



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

The effect of recumbency and hindlimb position on the lumbosacral interlaminar distance in dogs: a cadaveric computed tomography study

Citation for published version:

Panti, A, Greenhalgh, S, Longo, M & Liuti, T 2018, 'The effect of recumbency and hindlimb position on the lumbosacral interlaminar distance in dogs: a cadaveric computed tomography study', *Veterinary Anaesthesia and Analgesia*. <https://doi.org/10.1016/j.vaa.2018.05.008>

Digital Object Identifier (DOI):

[10.1016/j.vaa.2018.05.008](https://doi.org/10.1016/j.vaa.2018.05.008)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Veterinary Anaesthesia and Analgesia

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



1 **Word Count** 2,911

2 **Abstract**

3 **Objective** To examine the effect of sternal or lateral recumbency, with or without
4 cranial extension of the hindlimbs, on the distance between the dorsal lumbosacral
5 laminae in dogs.

6 **Study design** Blinded, randomised, crossover, experimental study.

7 **Animals** A total of 19 canine cadavers.

8 **Methods** Computed tomography of the lumbosacral junction was performed in four
9 positions: sternal and right lateral recumbency, with hindlimbs extended cranially or
10 not. Order of positioning was randomised. The lumbosacral interlaminar (LSI) distance,
11 defined as the distance between the dorsal laminae of the seventh lumbar vertebra
12 (caudal margin) and sacrum (cranial margin), was measured for each position by two
13 independent assessors who were unaware of positioning. Mean distances in each
14 position were compared using a paired t-test, corrected for multiple comparisons.

15 **Results** For $n = 19$ cadavers [6 female, median (range) age 9 (0.3 – 16) years, 20.4 (1.0
16 – 34.0) kg], cranial extension of the hindlimbs increased the LSI distance, compared to
17 control, in both sternal (9.2 ± 2.2 mm *versus* 3.1 ± 1.3 mm, $p < 0.001$) and right lateral
18 recumbency (8.2 ± 1.9 mm *versus* 4.9 ± 1.5 mm, $p < 0.001$). With the hindlimbs
19 extended cranially, sternal recumbency increased LSI distance when compared to right
20 lateral recumbency ($p < 0.001$).

21 **Conclusions and clinical relevance** Cranial extension of the hindlimbs in both sternal
22 and lateral recumbency increases the LSI distance to an extent that is both statistically
23 significant and of potential clinical relevance. Although ease of epidural access or
24 injection was not assessed, the small (1 mm) difference in LSI distance between cranial

25 hindlimb extension in sternal *versus* right lateral recumbency is unlikely to be of clinical
26 relevance. Conversely, cranial extension of the hindlimbs in either sternal or lateral
27 recumbency would be expected to facilitate epidural injection.

28 **Keywords** anatomy, canine, epidural, extradural, regional anaesthesia.

29 **Introduction**

30 The lumbosacral space is a commonly used site for epidural administration of analgesic
31 and anaesthetic drugs in dogs (Jones 2001; Campoy 2004). Lumbosacral injection may
32 be performed in sternal or lateral recumbency (Heath 1992; Jones 2001; Campoy 2004).
33 Anecdotally, sternal recumbency appears to be more commonly utilised, for reasons of
34 operator convenience and ease of animal positioning. However, individual preference or
35 animal-specific factors, including degenerative joint disease or hindlimb fracture, may
36 lead to lateral recumbency being selected for the procedure (Heath 1986).

37 Studies describing lumbosacral injection in dogs, irrespective of recumbency,
38 frequently state that the hindlimbs were pulled forwards, as part of their description of
39 animal positioning (Iff & Moens 2010; Adami et al. 2013; Liotta et al. 2015; Kawalilak
40 et al. 2015; Ertelt et al. 2016; Liotta et al. 2016; Viscasillas et al. 2016; Martinez-
41 Taboada & Redondo 2017). Cranial extension of the hindlimbs has been recommended
42 since the early descriptions of lumbosacral injection in dogs (Bradley et al. 1980). This
43 recommendation is based on the assumption that such positioning produces flexion of
44 the vertebral column, including at the lumbosacral junction (Wetmore & Glowaski
45 2000; Jones 2001; Campoy 2004). Lumbosacral flexion widens the distance between
46 the dorsal laminae of the lumbosacral vertebrae [hereinafter referred to as the
47 lumbosacral interlaminar (LSI) distance] and may therefore facilitate injection or
48 catheter placement.

49 In humans, lumbar epidural injection is usually performed between the third and
50 fifth lumbar vertebrae (Boon et al. 2004). A number of positioning techniques,
51 including hip flexion, have been shown to increase the interspinous distance (Fisher et
52 al. 2001; Sandoval et al. 2004; Jones et al. 2013; Dimaculangan et al. 2016). In dogs,

53 the idea that a similar effect could be achieved at the lumbosacral junction through
54 cranial positioning of the hindlimbs has been challenged (Valverde 2008). Instead, it
55 was suggested, based on experience with cadavers, that cranial positioning of the
56 hindlimbs might enhance landmark palpation rather than increasing the LSI distance per
57 se (Valverde 2008). It was subsequently demonstrated that cranial positioning of the
58 hindlimbs, at least in sternal recumbency, can increase the LSI distance (Di Concetto et
59 al. 2012). However, the effect of hindlimb positioning in lateral recumbency was not
60 assessed, and as a result it was also not possible to compare the LSI distance in sternal
61 *versus* lateral recumbency.

62 We therefore designed a study to compare the effect of hindlimb positioning on the
63 LSI distance in both sternal and lateral recumbency. We hypothesised that cranial
64 extension of the hindlimbs would increase the LSI distance in both sternal and lateral
65 recumbency. Additionally, we hypothesised that cranial extension of the hindlimbs in
66 sternal recumbency would result in a greater LSI distance than cranial extension of the
67 hindlimbs in lateral recumbency.

68 **Materials and methods**

69 **Dogs**

70 A blinded, crossover, experimental study was performed on canine cadavers. Ethical
71 approval was granted by the University of Edinburgh Veterinary Ethical Review
72 Committee (VERC# 02/10). Canines of any size and age euthanized for causes
73 unrelated to the present study and donated to the hospital by their owners were included
74 in the study. Dogs with a clinical history, or radiological evidence (on computed
75 tomography scan review by a radiologist (M.L., T.L.), of lumbosacral or pelvic

76 abnormality, including fracture, hemivertebrae, transitional vertebrae, intervertebral disc
77 disease, severe degenerative joint disease or spondylosis deformans, were excluded.
78 Weight, sex, age and reason for euthanasia were recorded.

79 **Procedures**

80 The four positions into which each cadaver was placed are illustrated in Figure 1. These
81 comprised sternal recumbency with hindlimbs extended caudally (control) or cranially,
82 and right lateral recumbency with hindlimbs lying neutrally (control) or extended
83 cranially. The order in which each case was placed into each of the four positions was
84 randomised independently, firstly by randomly selecting the initial recumbency and
85 then, for each recumbency, randomly selecting the initial hindlimb position
86 (www.randomizer.org). Positioning was always performed by the same two
87 investigators (M.L., T.L.). Foam wedges and sandbags were used to align each dog
88 correctly within the gantry, keeping the pelvis and spine parallel to the table, as
89 previously described (Puggioni et al. 2006), and maintaining the hindlimbs in the
90 desired position.

91 For each of the four positions, a multi-detector computed tomography exam of the
92 lumbosacral junction was performed in helical mode, at 100 kV and 100-150 mAs, with
93 a 1 mm slice thickness, spiral pitch factor of 0.8, rotation time of 1 second, and matrix
94 size 512x512 (Somatom 64; Siemens, Germany). The entire lumbar spine and sacrum
95 were included in the sequences to rule out lumbosacral abnormality and to allow
96 measurements to be made at the correct intervertebral space. Images were acquired
97 within 24 hours of euthanasia; cadavers were stored at 4°C until scanning.

98 The distance between the dorsal laminae of the seventh lumbar vertebra (caudal
99 margin) and sacrum (cranial margin), referred to as the LSI distance (Fig. 2), was

100 measured in each position, at the level of the midline, by two independent assessors
101 (A.P., M.L.), each making one measurement in each position. The assessors viewed
102 images containing only the lumbar spine and lumbosacral junction, and were therefore
103 unaware of recumbency or hindlimb position at the time of measurement. Multiplanar
104 reconstruction and measurement were performed using certified medical software
105 (Osirix PRO; Ayca, Germany). Images were reconstructed at a 0.1 mm increment. A
106 bone reconstruction algorithm (I70h, WW735, WW4096) was used to detect
107 lumbosacral abnormality, and to measure the LSI distance and the mid-body height of
108 the fifth lumbar vertebra (L5) (Fig. 2). A soft tissue reconstruction algorithm (I40s,
109 WL45, WW360) was used to detect any additional lumbosacral abnormalities.

110 **Statistical analysis**

111 Sample size calculations based on pilot data suggested that a minimum of 15 cases
112 would be required to detect a change in distance of $\geq 50\%$ (Type I error rate 0.05, Type
113 II error rate 0.2). We therefore aimed to include 20 dogs in the study population to
114 ensure adequate power. For each position, the mean of the measurements recorded by
115 the two independent assessors was calculated and used in the subsequent analysis.

116 Data were assessed graphically for normality prior to analysis. Data are presented
117 as mean \pm standard deviation (SD) unless otherwise stated. Mean LSI distance in each
118 position was compared using a paired t-test, corrected for multiple comparisons using a
119 Bonferroni correction. The relationship between LSI distance and mid-body height of
120 L5 or body weight was assessed using Pearson correlation analysis. Positive or negative
121 values of r between 0.30 and 0.49, 0.50 and 0.69, and 0.70 and 1, were considered to
122 represent weak, moderate or strong correlations, respectively. Inter-assessor reliability

123 was examined by calculation of the intraclass correlation coefficient, using a two-way
124 mixed, single measure, absolute agreement model.

125 Values of $p \leq 0.05$ were considered significant. Data were analysed using Excel for
126 Mac (version 15.38; Microsoft, WA, USA), Prism 7 for Mac OS X (version 7.0c;
127 GraphPad Software Inc, CA, USA), and SPSS Statistics (version 23.0.0.3; IBM, NY,
128 USA).

129 **Results**

130 Nineteen cadavers were included in the final analysis. One cadaver was excluded prior
131 to analysis because of the presence of pelvic fractures and sacroiliac luxation. Summary
132 descriptive data for the study population are shown in Table 1. Data for individual cases
133 are provided in Table S1.

134 Analysis of LSI distances in sternal recumbency confirmed that hindlimb position
135 significantly alters LSI distance (Fig. 3a). Cranial extension of the hindlimbs increased
136 LSI distance compared to caudal extension (9.2 ± 2.2 mm *versus* 3.1 ± 1.3 mm, $p <$
137 0.001). Thus, between the two extremes of hindlimb position in sternal recumbency,
138 there was almost a three-fold difference in LSI distance.

139 The LSI distance was then assessed in right lateral recumbency, comparing
140 hindlimbs positioned neutrally or extended cranially. Again, cranial extension of the
141 hindlimbs significantly increased the mean LSI distance compared to neutral
142 positioning (8.2 ± 1.9 mm *versus* 4.9 ± 1.5 mm, $p < 0.001$) (Fig. 3b). On average,
143 cranial extension of the hindlimbs in lateral recumbency increased the LSI distance by
144 67% compared to control.

145 Having confirmed that cranial extension of the hindlimbs increases the LSI distance
146 in both sternal and lateral recumbency, we next examined whether one recumbency was

147 superior. With the hindlimbs extended cranially, sternal recumbency resulted in only a 1
148 mm (12%) increase in mean LSI distance when compared to right lateral recumbency
149 (9.2 ± 2.2 mm *versus* 8.2 ± 1.9 mm, $p < 0.001$) (Fig. 3c).

150 The mid-body height of L5 was measured at the same time as LSI distance to assess
151 the effect of size on LSI distance. Body weight was also recorded for 16 dogs. Both L5
152 mid-body height and body weight showed only weak correlation with LSI distance in
153 right lateral recumbency with neutral hindlimb position (Fig. 4a, c); L5 height: $r = 0.49$,
154 95% C.I. 0.04-0.77, $p = 0.04$; body weight: $r = 0.34$, 95% C.I. -0.19-0.71, $p = 0.20$. A
155 moderate correlation was observed with cranial hindlimb extension (Fig. 4b, d); L5
156 height: $r = 0.54$, 95% C.I. 0.11-0.80, $p = 0.02$; body weight: $r = 0.60$, 95% C.I. 0.14-
157 0.84, $p = 0.01$.

158 Inter-assessor reliability was examined by calculation of an intraclass correlation
159 coefficient from all 76 measurements (19 dogs in four positions) made by each of the
160 two assessors. This gave a value of 0.89 (95% C.I. 0.82-0.94), suggesting excellent
161 agreement between the two assessors.

162 Discussion

163 The findings of this canine cadaveric study support the primary hypothesis that cranial
164 extension of the hindlimbs increases the LSI distance in both sternal and lateral
165 recumbency. The results also confirm and extend those of a previous, clinical study (Di
166 Concetto et al. 2012), which demonstrated that cranial extension of the hindlimbs
167 increased the LSI distance in sternal recumbency, but did not examine the effect of
168 hindlimb position in lateral recumbency.

169 The earlier study by Di Concetto et al. (2012) suggested that cranial extension of
170 the hindlimbs in sternal recumbency increases the LSI distance by 83% on average. Our

171 study found a similar effect (67% average increase) of cranial extension of the
172 hindlimbs in right lateral recumbency. The magnitude of effect of hindlimb position that
173 we measured in sternal recumbency cannot be compared directly to this previous study,
174 nor translated directly into a clinical setting, because we elected to use caudal extension
175 of the hindlimbs as our control position in sternal recumbency. Similarly, comparison of
176 the relative effect of changing hindlimb position in sternal *versus* lateral recumbency in
177 this study is of no value because of the difference in control positions. The effect on the
178 LSI distance of changing hindlimb position in sternal recumbency was intentionally not
179 expressed as a percentage to minimise the risk of the misperception that hindlimb
180 position had a greater effect on LSI distance in sternal recumbency than in lateral
181 recumbency.

182 In lateral recumbency, cranial hindlimb extension was compared to a clinically
183 relevant, neutral, control position. Conversely, although caudal extension of the
184 hindlimbs in sternal recumbency would not be used clinically, it was selected for two
185 reasons. Firstly, it has previously been suggested that cranial extension of the hindlimbs
186 does not increase the size of the LSI space in cadavers (Valverde 2008). Therefore, we
187 wanted to test the limits of hindlimb excursion in our cadaveric study to maximise the
188 validity of a negative finding had we been unable to detect an effect. Secondly,
189 positioning the hindlimbs in a neutral, flexed position in sternal recumbency can lead to
190 the presence of photon starvation artefact on computed tomography images (Schwarz &
191 Saunders 2011), which could have affected the accuracy with which we were able to
192 measure LSI distance, through decreasing the signal to noise ratio. To optimise
193 measurement accuracy, the reconstruction increment was minimized to 0.1 mm to
194 maximize the longitudinal resolution, considering the pitch factor of 0.8 (Brink et al.

195 1994). Any potential bias was assumed to be consistent across positions and
196 homogeneously spread between observers.

197 When comparing LSI distance with cranial extension of the hindlimbs in sternal
198 *versus* lateral recumbency, we found only a small, albeit statistically significant,
199 difference. Although this enabled us to accept our secondary hypothesis, that cranial
200 extension of the hindlimbs in sternal recumbency would result in a greater LSI distance
201 than cranial extension of the hindlimbs in lateral recumbency, the clinical significance
202 of an average increase in LSI distance of 1 mm (or 12%) is likely to be minimal. A
203 similar finding (average increase of 3%), albeit using a different measurement
204 methodology and plain film radiography, was obtained in a canine cadaveric study that
205 compared cranial extension of the hindlimbs in sternal or lateral recumbency and its
206 effect on the mid-laminar distance between the fifth and sixth lumbar vertebrae
207 (Puggioni et al. 2006).

208 In human medicine, epidural and spinal injection for neuraxial anaesthesia is
209 commonly performed between lumbar vertebrae, rather than at the lumbosacral junction
210 (Boon et al. 2004). Patients are routinely advised to arch their back in order to widen the
211 interlaminar space and facilitate needle placement. Hip flexion has also been shown to
212 widen the interspinous space between multiple lumbar vertebrae (Fisher et al. 2001).
213 Whereas the average percentage increase in the interspinous space width was relatively
214 slight in this human study, ranging from 7% to 21%, our study demonstrates that cranial
215 extension of the hindlimbs in dogs in right lateral recumbency is able to increase the
216 LSI distance by an average of 67%.

217 The effect of canine size on LSI distance was assessed by examining its association
218 with body weight or the mid-body height of L5. A positive linear relationship was

219 anticipated and, to an extent, observed. The lack of a strong correlation between either
220 of the metrics of canine size and LSI distance suggests that other factors influence
221 individual variation in LSI distance. These might include breed, body condition and age.
222 It is interesting that the strength of correlation improved when the hindlimbs were
223 extended cranially. This suggests that the manner in which the hindlimbs lie in a
224 neutral, unstressed position may itself be a source of variation in LSI distance and that
225 cranial extension of the hindlimbs reduces this variation.

226 The cadaveric nature of our study is an obvious limitation. However, one would
227 expect that alive, anaesthetised dogs should be no harder to position. Indeed, with
228 adequate muscle relaxation, the effect of cranial extension of the hindlimbs on LSI
229 distance might even be slightly greater, an inference supported by the findings of Di
230 Concetto et al. (2012). Unintentional variation in positioning of the hindlimbs, spine or
231 pelvis could have affected individual measurements. However, positioning was always
232 performed by the same two, experienced investigators. Further, an advantage of
233 computed tomography over traditional radiography is that, following multiplanar
234 reconstruction, measurement of the LSI distance was always made at the mid-sagittal
235 plane. The excellent agreement between assessors in this study supports the validity of
236 our approach and findings. However, intra-assessor variability was not assessed. While
237 only right lateral recumbency was assessed in our study, we would not anticipate that
238 the effect of hindlimb position on LSI distance would be any different in left lateral
239 recumbency. Although comprising only a limited number of dogs, the wide range of
240 ages, weights and breeds included (Table S1) means that our findings are likely to be
241 applicable to the majority of canines.

242 Importantly, the finding of an increased LSI distance with cranial extension of the
243 hindlimbs in both sternal and lateral recumbency does not necessarily mean that
244 lumbosacral injection is easier or more likely to be successful in these positions. This is
245 a long-standing assumption within both the veterinary and human literature, but one that
246 should ideally be confirmed with a prospective, randomised, blinded clinical trial.
247 Concealing hindlimb position from the person performing epidural injection could pose
248 a challenge, but should be surmountable. Failure rates of 7% and 16% have been
249 reported for epidural injection in dogs (Heath 1986; Troncy et al. 2002). Although
250 reasonably low, this still suggests that epidural injection is unsuccessful in around one
251 in ten dogs, so simple modifications that may facilitate successful injection are worthy
252 of investigation.

253 A lack of clear superiority of sternal over lateral recumbency supports the
254 conclusion that either is an appropriate position in which to perform lumbosacral
255 injection. It is important to note that foam wedges and sandbags were used to align each
256 dog correctly within the gantry, so as to keep the pelvis and spine parallel to the table as
257 previously described (Puggioni et al. 2006). This is not always performed in a clinical
258 setting and could itself alter the ease of epidural access, irrespective of position or
259 recumbency. In general, the choice of recumbency should be determined based on
260 patient-specific factors and operator preference (Bradley et al. 1980; Naganobu &
261 Hagio 2007; Martinez-Taboada & Redondo 2017). In addition to anatomical or medical
262 considerations that may make lateral recumbency preferable, lightly sedated or
263 conscious dogs may be more easily restrained and positioned on their side. As such,
264 although sternal recumbency is preferred by many, it is important that veterinary

265 anaesthetists are trained in, and capable of, performing lumbosacral injection in both
266 sternal and lateral recumbency.

267 In summary, this canine cadaveric study shows that cranial extension of the
268 hindlimbs in both sternal and lateral recumbency increases the distance between the
269 dorsal lumbosacral laminae to an extent that is both statistically significant and of
270 potential clinical relevance. Our findings support the longstanding recommendation that
271 the hindlimbs are pulled forward when positioning for lumbosacral injection. The small
272 difference in LSI distance found between cranial extension of the hindlimbs in sternal
273 *versus* lateral recumbency, although statistically significant, is of questionable clinical
274 relevance. Therefore, neither recumbency appears to offer inherently superior access to
275 the lumbosacral epidural space when the hindlimbs are cranially extended.

276 **References**

- 277 Adami C, Bergadano A, Spadavecchia C (2013) Limitations of the use of pressure
278 waves to verify correct epidural needle position in dogs. *Vet Med Int* 2013, 159489.
279 doi: 10.1155/2013/159489.
- 280 Boon JM, Abrahams PH, Meiring JH, Welch T (2004) Lumbar puncture: anatomical
281 review of a clinical skill. *Clin Anat* 17, 544–553. doi: 10.1002/ca.10250.
- 282 Bradley RL, Withrow SJ, Heath RB et al. (1980) Epidural analgesia in the dog. *Vet*
283 *Surg* 9, 153–156. doi: 10.1111/j.1532-950X.1980.tb01673.x.
- 284 Brink JA, Heiken JP, Wang G et al. (1994) Helical CT: principles and technical
285 considerations. *Radiographics* 14, 887–893. doi: 10.1148/radiographics.14.4.7938775.
- 286 Campoy L (2004) Epidural and spinal anaesthesia in the dog. *In Practice* 26, 262–269.
- 287 Di Concetto S, Mandsager RE, Riebold TW et al. (2012) Effect of hind limb position on
288 the craniocaudal length of the lumbosacral space in anesthetized dogs. *Vet Anaesth*
289 *Analg* 39, 99–105. doi: 10.1111/j.1467-2995.2011.00676.x.
- 290 Dimaculangan DP, Mazer JA, Maracaja-Neto LF (2016) Sonographic evaluation of
291 lumbar interlaminar space opening in a variety of patient body positions for optimal
292 neuraxial anesthesia delivery. *J Clin Anesth* 34, 159–165. doi:
293 10.1016/j.jclinane.2016.03.045.

- 294 Ertelt K, Turković V, Moens Y (2016) Clinical practice of epidural puncture in dogs
295 and cats assisted by a commercial acoustic puncture assist device-epidural locator:
296 preliminary results. *J Vet Med Educ* 43, 21–25. doi: 10.3138/jvme.1114-112R1.
- 297 Fisher A, Lupu L, Gurevitz B et al. (2001) Hip flexion and lumbar puncture: a
298 radiological study. *Anaesthesia* 56, 262–266. doi: 10.1046/j.1365-2044.2001.01717-4.x.
- 299 Heath RB (1986) The practicality of lumbosacral epidural analgesia. *Semin Vet Med*
300 *Surg (Small Anim)* 1, 245–248.
- 301 Heath RB (1992) Lumbosacral epidural management. *Vet Clin North Am Small Anim*
302 *Pract* 22, 417–419. doi: 10.1016/S0195-5616(92)50655-6.
- 303 Iff I, Moens YPS (2010) Evaluation of extradural pressure waves and the ‘lack of
304 resistance’ test to confirm extradural needle placement in dogs. *Vet J* 185, 328–331.
305 doi: 10.1016/j.tvjl.2009.06.006.
- 306 Jones AR, Carle C, Columb M (2013) Effect of table tilt on ligamentum flavum length
307 measured using ultrasonography in pregnant women. *Anaesthesia* 68, 27–30. doi:
308 10.1111/anae.12006.
- 309 Jones RS (2001) Epidural analgesia in the dog and cat. *Vet J* 161, 123–131. doi:
310 10.1053/tvj.2000.0528.
- 311 Kawalilak LT, Tucker RL, Greene SA (2015) Use of contrast-enhanced computed
312 tomography to study the cranial migration of a lumbosacral injectate in cadaver dogs.
313 *Vet Radiol Ultrasound* 56, 570–574. doi: 10.1111/vru.12264.
- 314 Liotta A, Busoni V, Carrozzo MV et al. (2015) Feasibility of ultrasound-guided
315 epidural access at the lumbo-sacral space in dogs. *Vet Radiol Ultrasound* 56, 220–228.
316 doi: 10.1111/vru.12207.
- 317 Liotta A, Sandersen C, Couvreur T, Bolen G (2016) Technique, difficulty, and accuracy
318 of computed tomography-guided translaminar and transforaminal lumbosacral epidural
319 and intraarticular lumbar facet joint injections in dogs. *Vet Radiol Ultrasound* 57, 191–
320 198. doi: 10.1111/vru.12320.
- 321 Martinez-Taboada F, Redondo JI (2017) Comparison of the hanging-drop technique and
322 running-drip method for identifying the epidural space in dogs. *Vet Anaesth Analg* 44,
323 329–336. doi: 10.1016/j.vaa.2016.03.002.
- 324 Naganobu K, Hagio M (2007) The effect of body position on the ‘hanging drop’
325 method for identifying the extradural space in anaesthetized dogs. *Vet Anaesth Analg*
326 34, 59–62. doi: 10.1111/j.1467-2995.2006.00290.x.
- 327 Puggioni A, Arnett R, Clegg T et al. (2006) Influence of patient positioning on the L5-
328 L6 mid-laminar distance. *Vet Radiol Ultrasound* 47, 449–452. doi: 10.1111/j.1740-
329 8261.2006.00171.x.

- 330 Sandoval M, Shestak W, Stürmann K, Hsu C (2004) Optimal patient position for
331 lumbar puncture, measured by ultrasonography. *Emerg Radiol* 10, 179–181. doi:
332 10.1007/s10140-003-0286-3.
- 333 Schwarz T, Saunders J (2011) *Veterinary Computed Tomography*. Wiley-Blackwell,
334 Chichester, UK, pp. 48–51.
- 335 Troncy E, Junot S, Keroack S et al. (2002) Results of preemptive epidural
336 administration of morphine with or without bupivacaine in dogs and cats undergoing
337 surgery: 265 cases (1997-1999). *J Am Vet Med Assoc* 221, 666–672. doi:
338 10.2460/javma.2002.221.666.
- 339 Valverde A (2008) Epidural analgesia and anesthesia in dogs and cats. *Vet Clin North*
340 *Am Small Anim Pract* 38, 1205–1230. doi: 10.1016/j.cvsm.2008.06.004.
- 341 Viscasillas J, Gregori T, Castiñeiras D et al. (2016) Description and evaluation of four
342 ultrasound-guided approaches to aid spinal canal puncture in dogs. *Vet Anaesth Analg*
343 43, 444–452. doi: 10.1111/vaa.12324.
- 344 Wetmore LA, Glowaski MM (2000) Epidural analgesia in veterinary critical care. *Clin*
345 *Tech Small Anim Pract* 15, 177–188. doi: 10.1053/svms.2000.16545.

346

347 **Figure Legends**

348 **Figure 1** Computed tomography of the lumbosacral junction was performed in four
349 positions. Dogs were placed in sternal recumbency (a,b) with hindlimbs extended
350 caudally (a) or cranially (b). Each dog was also placed in right lateral recumbency (c,d)
351 with hindlimbs in a neutral position (c) or extended cranially (d).

352

353 **Figure 2** The effect of recumbency and hindlimb position on lumbosacral interlaminar
354 (LSI) distance. Sagittal reconstructions with bone window of computed tomography
355 images were produced in four different positions for each dog: sternal recumbency with
356 hindlimbs extended caudally (a) or cranially (b); right lateral recumbency with
357 hindlimbs in a neutral position (c) or extended cranially (d). White arrows indicate the
358 lumbosacral junction. The lines identified by * and † indicate the sites at which the LSI

359 distance and the L5 mid-body height, respectively, were measured. All images are from
360 the same dog. L5, fifth lumbar vertebra; L7, seventh lumbar vertebra; S, sacrum.

361

362 **Figure 3** The effect of cranial extension of the hindlimbs and recumbency on
363 lumbosacral interlaminar (LSI) distance. In sternal (a) or right lateral (b) recumbency,
364 cranial extension of the hindlimbs significantly increases the LSI distance versus control
365 (caudal hindlimb extension (a) and neutral hindlimb position (b)). Comparing cranial
366 extension of the hindlimbs in sternal versus right lateral recumbency (c) reveals a small,
367 but statistically significant, difference in LSI distance.

368

369 **Figure 4** Correlation between L5 mid-body height or body weight and lumbosacral
370 interlaminar (LSI) distance. L5 mid-body height (a,b) and body weight (c,d) correlate
371 only weakly with LSI distance when hindlimbs are in a neutral position (a,c) (as in Fig.
372 1c) and moderately when hindlimbs are extended cranially (b,d) (as in Fig. 1d).

Table 1 Summary descriptive data for 19 dogs comprising the study population

Signalment	Median (range) or number
Age (years)	9 (0.3 - 16)
Sex	female 6 (5 neutered) male 13 (9 neutered)
Weight (kg)	20.4 (1.0 - 34.0)*

*Weight was recorded for 16/19 dogs.

Figure 1

Figure 1. Computed tomography of the lumbosacral junction was performed in four positions. Dogs were placed in sternal recumbency (a,b) with hindlimbs extended caudally (a) or cranially (b). Each dog was also placed in right lateral recumbency (c,d) with hindlimbs in a neutral position (c) or extended cranially (d).

1583x1294mm (72 x 72 DPI)

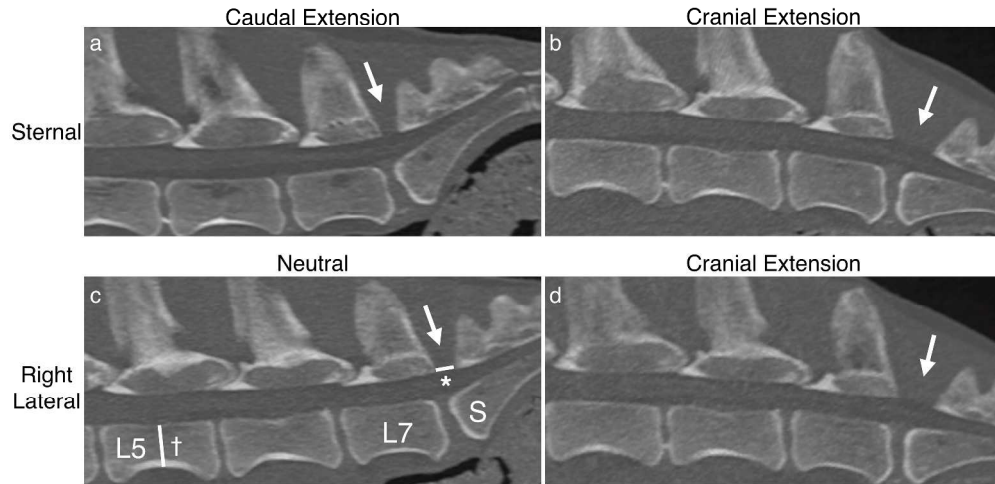
Figure 2

Figure 2. The effect of recumbency and hindlimb position on lumbosacral interlaminar (LSI) distance. Sagittal reconstructions with bone window of computed tomography images were produced in four different positions for each dog: sternal recumbency with hindlimbs extended caudally (a) or cranially (b); right lateral recumbency with hindlimbs in a neutral position (c) or extended cranially (d). White arrows indicate the lumbar-sacral junction. The lines identified by * and † indicate the sites at which the LSI distance and the L5 mid-body height, respectively, were measured. All images are from the same dog. L5, fifth lumbar vertebra; L7, seventh lumbar vertebra; S, sacrum.

1583x886mm (72 x 72 DPI)

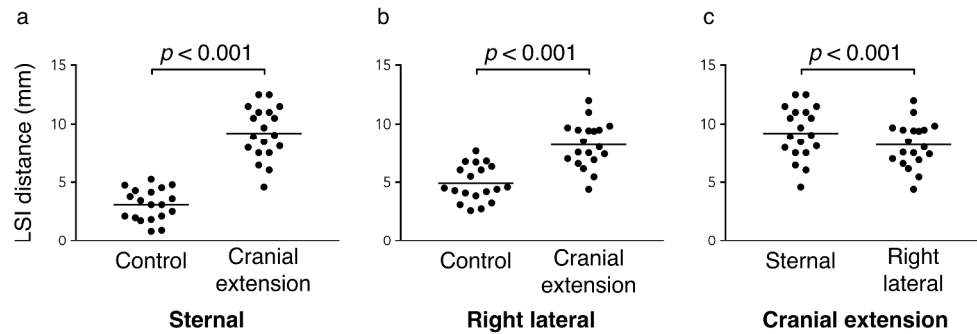
Figure 3

Figure 3. The effect of cranial extension of the hindlimbs and recumbency on lumbosacral interlaminar (LSI) distance. In sternal (a) or right lateral (b) recumbency, cranial extension of the hindlimbs significantly increases the LSI distance versus control (caudal hindlimb extension (a) and neutral hindlimb position (b)). Comparing cranial extension of the hindlimbs in sternal versus right lateral recumbency (c) reveals a small, but statistically significant, difference in LSI distance.

1583x637mm (72 x 72 DPI)

Figure 4

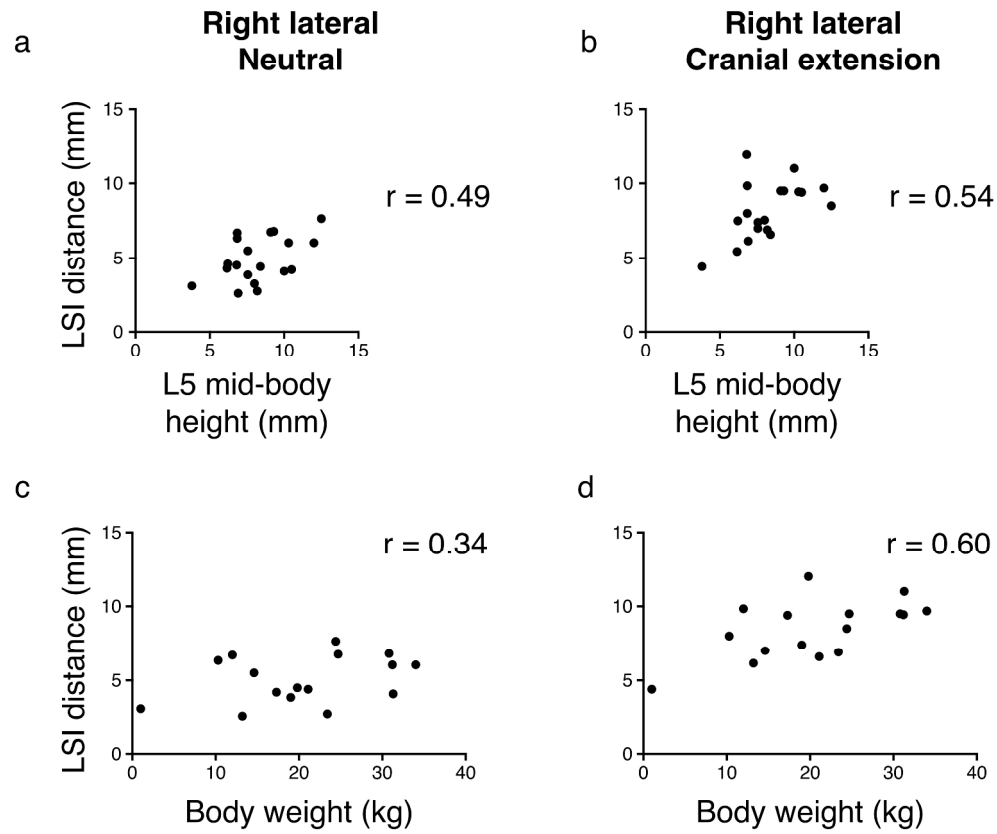


Figure 4. Correlation between L5 mid-body height or body weight and lumbar sacral interlaminar (LSI) distance. L5 mid-body height (a,b) and body weight (c,d) correlate only weakly with LSI distance when hindlimbs are in a neutral position (a,c) (as in Fig. 1c) and moderately when hindlimbs are extended cranially (b,d) (as in Fig. 1d).

1150x1121mm (72 x 72 DPI)