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1   **Results of computed tomography in dogs with suspected wooden foreign bodies**

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8

12   Running head: CT of wooden foreign bodies

13 **Abstract**

14 Detection of wooden foreign bodies in dogs can be challenging. A retrospective, cross-sectional study

15 was done to describe computed tomographic (CT) signs associated with wooden foreign bodies, and to

16 estimate the accuracy of CT for detection of wooden foreign bodies. Patient records and CT images were

17 reviewed of 72 dogs that had a history of suspected stick injury and CT of the affected body part, or

18 possible wooden foreign object reported on CT, and had surgical exploration during the same period of

19 hospitalization. Duration of clinical signs was acute in 48 (67%) dogs and chronic in 24 (33%). Wood was

20 removed from 55 dogs, including a piece of a tree or shrub in 33 (60%) instances, kebab stick in 8 (15%),

21 piece of bamboo garden cane in 2 (4%), cocktail stick in 2 (4%), thorn in 1 (2%), and unidentified wood in

22 the remaining 9 instances. Based on review of CT images with knowledge of the surgical findings,

23 sensitivity of CT for wooden foreign bodies was 79% (95% CI 65-89%), specificity 93% (78-98%), positive

24 likelihood ratio 11.5 (2.9- 44.1), and negative likelihood ratio 0.23 (0.13-0.41). Wooden foreign bodies

25 were predominantly rectangular or linear, with median length 48mm (range 2-270mm), median

26 thickness 3mm (range 1-22mm), and median attenuation 111HU (range $^{-}$344-$^{+}$640HU). A CT finding of

27 gas in soft tissues was significantly associated with acute cases, whereas suspected foreign material,

28 cavitary lesions, fat stranding, and periosteal reaction on adjacent bones were associated with chronic

29 cases.

30   **Introduction**

31   Wooden stick injuries are a well-recognized problem in dogs, frequently occurring because of dogs

32   chasing and retrieving wooden sticks and sustaining oropharyngeal penetration injuries.[1-4]

33   Oropharyngeal stick injuries frequently cause acute signs including pain, blood in the saliva, and

34   dysphagia. In such cases, surgical exploration and lavage of the wound and removal of foreign material

35   usually resolves the problem.[1, 3, 4] When the initial trauma is not recognized or treated and stick injuries

36   become chronic, an abscess and/or discharging sinus may develop.[5-8] Stick foreign bodies can also reach

37   sites distant from the point of penetration by migration through tissues, which complicates diagnosis

38   and management.[9-12] Sticks, wooden fragments and other wooden foreign bodies have been reported in

39   many anatomic sites in dogs, including the orbit, larynx, cervical region, axilla, thorax, abdomen, and

40   limbs.[8, 11-17]

41   Detection of wooden foreign bodies in dogs can be challenging. In dogs with acute oropharyngeal

42   injuries, radiography is indicated to look for gas in tissues, which indicates that perforation of the

43   pharyngeal wall or esophagus has occurred, and retained pieces of wood. More comprehensive imaging

44   may be necessary because of the possibility of retained foreign material in dogs with persistent or

45   recurrent signs of localized infection, unexplained pleuritis or peritonitis, suspected abscess or draining

46   sinus. Radiography[3, 6], sinography[7, 18], ultrasonography[10, 19, 20], computed tomography (CT)[21-26], and

47   magnetic resonance (MR) imaging[6, 23, 27, 28] have been used in dogs with suspected penetrating or

48   migrating foreign bodies. The choice of modality in any individual case will depend on various factors

49   including site of injury, type of suspected foreign body, and availability. In humans with wooden foreign

50   bodies, different reports have emphasized ultrasound[29, 30], CT [31-33] and MR[34] without a clear priority.

51   Computed tomography is preferred in many instances because it enables an efficient, cross-sectional

52   examination of any part of the body with relatively high spatial resolution. In a canine cadaver study,

53   non-contrast CT was more accurate (sensitivity 75%, specificity 96%) than ultrasound or MR imaging for

54   identification of wooden foreign bodies in the manus.[35] Existing reports describe a variety of

55   appearances for wood in CT images, including hypo- or hyperattenuating foci compared to adjacent soft

56   tissues, structures that contain gas or have gas on their surface, with shapes, such as angular or linear,

57   that do not conform to normal anatomy[21-26,35]; however, there is a lack of data regarding the accuracy of

58   CT for wooden foreign bodies in live veterinary patients.

59   The aims of the present study were to describe the clinical and CT signs associated with wooden foreign

60   bodies in a series of dogs, to test the hypothesis that signs differ between acute and chronic cases, and

61   to estimate the accuracy of CT for detection of wooden foreign bodies.

62

63   **Methods**

64   For this retrospective cross-sectional study, computerized patient records at The Queen Mother Hospital

65   for Animals in the period 2005-2015 were searched (by EHWP) for dogs that had a history of suspected

66   stick injury and CT of the affected body part, or possible wooden foreign object reported on CT, and

67   surgical exploration during the same period of hospitalization. Data extracted from records included

68   signalment, history, duration and nature of clinical signs, results of CT, results of surgery, and type of

69   wood retrieved (where known).

70   For the purposes of this study, CT images were reviewed by a board-certified radiologist (CRL) with

71   knowledge of the surgical findings. Images were reviewed using soft tissue (level 50HU, width 350HU)

72   and lung (level -500HU, width 2000HU) windows. Oblique multiplanar reconstructions were used as

73   required on an individual case basis. When suspected foreign material was identified, its maximal short

74   and long axis dimensions were determined using the measuring tool in a proprietary DICOM viewer

75   (Image Viewer Version 4.1, Visbion Ltd, Chertsey, UK) and its attenuation in Hounsfield units (HU) was

76   measured using a hand-drawn region of interest fitted to the cross-section of the object. Within a

77   suspected foreign body, zones of variable density were included in the region of interest, but if a cavity

78   appeared gas-filled because its HU values were comparable to air surrounding the patient, it was not

79   included. The average of three HU measurements was recorded.

80   Clinical data were summarized using median and range. Cases with duration of clinical signs prior to

81   referral <7 days were classified as acute and those with duration of 7 or more days were classified as

82   chronic.[4] Statistical testing was done by CRL. Differences in prevalence of clinical signs in acute versus

83   chronic cases were tested using Fisher's exact test. The difference in median attenuation values of wood

84   found in acute versus chronic cases was tested using the Mann-Whitney test. (SPSS Statistics V22, IBM

85   Corporation, New York, USA). Differences with $p<0.05$ were considered significant. Binomial 95%

86   confidence intervals (CI) for estimates of sensitivity, specificity, positive likelihood ratio (PLR), and

87   negative likelihood ratio (NLR) were determined using the online statistical calculator provided by the

88   Center for Evidence Based Medicine (http://ktclearinghouse.ca/cebm/practise/ca/calculators/statscalc).

89

90   **Results**

91   Records were found of 72 dogs that satisfied the inclusion criteria. No dogs were excluded. There were

92   51 male dogs (35 neutered) and 21 females (17 neutered). The median age of the dogs was 3.9 years

93   (range 9 months-11.9 years). Their median body weight was 25.0kg (range 6.8-50kg). The most

94   prevalent breeds were 20 (28%) Labrador retrievers, 12 (17%) mixed breed, 11 (15%) English Springer

95   Spaniels 7 (10%) Border Collies, and 5 (7%) Staffordshire bull terriers. In addition, there were 1 or 2 dogs

96   of 14 other canine breeds.

97   A single slice helical scanner (PQ5000, Universal Medical Systems, Solon, OH) was used for CT before

98   August 2009 and a 16-slice helical scanner (Mx8000 IDT, Philips, Best, The Netherlands) was used from

99   August 2009. CT settings were optimized for examination of soft tissues. Settings included helical

100   acquisition, slice thickness 2-5mm, 120-250mAs, 120kVp, field of view 240-400mm, matrix 512x512, and

101   medium frequency ('soft tissue') reconstruction algorithm. Pre- and post-contrast CT series were

102   obtained in all patients. For post-contrast series, 2ml/kg of iohexol 300mg/ml (Omnipaque 300, GE

103   Healthcare, Oslo, Norway) was injected intravenously either by hand (for small dogs) or at 2ml/s using a

104   power injector (Stellant, Medrad Inc., Pennsylvania, USA), and the acquisition initiated at 60 seconds

105   after the start of intravenous injection.

106   In 35 (48%) instances the owners reported observing trauma that caused a penetration injury, and in 21

107   (29%) instances a piece of wood had been removed from a wound prior to referral. Duration of clinical

108   signs prior to referral was <7 days in 48 (67%) dogs and 7 or more days in 24 (33%) dogs. In addition to

109   the wound caused by stick entry, which was evident in 35 (49%) dogs, the most prevalent clinical signs

110   were soft tissue swelling in 25 (35%) dogs, signs of pain on palpation in 20 (28%), pyrexia (rectal

111   temperature >39.1C) in 15 (21%) dogs, and lethargy in 8 (11%). Prevalence of clinical signs observed in at

112   least 2 dogs is summarized in table 1. A wound was significantly associated with acute cases (p=0.001),

113   whereas a draining sinus (p=0.01) and vomiting (p=0.03) were significantly associated with chronic

114   cases.

115   Of the 72 dogs included in this study, 50 (69%) had history of trauma and/or clinical signs of a

116   penetrating wound. In these dogs, lesions were found in the cervical region in 20 (40%) dogs, the oral

117   cavity in 12 (24%), pharynx in 12 (24%), thorax in 5 (10%), and inguinal region in 1 (2%). In contrast, in

118   the 22 (31%) dogs with no history of trauma nor clinical signs of a penetrating wound, lesions were

119   found in the abdomen in 10 (46%) dogs, cervical region in 5 (23%), thorax in 4 (18%), pharynx in 2 (9%),

120   and nasal cavity in 1 (5%).

121   Over the course of their veterinary care, wood was removed from 55 dogs, including 21 in which

122   removal was reported to have occurred prior to referral. Wood was identified as a piece of a branch of a

123   tree or shrub in 33 (60%) instances, kebab stick in 8 (15%), piece of bamboo garden cane in 2 (4%),

124   cocktail stick in 2 (4%), thorn in 1 (2%) and was unidentified in the remaining 9 (16%) instances.

125   Evidence of a wooden foreign body was identified in CT images in 36 dogs; however, after CT, fragments

126   of wood or sticks were removed surgically from 43 dogs (including 9 dogs from which another piece of

127   wood had already been removed from a wound prior to referral). Wood was removed surgically from

128   the cervical region in 18 (42%) dogs, pharynx in 7 (16%), peritoneal cavity in 7 (16%), lung in 4 (9%),

129   thoracic wall in 3 (7%), nasal cavity in 1 (2%), stomach in 1 (2%), duodenum in 1 (2%), and inguinal

130   region in 1 (2%). All of the kebab sticks and cocktail sticks were retrieved from the thoracic wall or

131   abdomen.

132   In 2 dogs, a suspected wooden foreign body was identified in CT images but no foreign material was

133   found at exploratory surgery, hence these were classified as false positive results. In one of these dogs,

134   clinical follow-up over a period exceeding 2 years found no persistent or recurrent signs, supporting the

135   conclusion that there was no retained foreign material. The other dog, which had chronic immune-

136   mediated anemia and signs of a wooden foreign body detected unexpectedly at abdominal CT, collapsed

137   and died 4 weeks after discharge, and no necropsy was performed.

138   Classification of CT results with respect to presence/absence of wooden foreign bodies was true positive

139   34, false positive 2, true negative 27, and false negative 9. Sensitivity of CT for wooden foreign bodies

140   was 79% (95% CI 65-89%), specificity was 93% (78-98%), PLR was 11.5 (2.9- 44.1), and NLR was 0.23

141   (0.13-0.41).

142   In CT images, the 34 wooden foreign bodies confirmed as true positives were predominantly rectangular

143   or linear, with their length greatly exceeding their width. The median length of wooden foreign bodies

144   was 48mm (range 2-270mm) and the median thickness was 3mm (range 1-22mm). The median

145   attenuation of wooden foreign bodies was 111HU (range $^{-}$344-$^{+}$640HU). In 6/34 (18%) instances, the

146 foreign material contained linear variations in density compatible with wood structure (Figure 1). A

147 median attenuation value <0HU was observed in CT images of 6 wooden foreign bodies found in acute

148 cases, but in none of the chronic cases. The difference in median attenuation of wooden foreign bodies

149 between dogs with acute versus chronic histories was of borderline statistical significance (p=0.05).

150 CT signs observed in dogs in this series are summarized in table 2. A CT finding of gas in soft tissues was

151 significantly associated with acute cases (p<0.001), whereas suspected foreign material (p<0.001),

152 cavitary lesions (p=0.002), fat stranding (p=0.01), and periosteal reaction on adjacent bones (p=0.01)

153 were significantly associated with chronic cases (Figure 2).

154

155 **Discussion**

156 The predominance of lesions affecting the oral cavity, pharynx and cervical region in dogs with history

157 and/or clinical signs of a traumatic injury in this study corresponds with the belief that stick injuries

158 frequently occur when dogs run onto a stick or collide with a tree or shrub.[1-4] Conversely, the current

159 findings that none of the dogs with sticks in the abdomen had a history of trauma, and that the kebab

160 sticks and cocktail sticks were all retrieved from the thoracic wall or abdomen, suggest that these sticks

161 were ingested, probably because at the time of ingestion they had food attached.[9,11]

162 Just as the etiology of wooden foreign bodies can be divided into penetrating trauma and ingestion, the

163 clinical and imaging findings can be divided into those associated with acute and chronic presentations.[4]

164 Clinical signs of a wound and CT signs of gas in soft tissues were significantly associated with acute

165 cases, whereas a draining sinus and CT findings of cavitary lesions, fat stranding, and periosteal reaction

166 on adjacent bones were significantly associated with chronic cases. Visualization of the wooden foreign

167 body by CT was possible in a larger proportion of chronic cases than acute cases in the present study.

168 This observation may reflect multiple factors, such as removal of obvious penetrating foreign bodies

169   prior to referral for imaging, and the difficulty distinguishing by CT small low-density wood fragments

170   from gas introduced by a penetrating injury. Although not specifically tested in the present study,

171   authors propose that post-contrast CT images would likely be most useful as an aid to detection of

172   cavitary lesions, such as abscess, rather than as a means of detecting foreign material directly, as

173   suggested previously.[22] This suggests that, careful scrutiny of initial, non-contrast CT images is advisable

174   because of the possibility that subsequent contrast accumulation in tissues could obscure a small

175   hyperdense foreign object.

176   Confirmed wooden foreign bodies were found to have a wide range of attenuation values in CT images (⁻

177   344-⁺640HU). This variation likely reflects normal differences in the native density of wood (depending

178   on the plant species, its maturity, and condition prior to entry into the body) and changes that may

179   occur as a result of absorption of body fluids by porous wood.[34,36] Wood with median attenuation value

180   <0HU was observed in CT images of dogs with acute histories, but not in dogs with chronic histories.

181   Although of borderline statistical significance, this difference is compatible with the hypothesis that

182   there is an increase over time in attenuation of wood lodged in tissues.[34,36] When a piece of wood is

183   markedly hyperdense compared to surrounding tissues, it is liable to be recognized easily; however, low-

184   density pieces of wood resemble gas in CT images obtained using a typical soft tissue window, and

185   hence may be missed, particularly in acute cases when a penetrating wound has allowed gas into the

186   tissues.[36] When examining a wound containing gas, use of a wide window is recommended to help

187   distinguish gas from low-density wood fragments.[33, 36, 37] Similarly, use of multiplanar reconstructions

188   aids CT identification of foreign bodies.[26] Even large pieces of wood may be difficult to recognize when

189   orientated obliquely to the image plane (Figure 3).

190   In the present study, the sensitivity of CT for wooden foreign bodies was 79% and specificity was 93%.

191   These results are similar to those of the previously reported canine cadaver study that employed non-

192   contrast CT.[35] PLR was 11.5 and NLR was 0.23 indicating that in a dog with a suspected wooden foreign

193   body, both positive and negative results for CT significantly affect the probability of diagnosis; however,

194   these estimates cannot be considered definitive because of limitations associated with the study design.

195   For example, dogs that did not undergo surgical exploration because foreign body was not considered in

196   the differential diagnosis or not recognized by CT would not be included. This omission would contribute

197   to over-estimation of the sensitivity of CT. Similarly, it is possible that some dogs with wooden foreign

198   bodies were misclassified as negatives because the object was not retrieved surgically. This error would

199   lead to over-estimation of the sensitivity and/or under-estimation of the specificity of CT. Clinical

200   suspicion of foreign material and careful review of the CT images in collaboration with the surgeon

201   should help minimize this error, but will not eliminate it. Images were reviewed with knowledge of the

202   surgical findings in order to ensure optimal search for foreign material, but under this circumstance

203   sensitivity is likely to be higher than when images are reviewed during case management. Based on

204   previous publications, it is clear that CT has a much higher sensitivity than radiography, which fails to

205   demonstrate wooden foreign bodies in many instances.[10,20,29,35] In the present study, direct comparison

206   with sensitivity of other modalities was not possible because few dogs had other imaging studies.

207   On the basis of these findings, CT may be recommended as a technique with moderate sensitivity and

208   high specificity for detection of wooden foreign bodies in dogs following penetrating injury or ingestion.

209

210   **Acknowledgement**

213

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229   Category 3

230   (a) Final Approval of the Completed Article

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321

322 Table 1. Prevalence of clinical signs in dogs with suspected wooden stick foreign bodies[†]

323 Clinical Sign	Number of affected dogs		
324	Acute cases	Chronic cases	Total
325	(n=48)	(n=24)	(n=72)
327 Wound caused by stick entry	31 (65%)[a]	4 (17%)[a]	35 (49%)
328 Soft tissue swelling	17 (35%)	11 (46%)	28 (39%)
329 Pain on palpation	17 (35%)	3 (13%)	20 (28%)
330 Pyrexia	8 (17%)	7 (29%)	15 (21%)
331 Lethargy	4 (8%)	4 (17%)	8 (11%)
332 Dyspnea	4 (8%)	1 (4%)	5 (7%)
333 Tachypnoea	3 (6%)	0	3 (4%)
334 Epistaxis	2 (4%)	0	2 (3%)
335 Inappetence	2 (4%)	2 (8%)	4 (6%)
336 Ptyalism	2 (4%)	1 (4%)	3 (4%)
337 Stiff neck	2 (4%)	0	2 (3%)
338 Retching	2 (4%)	0	2 (3%)
339 Cyanosis	2 (4%)	0	2 (3%)
340 Coughing	1 (2%)	2 (8%)	3 (4%)
341 Draining sinus	0[b]	4 (17%)[b]	4 (6%)
342 Vomiting	0[c]	3 (13%)[c]	3 (4%)
343 Diarrhea	0	2 (8%)	2 (3%)

344 _____

_____

[†] Values with same superscript are significantly different, $p < 0.05$

346   Table 2. Prevalence of CT signs in dogs with suspected wooden stick foreign bodies[‡]

| 347 Sign	Number of affected dogs		
348	Acute cases	Chronic cases	Total
349	(n=48)	(n=24)	(n=72)
350			
351 Gas in soft tissues	46 (96%)[a]	3 (13%)[a]	49 (68%)
352 Soft tissue swelling	21 (44%)	17 (71%)	38 (53%)
353 Enlarged regional nodes	20 (42%)	12 (50%)	32 (44%)
354 Suspected foreign material	16 (33%)[b]	20 (83%)[b]	36 (50%)
355 Pneumothorax	9 (19%)	0	9 (13%)
356 Cavitary lesion	7 (15%)[c]	12 (50%)[c]	19 (26%)
357 Fat stranding	5 (10%)[d]	9 (38%)[d]	14 (19%)
358 Intra-cavity fluid	3 (15%)	3 (50%)	6 (26%)
359 Periosteal reaction	0[e]	4 (17%)[e]	4 (6%)

360   _____

361

[‡] Values with same superscript are significantly different, p<0.05

362 **Legends**
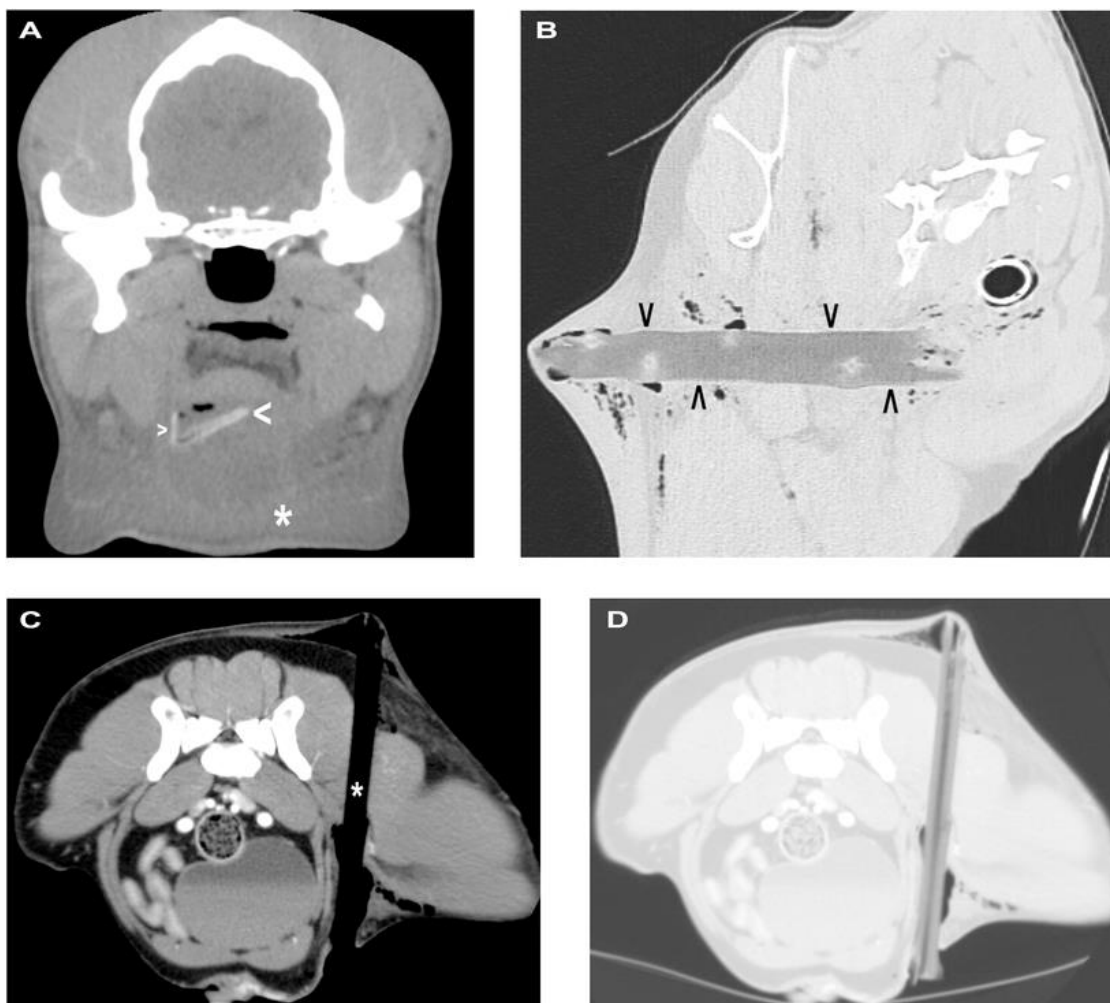
363

364 Figure 1. Examples of the CT appearance of wooden foreign bodies. A) Transverse, non-contrast CT
365 image (level 50HU, width 350HU) showing two relatively dense (110HU) angular wood splinters
366 (arrowheads) lodged in the base of the tongue of a dog with chronic signs of swelling (*), dysphagia, and
367 pyrexia. Foci of gas are visible dorsal to the wood fragments. B) Oblique, non-contrast CT image (level -
368 500HU, width 2000HU) showing a tree branch (between arrowheads) (-342HU) lodged in the axilla
369 following an acute penetrating injury. Multiple small gas foci are present in the adjacent tissues. C)
370 Transverse, post-contrast CT image (level 50HU, width 350HU) of the caudal abdomen showing a well-
371 defined, linear lucent tract through the left gluteal muscles of a dog that had an acute penetrating
372 wound. D) Same image as C displayed using a lung window (level -500HU, width 2000HU). The foreign
373 body (-320HU) is now visible as wood with a low density core. A piece of garden cane was removed
374 surgically.

375
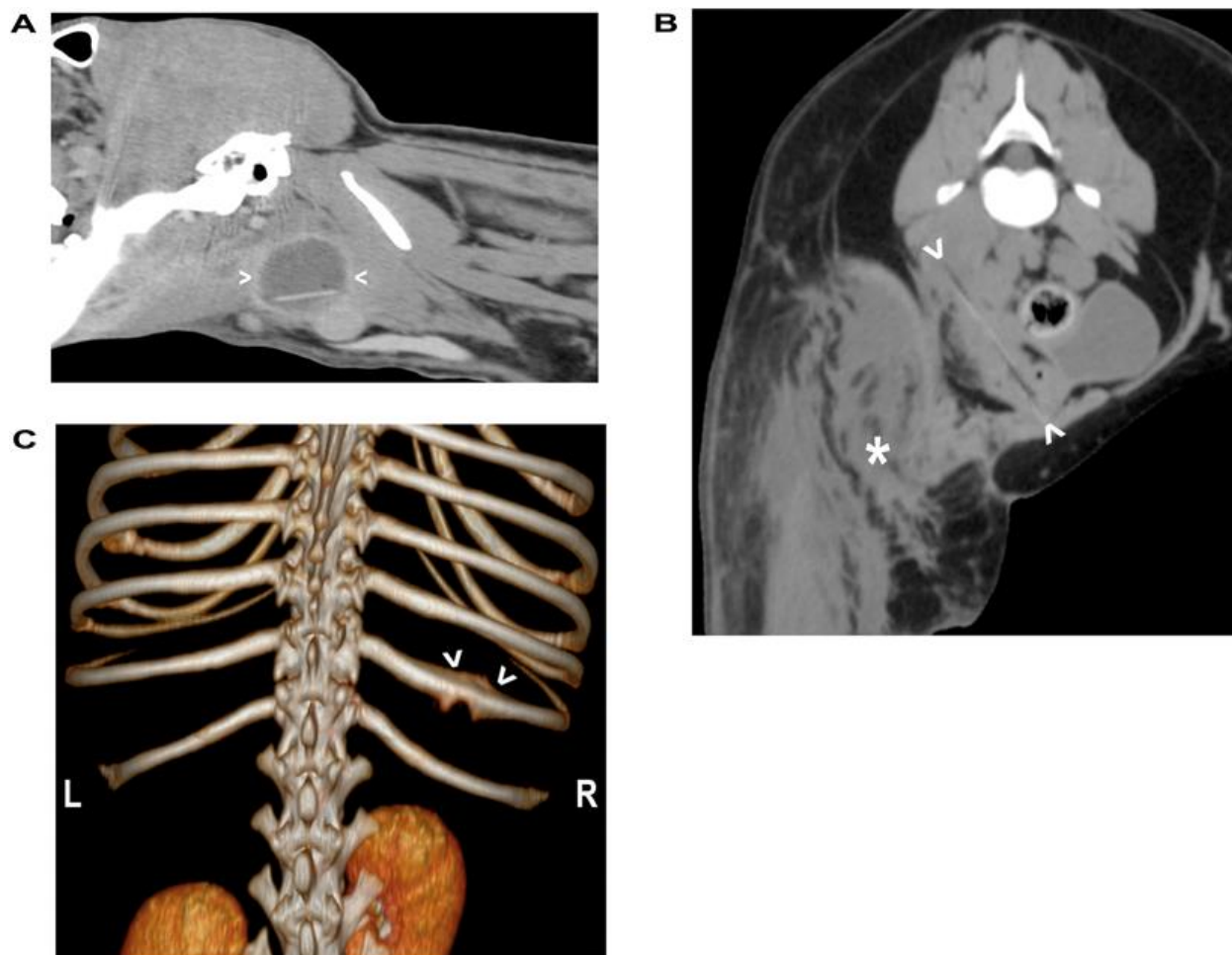
Figure 2. Examples of CT signs associated with chronic wooden foreign bodies in dogs. A) Sagittal, post-contrast CT image (level 50HU, width 350HU) showing an abscess (between arrowheads) surrounding a linear wood fragment (150HU) in the cervical region of a dog with focal painful swelling following suspected oral stick injury 3 weeks previously. B) Transverse, non-contrast CT image (level 50HU, width 350HU) showing marked, diffuse fat stranding (*) affecting the right inguinal region of a dog with acute onset of swelling and right pelvic lameness. A narrow linear foreign body (70HU) and associated gas tract are visible (arrowheads). A kebab stick was removed surgically. C) Surface-rendered, 3-dimensional CT image of the caudal thorax showing a solid, irregular periosteal reaction affecting the right 12th rib in a dog with a chronic draining sinus on the right thoracic wall. A kebab stick was removed surgically from this site. L, left; R, right.
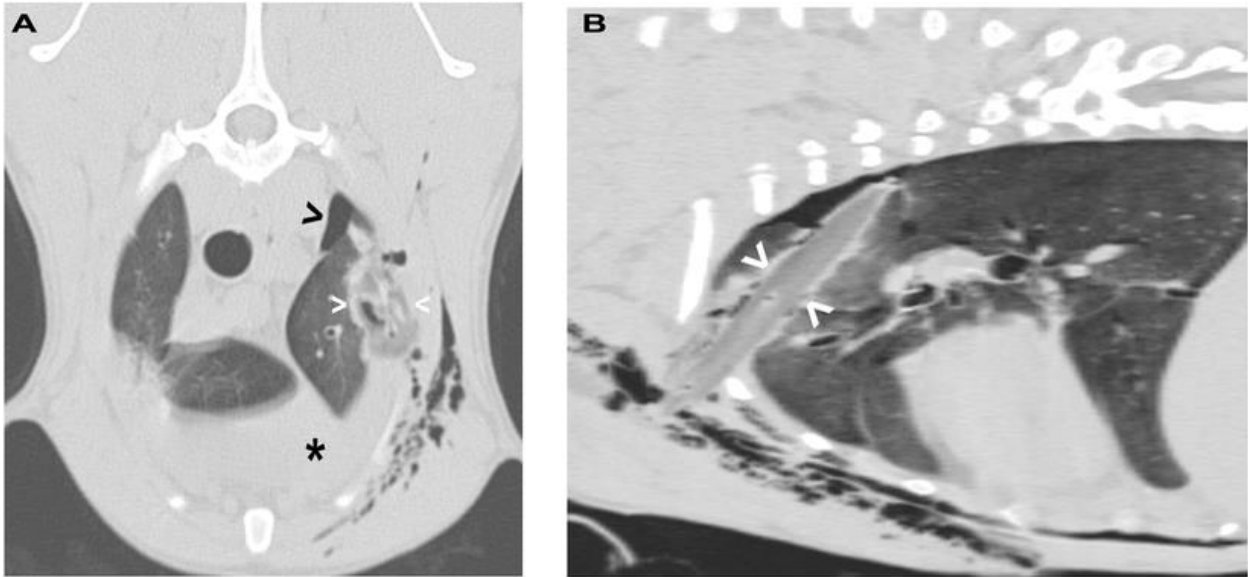
Figure 3. Example of use of multiplanar reconstruction to aid recognition of a large wooden foreign body. A) Transverse image of the cranial thorax of a dog with deep wound in the left axilla shows extensive sub-cutaneous emphysema, a small volume pneumothorax (black arrowhead), pleural fluid (*), and an oblong heterogeneous structure (between white arrowheads) on the lateral aspect of the left lung. The nature of this structure is not evident from this image alone. B) Oblique, approximately sagittal, image of the same dog shows clearly an 88mm long stick (between arrowheads) lodged in the thoracic wall and lung. Level -500HU, width 2000HU for both images.