TITLE: RESULTS OF COMPUTED TOMOGRAPHY IN DOGS WITH SUSPECTED WOODEN FOREIGN BODIES

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Results of computed tomography in dogs with suspected wooden foreign bodies

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Abstract

Detection of wooden foreign bodies in dogs can be challenging. A retrospective, cross-sectional study was done to describe computed tomographic (CT) signs associated with wooden foreign bodies, and to estimate the accuracy of CT for detection of wooden foreign bodies. Patient records and CT images were reviewed of 72 dogs that had a history of suspected stick injury and CT of the affected body part, or possible wooden foreign object reported on CT, and had surgical exploration during the same period of hospitalization. Duration of clinical signs was acute in 48 (67%) dogs and chronic in 24 (33%). Wood was removed from 55 dogs, including a piece of a tree or shrub in 33 (60%) instances, kebab stick in 8 (15%), piece of bamboo garden cane in 2 (4%), cocktail stick in 2 (4%), thorn in 1 (2%), and unidentified wood in the remaining 9 instances. Based on review of CT images with knowledge of the surgical findings, sensitivity of CT for wooden foreign bodies was 79% (95% CI 65-89%), specificity 93% (78-98%), positive likelihood ratio 11.5 (2.9- 44.1), and negative likelihood ratio 0.23 (0.13-0.41). Wooden foreign bodies were predominantly rectangular or linear, with median length 48mm (range 2-270mm), median thickness 3mm (range 1-22mm), and median attenuation 111HU (range $^{-}$344-$^{+}$640HU). A CT finding of gas in soft tissues was significantly associated with acute cases, whereas suspected foreign material, cavitary lesions, fat stranding, and periosteal reaction on adjacent bones were associated with chronic cases.

Introduction

Wooden stick injuries are a well-recognized problem in dogs, frequently occurring because of dogs chasing and retrieving wooden sticks and sustaining oropharyngeal penetration injuries.[1-4] Oropharyngeal stick injuries frequently cause acute signs including pain, blood in the saliva, and dysphagia. In such cases, surgical exploration and lavage of the wound and removal of foreign material usually resolves the problem.[1, 3, 4] When the initial trauma is not recognized or treated and stick injuries become chronic, an abscess and/or discharging sinus may develop.[5-8] Stick foreign bodies can also reach sites distant from the point of penetration by migration through tissues, which complicates diagnosis and management.[9-12] Sticks, wooden fragments and other wooden foreign bodies have been reported in many anatomic sites in dogs, including the orbit, larynx, cervical region, axilla, thorax, abdomen, and limbs.[8, 11-17]

Detection of wooden foreign bodies in dogs can be challenging. In dogs with acute oropharyngeal injuries, radiography is indicated to look for gas in tissues, which indicates that perforation of the pharyngeal wall or esophagus has occurred, and retained pieces of wood. More comprehensive imaging may be necessary because of the possibility of retained foreign material in dogs with persistent or recurrent signs of localized infection, unexplained pleuritis or peritonitis, suspected abscess or draining sinus. Radiography[3, 6], sinography[7, 18], ultrasonography[10, 19, 20], computed tomography (CT)[21-26], and magnetic resonance (MR) imaging[6, 23, 27, 28] have been used in dogs with suspected penetrating or migrating foreign bodies. The choice of modality in any individual case will depend on various factors including site of injury, type of suspected foreign body, and availability. In humans with wooden foreign bodies, different reports have emphasized ultrasound[29, 30], CT [31-33] and MR[34] without a clear priority. Computed tomography is preferred in many instances because it enables an efficient, cross-sectional examination of any part of the body with relatively high spatial resolution. In a canine cadaver study, non-contrast CT was more accurate (sensitivity 75%, specificity 96%) than ultrasound or MR imaging for

identification of wooden foreign bodies in the manus.[35] Existing reports describe a variety of appearances for wood in CT images, including hypo- or hyperattenuating foci compared to adjacent soft tissues, structures that contain gas or have gas on their surface, with shapes, such as angular or linear, that do not conform to normal anatomy[21-26,35]; however, there is a lack of data regarding the accuracy of CT for wooden foreign bodies in live veterinary patients.

The aims of the present study were to describe the clinical and CT signs associated with wooden foreign bodies in a series of dogs, to test the hypothesis that signs differ between acute and chronic cases, and to estimate the accuracy of CT for detection of wooden foreign bodies.

Methods

For this retrospective cross-sectional study, computerized patient records at The Queen Mother Hospital for Animals in the period 2005-2015 were searched (by EHWP) for dogs that had a history of suspected stick injury and CT of the affected body part, or possible wooden foreign object reported on CT, and surgical exploration during the same period of hospitalization. Data extracted from records included signalment, history, duration and nature of clinical signs, results of CT, results of surgery, and type of wood retrieved (where known).

For the purposes of this study, CT images were reviewed by a board-certified radiologist (CRL) with knowledge of the surgical findings. Images were reviewed using soft tissue (level 50HU, width 350HU) and lung (level -500HU, width 2000HU) windows. Oblique multiplanar reconstructions were used as required on an individual case basis. When suspected foreign material was identified, its maximal short and long axis dimensions were determined using the measuring tool in a proprietary DICOM viewer (Image Viewer Version 4.1, Visbion Ltd, Chertsey, UK) and its attenuation in Hounsfield units (HU) was 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

acquisition, slice thickness 2-5mm, 120-250mAs, 120kVp, field of view 240-400mm, matrix 512x512, and medium frequency ('soft tissue') reconstruction algorithm. Pre- and post-contrast CT series were obtained in all patients. For post-contrast series, 2ml/kg of iohexol 300mg/ml (Omnipaque 300, GE Healthcare, Oslo, Norway) was injected intravenously either by hand (for small dogs) or at 2ml/s using a power injector (Stellant, Medrad Inc., Pennsylvania, USA), and the acquisition initiated at 60 seconds after the start of intravenous injection.

In 35 (48%) instances the owners reported observing trauma that caused a penetration injury, and in 21 (29%) instances a piece of wood had been removed from a wound prior to referral. Duration of clinical signs prior to referral was <7 days in 48 (67%) dogs and 7 or more days in 24 (33%) dogs. In addition to the wound caused by stick entry, which was evident in 35 (49%) dogs, the most prevalent clinical signs were soft tissue swelling in 25 (35%) dogs, signs of pain on palpation in 20 (28%), pyrexia (rectal temperature >39.1C) in 15 (21%) dogs, and lethargy in 8 (11%). Prevalence of clinical signs observed in at least 2 dogs is summarized in table 1. A wound was significantly associated with acute cases ($p=0.001$), whereas a draining sinus ($p=0.01$) and vomiting ($p=0.03$) were significantly associated with chronic cases.

Of the 72 dogs included in this study, 50 (69%) had history of trauma and/or clinical signs of a penetrating wound. In these dogs, lesions were found in the cervical region in 20 (40%) dogs, the oral cavity in 12 (24%), pharynx in 12 (24%), thorax in 5 (10%), and inguinal region in 1 (2%). In contrast, in the 22 (31%) dogs with no history of trauma nor clinical signs of a penetrating wound, lesions were found in the abdomen in 10 (46%) dogs, cervical region in 5 (23%), thorax in 4 (18%), pharynx in 2 (9%), and nasal cavity in 1 (5%).

Over the course of their veterinary care, wood was removed from 55 dogs, including 21 in which removal was reported to have occurred prior to referral. Wood was identified as a piece of a branch of a

tree or shrub in 33 (60%) instances, kebab stick in 8 (15%), piece of bamboo garden cane in 2 (4%), cocktail stick in 2 (4%), thorn in 1 (2%) and was unidentified in the remaining 9 (16%) instances.

Evidence of a wooden foreign body was identified in CT images in 36 dogs; however, after CT, fragments of wood or sticks were removed surgically from 43 dogs (including 9 dogs from which another piece of wood had already been removed from a wound prior to referral). Wood was removed surgically from the cervical region in 18 (42%) dogs, pharynx in 7 (16%), peritoneal cavity in 7 (16%), lung in 4 (9%), thoracic wall in 3 (7%), nasal cavity in 1 (2%), stomach in 1 (2%), duodenum in 1 (2%), and inguinal region in 1 (2%). All of the kebab sticks and cocktail sticks were retrieved from the thoracic wall or abdomen.

In 2 dogs, a suspected wooden foreign body was identified in CT images but no foreign material was found at exploratory surgery, hence these were classified as false positive results. In one of these dogs, clinical follow-up over a period exceeding 2 years found no persistent or recurrent signs, supporting the conclusion that there was no retained foreign material. The other dog, which had chronic immune-mediated anemia and signs of a wooden foreign body detected unexpectedly at abdominal CT, collapsed and died 4 weeks after discharge, and no necropsy was performed.

Classification of CT results with respect to presence/absence of wooden foreign bodies was true positive 34, false positive 2, true negative 27, and false negative 9. Sensitivity of CT for wooden foreign bodies was 79% (95% CI 65-89%), specificity was 93% (78-98%), PLR was 11.5 (2.9- 44.1), and NLR was 0.23 (0.13-0.41).

In CT images, the 34 wooden foreign bodies confirmed as true positives were predominantly rectangular or linear, with their length greatly exceeding their width. The median length of wooden foreign bodies was 48mm (range 2-270mm) and the median thickness was 3mm (range 1-22mm). The median attenuation of wooden foreign bodies was 111HU (range $^{-}$344-$^{+}$640HU). In 6/34 (18%) instances, the

foreign material contained linear variations in density compatible with wood structure (Figure 1). A median attenuation value <0HU was observed in CT images of 6 wooden foreign bodies found in acute cases, but in none of the chronic cases. The difference in median attenuation of wooden foreign bodies between dogs with acute versus chronic histories was of borderline statistical significance (p=0.05).

CT signs observed in dogs in this series are summarized in table 2. A CT finding of gas in soft tissues was significantly associated with acute cases (p<0.001), whereas suspected foreign material (p<0.001), cavitary lesions (p=0.002), fat stranding (p=0.01), and periosteal reaction on adjacent bones (p=0.01) were significantly associated with chronic cases (Figure 2).

Discussion

The predominance of lesions affecting the oral cavity, pharynx and cervical region in dogs with history and/or clinical signs of a traumatic injury in this study corresponds with the belief that stick injuries frequently occur when dogs run onto a stick or collide with a tree or shrub.[1-4] Conversely, the current findings that none of the dogs with sticks in the abdomen had a history of trauma, and that the kebab sticks and cocktail sticks were all retrieved from the thoracic wall or abdomen, suggest that these sticks were ingested, probably because at the time of ingestion they had food attached.[9,11]

Just as the etiology of wooden foreign bodies can be divided into penetrating trauma and ingestion, the clinical and imaging findings can be divided into those associated with acute and chronic presentations.[4] Clinical signs of a wound and CT signs of gas in soft tissues were significantly associated with acute cases, whereas a draining sinus and CT findings of cavitary lesions, fat stranding, and periosteal reaction on adjacent bones were significantly associated with chronic cases. Visualization of the wooden foreign body by CT was possible in a larger proportion of chronic cases than acute cases in the present study. This observation may reflect multiple factors, such as removal of obvious penetrating foreign bodies

prior to referral for imaging, and the difficulty distinguishing by CT small low-density wood fragments from gas introduced by a penetrating injury. Although not specifically tested in the present study, authors propose that post-contrast CT images would likely be most useful as an aid to detection of cavitary lesions, such as abscess, rather than as a means of detecting foreign material directly, as suggested previously.[22] This suggests that, careful scrutiny of initial, non-contrast CT images is advisable because of the possibility that subsequent contrast accumulation in tissues could obscure a small hyperdense foreign object.

Confirmed wooden foreign bodies were found to have a wide range of attenuation values in CT images (-344-+640HU). This variation likely reflects normal differences in the native density of wood (depending on the plant species, its maturity, and condition prior to entry into the body) and changes that may occur as a result of absorption of body fluids by porous wood.[34,36] Wood with median attenuation value <0HU was observed in CT images of dogs with acute histories, but not in dogs with chronic histories. Although of borderline statistical significance, this difference is compatible with the hypothesis that there is an increase over time in attenuation of wood lodged in tissues. [34,36] When a piece of wood is markedly hyperdense compared to surrounding tissues, it is liable to be recognized easily; however, low-density pieces of wood resemble gas in CT images obtained using a typical soft tissue window, and hence may be missed, particularly in acute cases when a penetrating wound has allowed gas into the tissues.[36] When examining a wound containing gas, use of a wide window is recommended to help distinguish gas from low-density wood fragments.[33, 36, 37] Similarly, use of multiplanar reconstructions aids CT identification of foreign bodies.[26] Even large pieces of wood may be difficult to recognize when orientated obliquely to the image plane (Figure 3).

In the present study, the sensitivity of CT for wooden foreign bodies was 79% and specificity was 93%. These results are similar to those of the previously reported canine cadaver study that employed non-contrast CT.[35] PLR was 11.5 and NLR was 0.23 indicating that in a dog with a suspected wooden foreign

body, both positive and negative results for CT significantly affect the probability of diagnosis; however, these estimates cannot be considered definitive because of limitations associated with the study design. For example, dogs that did not undergo surgical exploration because foreign body was not considered in the differential diagnosis or not recognized by CT would not be included. This omission would contribute to over-estimation of the sensitivity of CT. Similarly, it is possible that some dogs with wooden foreign bodies were misclassified as negatives because the object was not retrieved surgically. This error would lead to over-estimation of the sensitivity and/or under-estimation of the specificity of CT. Clinical suspicion of foreign material and careful review of the CT images in collaboration with the surgeon should help minimize this error, but will not eliminate it. Images were reviewed with knowledge of the surgical findings in order to ensure optimal search for foreign material, but under this circumstance sensitivity is likely to be higher than when images are reviewed during case management. Based on previous publications, it is clear that CT has a much higher sensitivity than radiography, which fails to demonstrate wooden foreign bodies in many instances.[10,20, 29, 35] In the present study, direct comparison with sensitivity of other modalities was not possible because few dogs had other imaging studies.

On the basis of these findings, CT may be recommended as a technique with moderate sensitivity and high specificity for detection of wooden foreign bodies in dogs following penetrating injury or ingestion.

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321

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

Clinical Sign	Number of affected dogs		
	Acute cases (n=48)	Chronic cases (n=24)	Total (n=72)
Wound caused by stick entry	31 (65%)[a]	4 (17%)[a]	35 (49%)
Soft tissue swelling	17 (35%)	11 (46%)	28 (39%)
Pain on palpation	17 (35%)	3 (13%)	20 (28%)
Pyrexia	8 (17%)	7 (29%)	15 (21%)
Lethargy	4 (8%)	4 (17%)	8 (11%)
Dyspnea	4 (8%)	1 (4%)	5 (7%)
Tachypnoea	3 (6%)	0	3 (4%)
Epistaxis	2 (4%)	0	2 (3%)
Inappetence	2 (4%)	2 (8%)	4 (6%)
Ptyalism	2 (4%)	1 (4%)	3 (4%)
Stiff neck	2 (4%)	0	2 (3%)
Retching	2 (4%)	0	2 (3%)
Cyanosis	2 (4%)	0	2 (3%)
Coughing	1 (2%)	2 (8%)	3 (4%)
Draining sinus	0[b]	4 (17%)[b]	4 (6%)
Vomiting	0[c]	3 (13%)[c]	3 (4%)
Diarrhea	0	2 (8%)	2 (3%)

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

345

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

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

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

Legends

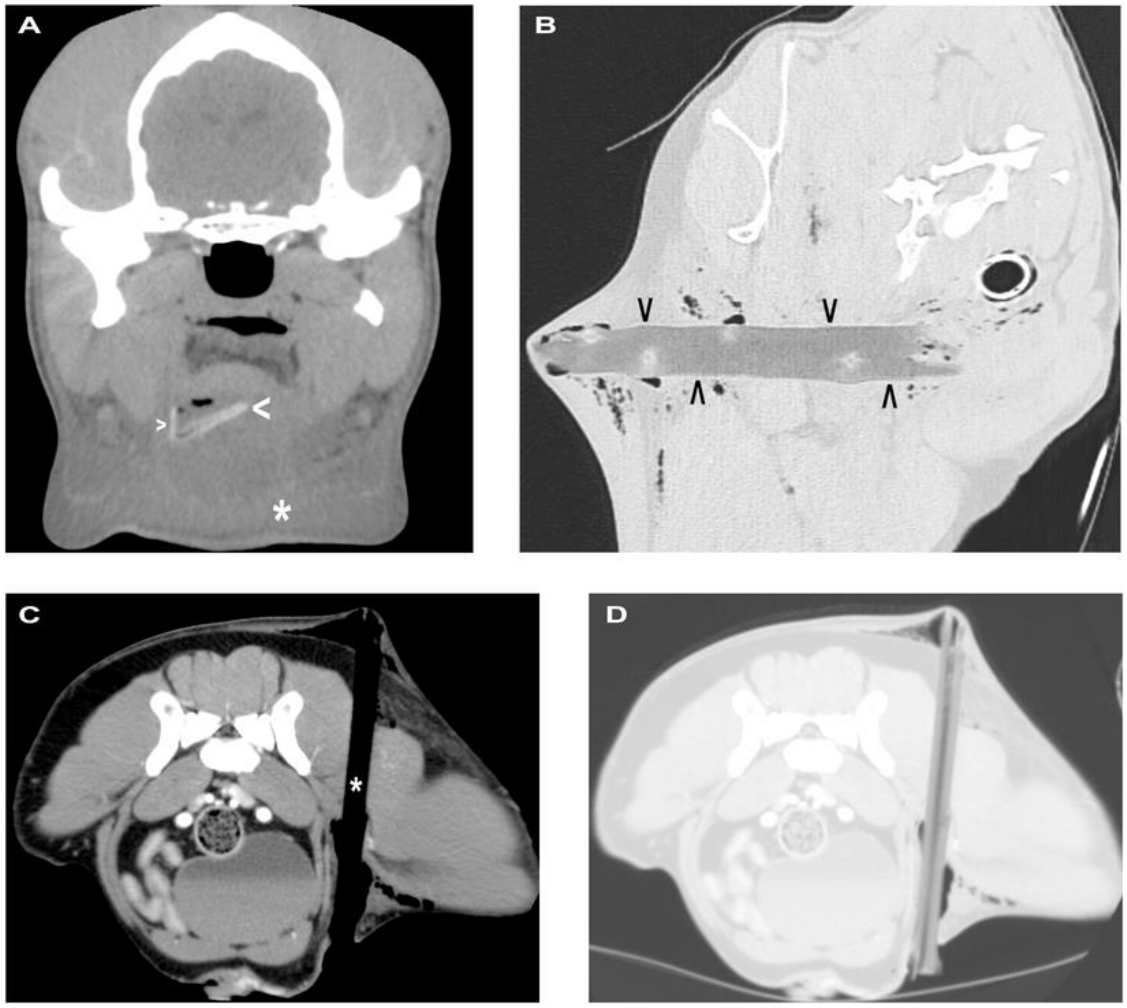

Figure 1. Examples of the CT appearance of wooden foreign bodies. A) Transverse, non-contrast CT image (level 50HU, width 350HU) showing two relatively dense (110HU) angular wood splinters (arrowheads) lodged in the base of the tongue of a dog with chronic signs of swelling (*), dysphagia, and pyrexia.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

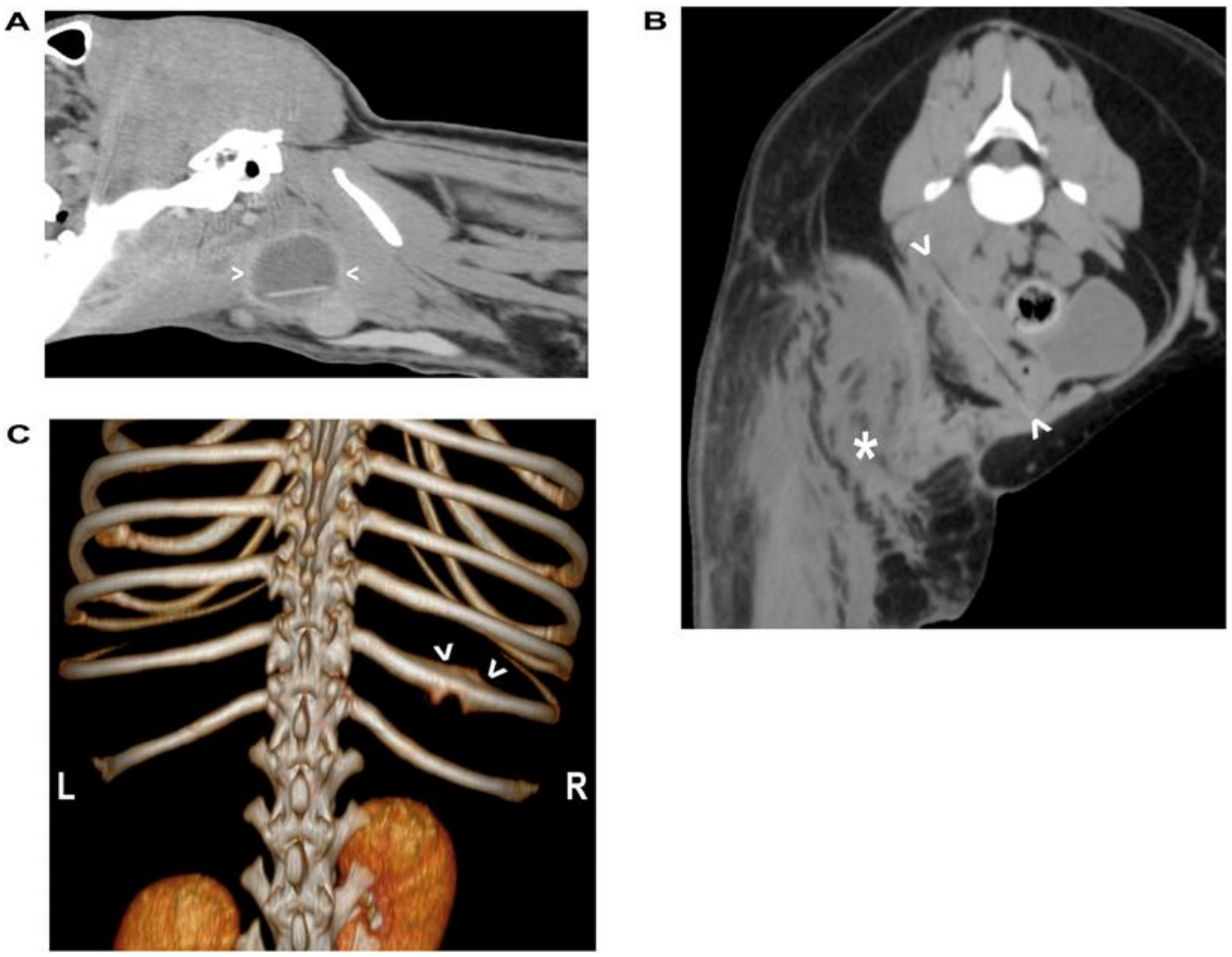

Figure 2. Examples of CT signs associated with chronic wooden foreign bodies in dogs. A) Sagittal, post-contrast CT image (level 50HU, width 350HU) showing an abscess (between arrowheads) surrounding a linear wood fragment (150HU) in the cervical region of a dog with focal painful swelling following 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.

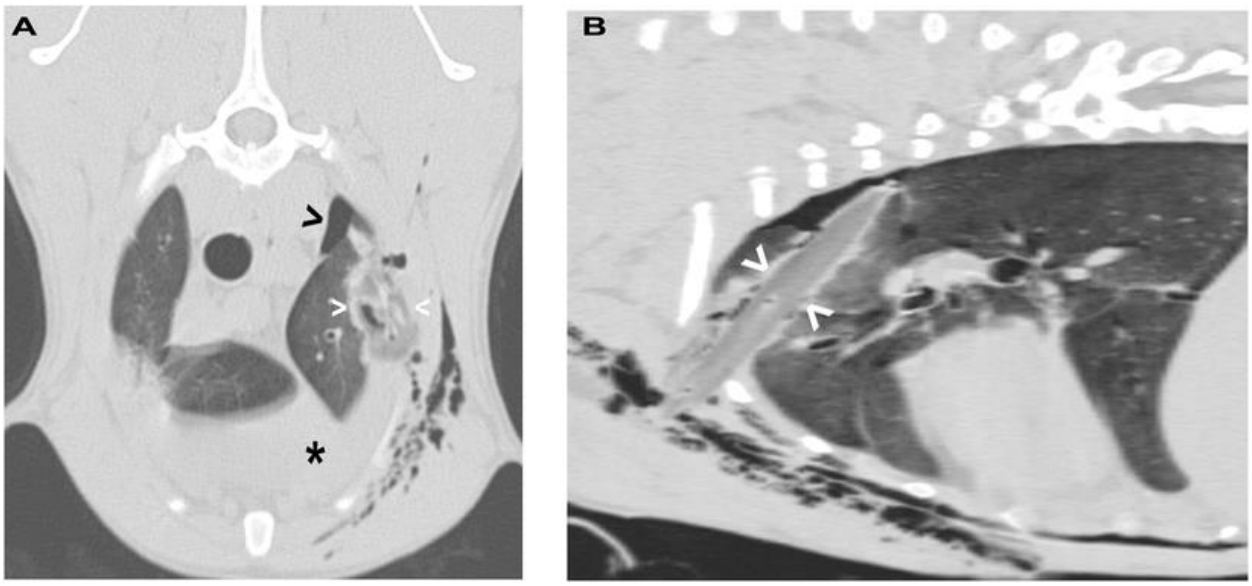

Figure 3. Example of use of multiplanar reconstruction to aid recognition of a large wooden foreign body. A) Transverse image of the cranial thorax of a dog with deep wound in the left axilla shows extensive sub-cutaneous emphysema, a small volume pneumothorax (black arrowhead), pleural fluid (*), and 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.