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Ultrasound-guided thoracic paravertebral block: Cadaveric study in foxes (*Vulpes vulpes*)

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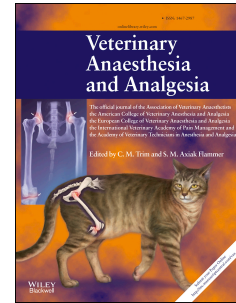
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1 SHORT COMMUNICATION

2 **Ultrasound-guided thoracic paravertebral block: Cadaveric study in foxes (*Vulpes***
3 ***vulpes*)**

4

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14 Running head: US-guided thoracic paravertebral block

15

16 **Abstract**

17 **Objective** To describe an ultrasound guided thoracic paravertebral block in canidae.

18 **Study design** Prospective experimental cadaveric study.

19 **Animals** Twelve thawed fox cadavers

20 **Material and methods** A 15 MHz linear transducer was used to visualise the paravertebral
21 space at the level of the fifth thoracic vertebrae. Iohexol (300 mg mL^{-1}) at 0.2 mL Kg^{-1} was
22 injected into the right and left paravertebral spaces under ultrasound guidance using a Tuohy
23 needle. The needle was advanced in a lateral to medial direction using an in-plane technique.
24 Injections were performed by two operators, each performing twelve injections in six fox
25 cadavers. A thoracic computed tomography was then performed and evaluated by a single
26 operator. The following features were recorded; paravertebral contrast location (yes/no),
27 length of contrast column (number of intercostal spaces), location of contrast relative to the
28 fifth thoracic vertebrae (cranial/caudal/mixed), epidural contrast contamination (yes/no),
29 pleural contrast contamination (yes/no) and mediastinal contrast contamination (yes/no).

30 **Results** All the injections resulted in paravertebral contrast distribution (24/24). The mean
31 length of the contrast column was five intercostal spaces. Contrast spread was caudal to the
32 injection site in 54% (7/24), cranial in 29% (4/24) and mixed in 17% (3/24). Pleural
33 contamination was observed in 50% (12/24) on injections; respectively 42% (10/24) and 4%
34 (1/24) of the injections resulted in mediastinal and epidural contamination.

35 **Conclusions and clinical relevance** Injection of the paravertebral space in canidae is possible
36 using the technique described. Possible complications include epidural, pleural and
37 mediastinal contamination. To establish clinical efficacy and safety of this technique, further
38 studies are required.

39

40 **Keywords** block, local anaesthesia, paravertebral, thoracic, ultrasound

41

42 **Introduction**

43 The thoracic paravertebral space (TPVS) is a wedge shaped space located on either side of the
44 vertebral column. The TPVS is filled with adipose tissue that contains the intercostal nerve,
45 intercostal vessels and the sympathetic trunk (Krediet et al. 2015). The parietal pleura forms
46 the anterolateral boundary. The vertebral body, the intervertebral disc and the intervertebral
47 foramen form the base. The transverse process and the superior costotransverse ligament form
48 the posterior boundary. The endothoracic fascia lies between the parietal pleura anteriorly and
49 the superior costotransverse ligament posteriorly and is attached to the periosteum of the
50 vertebral body (Karmakar & Ho 2007).

51 The endothoracic fascia divides the TPVS into two compartments: an anterior compartment
52 (or extrapleural) and a posterior compartment (also called subendothoracic). The sympathetic
53 ganglion is contained in the anterior compartment. The spinal nerve is positioned in the
54 posterior compartment. The spinal nerves are segmented into small bundles within the TPVS
55 which make them accessible to local anaesthetic solution injected into the TPVS. Thoracic
56 paravertebral (TPVB) involves injecting local anaesthetic alongside the thoracic vertebra
57 close to where the spinal nerves emerge from the intervertebral foramen (Karmakar & Ho
58 2007). Ipsilateral somatic and sympathetic nerve blockade are achieved with the TPVB. In
59 human medicine the main indications for TPVB include breast, thoracic surgery and pain
60 management following thoracic trauma and thoracotomies (Karmakar & Ho 2007). The
61 ultrasound-guided TPVB is a well validated technique in human medicine (Krediet et al 2015)
62 while it has not previously described in veterinary patients.

63 The aim of this descriptive study was to investigate the ultrasound anatomy and a technique to
64 approach to the in canidae patients, define the distribution of the contrast within the TPVS
65 and recognise potential complications.

66

67 **Materials and Methods**

68 Twelve thawed fox (*vulpes vulpes*) cadavers were included in the study. Cadaver foxes were
69 donated by an independent, pest eradication company in accordance with local RVC Ethical
70 approval, (URN 2015 1417).

71 Cadavers were 5.0 ± 1.4 kg with a body condition score between 3 and 4 out of 9 on the
72 World Small Animal Veterinary Association Global Nutrition Committee scale. The TPVBs
73 were performed using a S9v Sonoscape ultrasound machine with a 15MHz linear transducer
74 (Sonoscape, China). Injections were performed by two operators (PM, JV), each operator
75 performing twelve injections in six cadavers.

76
77 Cadavers were positioned in lateral recumbency with the targeted paravertebral space
78 positioned uppermost. The thoracic region was clipped and ultrasonographic gel (Blue
79 ultrasound gel; Henleys Medical, UK) was applied to the skin. The transducer was placed in a
80 transverse orientation adjacent to the dorsal spinous process of the fifth thoracic vertebrae.

81 The transverse process and rib of the fifth thoracic vertebrae were identified and the
82 transducer moved caudally in order to locate the TPVS. The transducer was then positioned
83 parallel to the neck of the rib, oblique to the TPVS (Fig. 1). The TPVS appeared as a wedge-
84 shaped hypoechoic area with hyperechoic boundaries dorsally (intercostal membrane) and
85 ventrally (pleural membrane) (Fig. 1). An epidural 20-gauge, 50 mm Tuohy needle (Pebax
86 catheter, Vygon France) was used for the injections. The needle was advanced into the TPVS
87 in a lateral to medial direction using an in-plane technique. The bevel of the needle was
88 orientated away from the pleura. A decrease in resistance was felt as the needle penetrated the
89 internal intercostal membrane, passing into the TPVS. This was often accompanied by a
90 popping sensation. In order to simulate the antemortem technique, aspiration was performed
91 to help avoid intravascular injection. Ioxol (300 mg mL^{-1}) at 0.2 mL Kg^{-1} (Omnipaque 300,
92 GE Healthcare, Germany) was injected into the right and left paravertebral spaces at the level
93 of the fifth thoracic vertebrae over a 30 second period. Visualization of movement of the

94 pleural membrane during injection was recorded for each subject (yes/no). After rotating the
95 cadaver onto the other side, the technique was repeated on the contralateral side. A thoracic
96 computed tomography (CT) scan was then performed with the cadaver in sternal recumbency.
97 All scans were obtained using a 16-slice MDCT scanner (MX 8000 IDT, Philips Medical
98 Systems, Cleveland, USA). The CT settings were: helical acquisition, slice thickness 3mm,
99 image reconstruction interval 1.5mm, helical pitch 0.688, tube rotation time 0.75s, x-ray tube
100 current 150 mAs, x-ray tube potential 120kVp, matrix 512x512 and medium frequency ('soft
101 tissue') reconstruction algorithm. Scans were performed in a cranial to caudal direction.
102 Images were evaluated using "Bone" windowing (window level 300 window width 1500).
103 The CT scans were reviewed by a single operator (IJ). The following features were recorded;
104 paravertebral contrast location (yes/no), length of contrast column (number of intercostal
105 segments), location of contrast relative to the fifth thoracic vertebrae (cranial/caudal/mixed),
106 pattern of contrast spread (linear/intercostal/cloud) epidural contrast contamination (yes/no),
107 pleural contrast contamination (yes/no), mediastinal contrast contamination (yes/no), contrast
108 contamination of other areas (yes/no).
109 Data was analysed with IBM SPSS Statistic for Windows 21.0 (IBM Corp., NY, USA).
110 Normality was assessed using the Shapiro-Wilk test. Descriptive statistics were used. Means
111 and standard deviations are reported for parametric data.

112 **Results**

113 Movement of the pleural membrane was observed during 100% (24/24) of injections. All
114 injections (24/24) resulted in identification of contrast within the paravertebral space. Linear
115 spread was observed in all subjects (24/24). In 42% (10/24) of subjects, spread was
116 considered to be both linear and intercostal.

117 The mean length of the contrast column was 5.0 ± 1.5 intercostal segments. Contrast spread
118 was caudal to the fifth thoracic vertebrae in 54% (13/24), cranial in 29% (7/24) and mixed in
119 17% (4/24). Half of the injections (12/24) resulted in pleural contamination, 42% (10/24) in

120 mediastinal contamination and 8% (2/24) in epidural contamination. Contamination of other
121 areas was found following 8 % (2/24) of injections, namely the cranial vena cava and right
122 atrium.

123 **Discussion**

124 Various techniques (blind, neurostimulation or ultrasound guided) have been described for
125 TPVB in human anaesthesia (Naja et al. 2004; Cowie et al. 2010; Marhofer et al. 2013). A
126 neurostimulator-guided TPVB has been described in dogs where needle placement was
127 verified by twitching of the intercostal muscles (Portela et al. 2012). This technique was
128 successful in 75% of subjects (Portela et al. 2012). Contrast was identified within the TPVS in
129 100% of foxes using the ultrasound guided technique described here; therefore we suggest
130 that US guided TPVB may be a superior technique.

131 The in-plane technique described allows direct visualization of the needle during its
132 advancement. This is essential as penetration of the intervertebral foramen is a possible
133 complication. The choice of needle is an important consideration. Tuohy needles provide
134 more resistance and thus enhanced perception of tissue firmness. Fifty millimetre needles
135 were most suitable for the foxes used in this study. Short needles may not reach the target
136 while long needles increase the risk of damaging deeper tissues and are more difficult to use.
137 Linear spread was observed after all injections but in 42% of the cases, it was also associated
138 with an intercostal one. A linear pattern of spread may be related to distribution of contrast in
139 the anterior compartment of the TVPS. This would result in blockade of the sympathetic
140 ganglion only. An intercostal spread may be related to distribution of contrast within the
141 posterior compartment. However, we cannot confirm this and further studies are required to
142 investigate the clinical significance of different patterns of distribution (Naja et al. 2004).
143 Previous investigators (Portela et al. 2012) obtained different results. They observed mostly
144 cloud-like rather than linear spread. This difference may have resulted from the technique
145 used to assess the correct position of the needle. Portela and others (2012) identified the

146 TPVS using electro-location and it is plausible to hypothesise that their injections were
147 performed after stimulating the intercostal nerve that is located in the posterior compartment.
148 This is supported by other researchers (Naja et al. 2004), who observed that injections into the
149 posterior compartment were more likely to result in a cloud-like type of spread.
150 The length of the contrast column within the TPVS was 5.0 ± 1.5 intercostal spaces. This is
151 comparable to previous reports in humans (Cowie et al. 2010; Marhofer et al. 2013). Our
152 findings also support the large variation in the distribution of the contrast found in human
153 patients. (Karmakar & Ho 2007; Marhofer et al. 2013). However, it is difficult to predict the
154 relationship between regional spreading of contrast in vitro and the clinical efficacy of
155 injectate in vivo. In most humans, regional local anaesthesia extends beyond the anatomical
156 distribution of the contrast (Marhofer et al. 2013). Therefore, it is not possible to predict
157 potential clinical efficacy based on the regional contrast distribution in cadavers.
158 Contamination of structures other than the TPVS was common using the technique described.
159 Mediastinal contamination occurred following 42% of injections. In humans, mediastinal
160 contamination has never been reported using the technique described. Mediastinal
161 contamination may have occurred because of the close anatomical relationship between the
162 TPVS, the mediastinum and unavoidable post mortem tissue degeneration.
163 Pleural contamination occurred following 50% of injections, which is much higher than that
164 reported in humans (Karmakar & Ho 2007). Tearing of the pleural membrane may lead to
165 leakage of contrast into the pleural space, potentially reducing the efficacy of the injected
166 pharmaceutical (Komatsu et al. 2015). We oriented the bevel of the Tuohy needle tip away
167 from the pleura in an attempt to reduce the risk of penetration (Komatsu et al. 2015).
168 Penetration of the pleural membrane was not observed during any injection using the
169 technique described. As cadaver specimens were used, it is also possible that pleural
170 contamination may have occurred secondary to post mortem change. When the pleura is

171 punctured, current guidelines are to change intercostal space and repeat the block (Komatsu et
172 al. 2015).

173 Contamination of the epidural space following TPVB has been reported in both dogs and
174 humans (Purcell-Jones et al. 1989; Cowie et al. 2010; Portela et al. 2012). The previously
175 described techniques resulted in epidural contamination following 15% of injections (Portela
176 et al. 2012). In humans, the incidence of epidural contamination may be as high as 70%
177 (Purcell-Jones et al. 1989; Cowie et al. 2010). Only 8% of injections resulted in epidural
178 contamination using the technique described. The use of ultrasound to guide needle placement
179 may have reduced the incidence of epidural spreading.

180 Contamination of the caudal vena cava occurred following 8% of injections using the
181 technique described. . Contamination of the systemic venous system has been reported in
182 humans (Purcell-Jones et al. 1989). The internal vertebral venous plexus lies adjacent to the
183 paravertebral space. Blood passes from the internal vertebral venous plexus to the azygos vein
184 and finally into the right atrium (Specchi et al. 2014). Injection of contrast into the internal
185 vertebral venous plexus may have resulted in contamination of the cranial vena cava and right
186 atrium. This finding could represent a major concern because of the intravenous toxicity of
187 local anaesthetics. We were not able to prevent intravascular injection of contrast in our
188 cadaver specimens. In live animals we would recommend aspirating prior to injection of local
189 anaesthetic to check for possible intravascular needle placement. The technique was
190 performed by two operators which may have introduces methodological bias as the study was
191 not designed to evaluate differences between operators.

192 Injections were performed on both sides in each subject prior to CT examination. It was
193 therefore impossible to evaluate potential contralateral spreading of the contrast column
194 (Karmakar & Ho 2007). The technique described here was performed in foxes. Domestic
195 dogs (*Canis lupus familiaris*) and foxes (*Vulpus vulpes*) are of the same Family (Canidae). To
196 the authors' knowledge, no comparative anatomical studies addressing differences between

197 the fox and dog have been performed. The authors are aware that this limitation may limit the
198 potential application of the technique in dogs. However, we suggest that the gross anatomy
199 and ultrasonographic appearance of the TPVS is similar in foxes and dogs and therefore
200 further studies are justified to evaluate the use of this technique in dogs.

201 **Conclusion**

202 Ultrasound-guided TPVB is possible in canidae. The described technique may be suitable for
203 use in the domestic dog. Further studies are needed to evaluate this technique in clinical
204 situations.

205 **Acknowledgements**

206 The authors declare no conflict of interest

207 **Authors' contributions**

208 PM and JV: performed the US-guided thoracic paravertebral blocks; IJ: performed the CT
209 scans and interpreted the images. All the authors contributed to the elaboration of the
210 manuscript.

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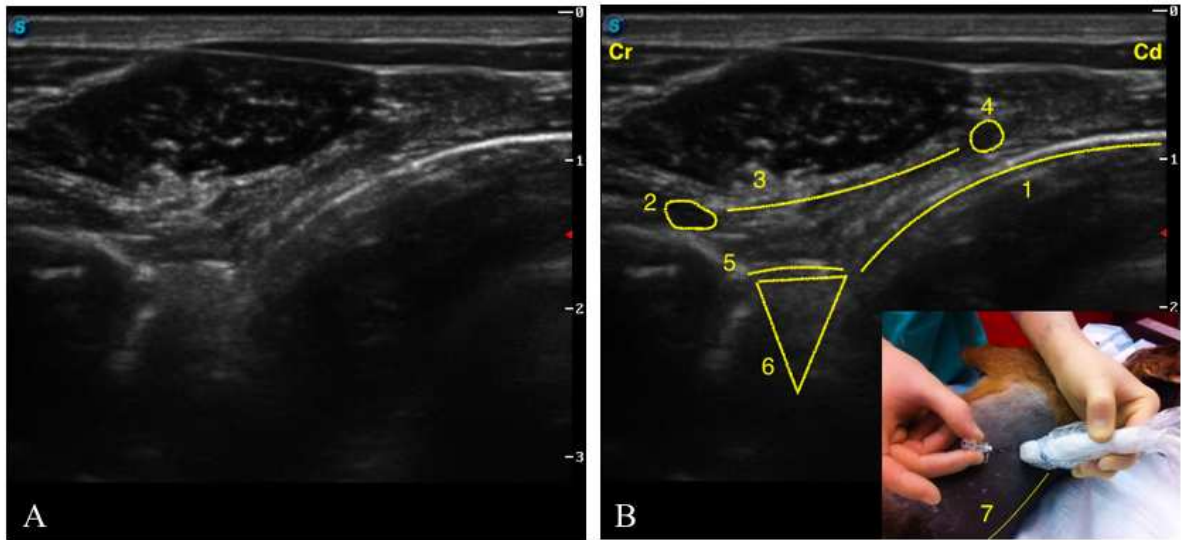
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241 **Figure 1** This picture represents a fox cavader **A.** Ultrasonographic appearance of the thoracic
242 paravertebral space (TPVS). **B.** Ultrasonographic landmarks for the TPVS block. Cr, Cranial;
243 Cd, Caudal; 1, pleura; 2, transverse process of the fifth vertebra; 3, costotransverse ligament;
244 4, fifth rib; 5, internal intercostal membrane; 6, paravertebral space; 7, spine. The picture on
245 the right side represents the fox in lateral recumbency with the positioning of the ultrasound
246 transducer.
247



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