ligament extends from the greater curvature of the gastric fundus to the
264 spleen (Habel, 2012). The attachment of the spleen to the superficial wall of the omentum has
265 been considered as the cranial border of the gastrosplenic ligament (Barone, 2001). No clear
266 caudal border has been defined. In the present observations, the gastrosplenic ligament was
267 bordered cranially by the cranial gastrosplenic fold and caudally by the caudal gastrosplenic
268 fold. While this gastrosplenic ligament could clearly be defined, we failed to observe a
269 distinct gastrophrenic ligament, which has been described as a short and robust ligament
270 loaded with fibro-elastic fibers (Barone, 2001). It has been reported as extending between the
271 gastric fundus and the diaphragm and continuing to the left as the phrenicosplenic ligament,
272 which connects the diaphragm and the spleen (Barone, 2001; Barone, 2009; Habel, 2012).
273 These ligaments have been assigned a suspensory role of the stomach and the spleen,
274 respectively (Barone, 2001). Such strong and well delineated ligaments could not be

275 demonstrated in the present study, but instead we observed a cranial protrusion of the splenic
276 portion of the greater omentum, composed of both a superficial and a deep wall. This
277 protrusion consisted of loose omental tissue, making a suspensory role doubtful. Considering
278 these findings, one might question whether the term ligament is appropriate for this structure
279 since a ligament is defined as an inelastic structure that joins two organs or connects an organ
280 to the body wall in a solid way (Barone, 2001).

281 The gastrosplenic ligament has been considered as a synonym of the splenic portion of the
282 greater omentum (Evans, 1993; Barone, 2001; Budras, 2002; Könich and Liebich, 2004;
283 Barone, 2009). Based on the present findings, however, both terms are not synonymous
284 because the splenic portion is an omental portion with a superficial and a deep wall, and
285 includes a cranial protrusion that extends craniodorsally beyond the cranial margin and the
286 dorsal extremity of the spleen. In contrast, the gastrosplenic ligament is a mere part of the
287 superficial wall of the splenic portion, bordered by the cranial and caudal gastrosplenic folds.

288 The veil portion of the omentum (Velum omentale) is the sagittal membrane that connects the
289 deep wall of the greater omentum with the left surface of the descending mesocolon (Habel,
290 2012). According to some authors (Evans, 1993), it contains the distal extremity of the left
291 pancreatic lobe. This could not be confirmed in the present study. Other discrepancies were
292 noted concerning the free margin of the veil portion, which has been described as a left free
293 margin (Evans, 1993), whereas we observed a caudal free margin in the present study.

294 The findings of the present study lead to a number of recommendations for elaboration of the
295 existing official nomenclature (N.A.V, 2012). In addition to the Plica hepatopancreatica and
296 the Plica gastropancreatica, which are listed in the current N.A.V., it is suggested to include
297 also the terms Plica gastrolienalis cranialis, Plica gastrolienalis intermedia and Plica
298 gastrolienalis caudalis for designating the omental folds that were observed consistently in the

299 present study and contain major blood vessels which form valuable topographic landmarks for
300 delineating various omental parts.

301 In contrast, the Ligamentum gastrophrenicum and the Ligamentum phrenicolienale, which are
302 listed in N.A.V. without any species designations, were not observed as clearly delineated
303 structures in any of the dogs examined in the present study.

304 Similar to the situation in pigs, a gastrosplenic branch was given off by the A. lienalis in all
305 examined dogs and therefore, it is suggested to list the term Ramus gastrolienalis for both the
306 porcine and canine species. Furthermore, two constant arterial branches were given off either
307 indirectly or directly by the A. lienalis in all dogs examined, and they were designated as the
308 Ramus gastricus cranialis and the Ramus gastrolienalis caudalis, respectively.

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393 Table 1: List of dogs and techniques used in the present study

Breed	Age group	Sex(F=female, M= male)	Implemented techniques
American Stafford	Young Adult	F neutered	Vascular casting with latex
English Cocker Spaniel	Young Adult	F	Vascular casting with latex
American Stafford	Young Adult	M neutered	Vascular casting with latex
Mongrel dog	Young Adult	M	Vascular casting with latex
Jack Russell terrier	Adult-Geriatric	F	Vascular casting with latex
Cairn terrier	Young Adult	F	Vascular casting with latex
Mongrel dog	Young Adult	F	Embalmed with injected blood vessels (*)
Mongrel dog	Young Adult	F	Embalmed with injected blood vessels (*)
Rottweiler	Immature	F	Dissection+video

394 (*Carolina's Perfect Solution©, preserved dog, double color injected)

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405 Legends to the figures

406 a. Oesophagus, b. Stomach, c. Duodenum, d. Spleen, e. Papillary process of the caudate lobe
407 of the liver, f. Descending colon, g. Transverse colon, h. Left pancreatic lobe, i. Left kidney, j.
408 Bursal portion (j' superficial wall, j'' deep wall), k. Splenic portion (k' superficial wall, k''
409 deep wall), l. Veil portion, m. Cranial gastrosplenic fold, n. Middle gastrosplenic fold, o.
410 Caudal gastrosplenic fold, p. Part of the tendinous centre of the diaphragm, q. Attachment of
411 the deep omental wall to the dorsal abdominal wall (transected)

412 1. Aorta, 2. Celiac artery, 3. Left gastric artery, 4. Hepatic artery, 5. Splenic artery, 6.
413 Gastrosplenic branch (6'. Splenic branch, 6''. Cranial gastric branch), 7. Left gastroepiploic
414 artery, 8. Caudal gastric branch, 9. Short gastric arteries, 10. Right gastric artery, 11.
415 Gastroduodenal artery, 12. Right gastroepiploic artery

416 Fig. 1: Schematic drawing of abdominal organs (stomach, spleen and left lobe of the
417 pancreas) with supplying arteries and attached omentum, based on cadaveric dissections. A:
418 Ventral view. B: Dorsal view.

419 Fig. 2: A: Caudal-to-cranial view into the omental bursa, approached through an incision and
420 subsequently lifting of the superficial wall of the bursal portion. B: Oblique right-to-left view
421 of the gastrosplenic ligament. The wall of the ligament holds three gastrosplenic folds that
422 contain large blood vessels. These folds do not smoothen when tension is applied on the
423 ligament.

424 Fig. 3: A, B, C: Caudal-to-cranial views of the cranial abdominal viscera of an embalmed dog
425 A: The right lateral margin of the omental veil portion blends with the left side of the
426 descending mesocolon. The asterisk indicates the fat-free fold that splits off from the left
427 lateral side of the omental veil and attaches to the visceral surface of the spleen. B: The
428 transverse colon is retracted dorsally to show the attachment of the deep wall of bursal portion
429 of the greater omentum (j'') to the left pancreatic lobe (h) (asterisks). C: The omental bursa is
430 opened by transecting the deep wall of the bursal portion from its attachment to the left
431 pancreatic lobe which is reflected dorsally. The single arrow indicates the hepatopancreatic
432 fold (with the hepatic artery) and the double arrows point to the gastropancreatic fold (with
433 the left gastric artery).

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