The Veterinary Journal 241 (2018) 24–30

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Original Article

# Presence of thoracic and lumbar vertebral malformations in pugs with and without chronic neurological deficits

C. Rohdin[a,b,*], J. Häggström[a], I. Ljungvall[a], H. Nyman Lee[c], S. De Decker[d], S. Bertram[d], K. Lindblad-Toh[e,f], K. Hultin Jäderlund[g]

[a] Department of Clinical Sciences, Swedish University of Agricultural Sciences, 75007 Uppsala, Sweden
[b] Anicura, Albano Small Animal Hospital, Rinkebyvägen 21, 182 36 Danderyd, Sweden
[c] Anicura, Bagarmossen Small Animal Hospital, Ljusnevägen 17, 128 48 Bagarmossen, Sweden
[d] Clinical Science and Services, Royal Veterinary College, University of London, Hawkshead Lane, AL9 7TA, North Mymms, UK
[e] Science for Life Laboratory, Department of Medical Biochemistry and Microbiology, Uppsala University, 751 23 Uppsala, Sweden
[f] Broad Institute of Harvard and Massachusetts Institute of Technology, Cambridge, MA, USA
[g] Department of Companion Animal Clinical Sciences, Norwegian University of Life Sciences, 0033 Oslo, Norway

ARTICLE INFO

*Article history:*
Accepted 11 September 2018

*Keywords:*
Caudal articular processes
CT
Hemivertebrae
Myelopathy
Transitional vertebrae

ABSTRACT

Congenital vertebral malformations (CVMs) are common in brachycephalic dogs such as the pug, and are often considered incidental findings. However, specific CVMs have been suggested to be associated with neurological deficits in pugs. The objective of this study was to investigate the clinical importance of CVMs in the pug by comparing computed tomography studies of the thoracolumbar spine from pugs without neurological deficits with those from pugs with a confirmed T3-L3 spinal cord lesion and neurological deficits consistent with a chronic T3-L3 myelopathy.

A total of 57 pugs were recruited into the study from Sweden ($n = 33$), United Kingdom ($n = 21$) and Norway ($n = 3$); 30 with neurological deficits and 27 without. Focal T3-L3 pathology was confirmed in all pugs with neurological deficits by magnetic resonance imaging ($n = 29$) and/or pathology ($n = 15$). Computed tomography studies of the thoracolumbar spine from pugs with and without neurological deficits were compared to investigate possible associations between presentation of neurological deficits consistent with chronic T3-L3 pathology and signalment variables, presence of CVMs and type of CVMs. Congenital vertebral malformations were as common in pugs with, as in pugs without, neurological deficits. Regardless of neurological status, the majority of pugs (96%) presented with one or more CVM. An association between presence, or type of CVM in the T1-L3 vertebral column, and neurological deficits consistent with T3-L3 pathology could not be confirmed.



## Introduction

Congenital vertebral malformations (CVMs) are common in brachycephalic dogs such as the pug, and include hemivertebrae, spina bifida, block vertebrae, transitional vertebrae and hypoplasia or aplasia of the caudal articular processes (CAPs) (Fisher et al., 2013; Gutierrez-Quintana et al., 2014; Bouma, 2016; Ryan et al., 2017; Bertram et al., 2018). Vertebral malformations in dogs are often considered incidental findings (Morgan, 1968; Guevar et al., 2014), but have been described clinically important in the pug (Done et al., 1975; Bailey and Morgan, 1992; Aikawa et al., 2007; Fisher et al., 2013; Charalambous et al., 2014; Faller et al., 2014; Bouma, 2016; Mathiesen et al., 2018). A specific type of CVM, hemivertebra, has been suggested to be associated with neurological deficits more often in pugs compared to other brachycephalic breeds like French and English bulldogs (Ryan et al., 2017).

Neurological signs related to CVMs are considered the consequence of vertebral canal stenosis and/or instability resulting in a focal myelopathy (Gutierrez-Quintana et al., 2014) during adolescence or adulthood (Aikawa et al., 2007; Westworth and Sturges, 2010; Moissonnier et al., 2011). Commonly, but not exclusively, CVMs are found in the thoracic area (Dewey et al., 2016; Ryan et al., 2017). Hence neurological dysfunction caused by CVMs most often present as a T3-L3 myelopathy; spastic and/or upper motor neuron (UMN) paraparesis and pelvic limb proprioceptive deficits (de Lahunta and Glass, 2009; Dewey et al., 2016). Anatomically, the neurological deficits from a T3-L3 myelopathy could theoretically correspond to any CVM in the T1-L3 area of the vertebral column (Evans, 1993). Gait abnormalities, with the majority indicating neurological causes, have been shown

* Corresponding author.
*E-mail address:* Cecilia.rohdin@slu.se (C. Rohdin).

https://doi.org/10.1016/j.tvjl.2018.09.008
1090-0233/

common in the pug (Rohdin et al., 2018), but the importance of CVMs in the development of these is not fully elucidated.

Published studies on CVMs in pugs consist of case reports, each describing a single type of CVM, lacking an objective and comprehensive overview of their clinical importance. The aim of this study was to investigate the clinical importance of CVMs in the pug by comparing computed tomography (CT) studies of the thoracolumbar spine from pugs without neurological deficits with those from pugs consistent with neurological deficits from a confirmed T3-L3 spinal cord lesion.

## Materials and methods

Dogs were eligible for participation in the study provided the owner had given informed consent and ethical approvals required for the study been obtained (Animal Ethics Committee of Sweden, Uppsala djurförsöksetiska nämnd; Approval Number C202/2014; Approval date 30 January 2015). Information retrieved from the medical records included neurological status, sex, age at onset of neurological signs and age at examination. Part of the included pugs were involved in another study (Ryan et al., 2017).

Thirty pugs with and 27 pugs without neurological deficits were included in the study. Of the 30 pugs (20 males and 10 females; median age at onset of clinical signs 88 months; IQR 67–96 months) with neurological deficits, 27 were included in Sweden and three in Norway. Of the 27 (13 males and 14 females; median age at examination 82 months; IQR 52–114) without neurological deficits, 21 were included in the UK and six in Sweden. A CT scan of the entire thoracic and lumbar vertebral column was performed in 56 pugs. In one pug without neurological deficits the study was limited to the thoracic and first three lumbar vertebrae.

### *Pugs with neurological deficits*

Client-owned pugs with neurological deficits were admitted for neurological evaluation at Anicura Albano Animal Hospital, Danderyd, at the University Animal Hospital, Uppsala, Sweden and at the Norwegian University of Life Sciences, Oslo, Norway, between 2014–2017. Inclusion criteria were signs of a chronic (>1 month's duration) spastic and/or UMN paraparesis and pelvic limb proprioceptive deficits, with focal T3-L3 spinal cord pathology (FSCP) confirmed by magnetic resonance imaging (MRI) and/or pathology. The pugs were recruited consecutively. No pugs were excluded due to lack of confirmed FSCP. Signs of other significant organ related or systemic disease excluded participation.

Focal spinal cord pathology was defined as any focal compressive spinal cord lesion and/or focal intramedullary T2W hyperintensity on MRI, confirmed in sagittal and transversal planes, or as an extensive focal loss of nervous tissue on histopathology. An external board certified diagnostic radiologist (VetImaging of New York, USA and Section for Radiology, Oslo, Norway) reviewed the MRI studies. Histopathological evaluation of the entire central nervous system was performed by a board certified pathologist (Institute for Pathology, Tierärztliche Hochschule Hannover and Section of Clinical and Comparative Neuropathology, Centre for Clinical Veterinary Medicine, Ludwig-Maximilians-University Munich). All pugs with neurological deficits had a neurological examination performed by a board-certified neurologist prior to imaging.

### *Pugs without neurological deficits*

Pugs without neurological deficits were retrospectively selected from the case records (all part of a brachycephalic obstructive airway study) at the Royal Veterinary College University of London, UK, and prospectively from Anicura Albano Animal Hospital, Sweden.

In order to confirm a normal neurological status, included dogs, with no historical documented neurological abnormalities, had a neurologic examination performed prior to CT examination, those from the UK by a board certified surgeon and those from Sweden by a board certified neurologist.

### *Computed tomography*

Computed tomography (CT) of the thoracolumbar vertebral column of pugs examined in Sweden was performed under general anaesthesia ($n = 23$) or immediately post-mortem ($n = 13$) with a dual slice CT scanner (Siemens, Somatom); 2 mm slice thickness ($n = 32$), or a 64 slice CT scanner (Siemens, Somatom); 2 mm slice thickness ($n = 1$). Computed tomography of pugs examined in the UK ($n = 21$) and Norway ($n = 3$) were performed under sedation or general anaesthesia with a 16 slice helical CT scanner (PQ 500, GE healthcare); 2 mm slice thickness, or a 128 slice CT scanner (Siemens, Somatom); 0.625 mm slice thickness.

After completion of the axial CT study, sagittal, dorsal and three-dimensional (3D) reconstructions were made. The studies of pugs examined in the UK were reconstructed with a soft tissue algorithm while the CT studies of pugs examined in Sweden and Norway were reconstructed with a soft tissue and a bone algorithm using medium and high frequency reconstruction algorithms. A standard image archiving and communication system software (Osirix foundation, V.5.5.2) was used to evaluate all images.

All CT examinations were independently reviewed by two board certified diagnostic radiologists; one of the authors and an external reviewer (VetImaging of NewYork, USA). The observers were not entirely blinded to the neurological status of all dogs. Results from the two radiologists were compared, and in cases of disagreement, images were re-evaluated before the final decision was taken by one of the observers radiologists and authors. The interobserver agreement was determined for the evaluation of the CVMs. Due to differences in resolution between studies (Fig. 1), as a result of type of acquisition, the CAPs cranial to the 8th thoracic vertebrae were not evaluated.

For each CT study, the number of thoracic and lumbar vertebrae was recorded and each vertebra was assessed for the presence of hemivertebrae, associated kyphosis, block vertebrae, spina bifida, transitional vertebrae and hypoplasia or aplasia of the CAPs. When the hemivertebrae caused kyphosis the Cobb angle was calculated. Presence of spondylosis and any other acquired vertebral column abnormality, e.g. intervertebral disc disease (IVDD) was described. In addition to comparing the CT variables between *all* pugs with and without neurological deficits, the CT variables were also compared between two contrasting groups of pugs <12 months ($n = 3$) and ≥90 months ($n = 25$) of age with neurological deficits, to pugs without neurological deficits.

Hemivertebra was defined as any defect in vertebral body formation as outlined by Gutierrez-Quintana (Gutierrez-Quintana et al., 2014). The Cobb angle was determined as described by Guevar (Guevar et al., 2014). Block vertebrae was defined as failure of vertebral segmentation with absence of the intervertebral disc space between two adjacent vertebral bodies (Westworth and Sturges, 2010) and spina bifida as incomplete closure of the vertebral arches resulting in a cleft through the dorsal spinous process (Westworth and Sturges, 2010). Transitional vertebrae

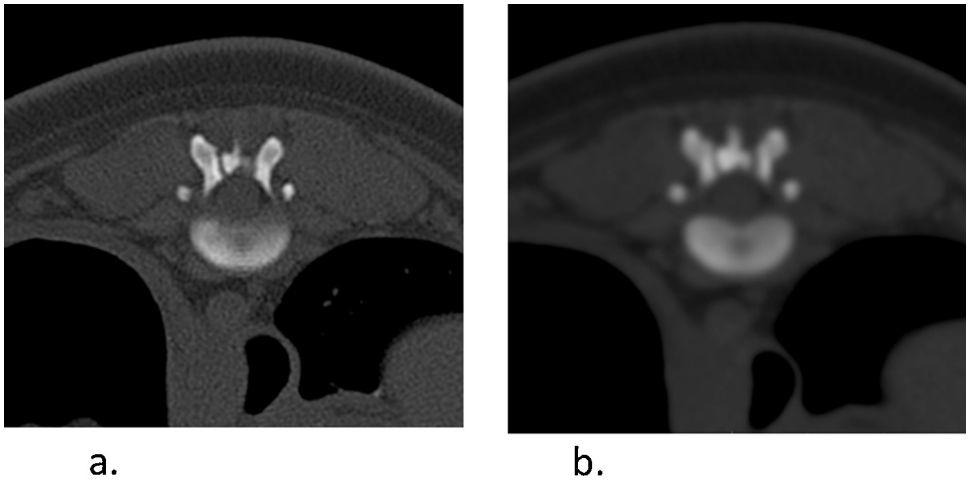


**Fig. 1.** Computed tomography images of the same pug at the identical level of the vertebral column reconstructed with a bone algorithm (a) and with a soft tissue algorithm using a bone window (b).