



## Original Article

## Vertebral formula and congenital abnormalities of the vertebral column in rabbits

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## ARTICLE INFO

## Article history:

Accepted 23 April 2018

## Keywords:

Congenital anomaly  
Rabbit  
Radiography  
Spine  
Transitional vertebra

## ABSTRACT

The aim of this retrospective study of 330 rabbits (164 males, 166 females) was to determine different vertebral formulas and prevalence of congenital vertebral anomalies in rabbits from radiographs of the cervical (C), thoracic (Th), lumbar (L) and sacral (S) segments of the vertebral column. The number of vertebrae in each segment of vertebral column, position of anticlinal vertebra and localisation and type of congenital abnormalities were recorded. In 280/330 rabbits (84.8%) with normal vertebral morphology, seven vertebral formulas were identified: C7/Th12/L7/S4 (252/330, 76.4%), C7/Th12/L6/S4 (11/330, 3.3%), C7/Th13/L7/S4 (8/330, 2.4%), C7/Th12/L7/S5 (4/330, 1.2%), C7/Th12/L8/S4 (3/330, 0.9%), C7/Th12/L7/S6 (1/330, 0.3%) and C7/Th11/L7/S4 (1/330, 0.3%). The anticlinal vertebra was identified as Th10 in 56.4% of rabbits and Th11 in 42.4% of rabbits. Congenital spinal abnormalities were identified in 50/330 (15.2%) rabbits, predominantly as a single pathology ( $n=44$ ). Transitional vertebrae represented the most common abnormalities ( $n=41$  rabbits) in the thoracolumbar ( $n=35$ ) and lumbosacral segments ( $n=6$ ). Five variants of thoracolumbar transitional vertebrae were identified. Cervical butterfly vertebrae were detected in three rabbits. One rabbit exhibited three congenital vertebral anomalies: cervical block vertebra, thoracic hemivertebra and thoracolumbar transitional vertebra. Five rabbits exhibited congenital vertebral abnormalities with concurrent malalignment, specifically cervical kyphosis/short vertebra ( $n=1$ ), thoracic lordoscoliosis/thoracolumbar transitional vertebrae ( $n=1$ ), thoracic kyphoscoliosis/wedge vertebrae ( $n=2$ ) and thoracolumbar lordoscoliosis/thoracolumbar transitional vertebrae/lumbosacral transitional vertebrae ( $n=1$ ). These findings suggest that vertebral columns in rabbits display a wide range of morphologies, with occasional congenital malformations.

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## Introduction

Interventional diagnostic procedures and pathologies of the vertebral column, potentially requiring surgery, have been described in pet rabbits (*Oryctolagus cuniculus*) (Whittington and Bennett, 2011; Gasper et al., 2014; Meredith and Richardson, 2015); however, various numbers of vertebrae in rabbits have been described and different vertebral formulas have been published (Greenaway et al., 2001; Narita and Kuratani, 2005; Capello and Lennox, 2008; Reese and Fehr, 2011). Most commonly, textbooks publish the following vertebral formula: C7, Th12–13, L6–L7, S4 and

Cd15–16, but information about the frequency of variations in vertebral formulas and position of anticlinal vertebra, which can be used as a point of reference in diagnostic imaging studies, is lacking (Capello and Lennox, 2008; Reese and Fehr, 2011; Vella and Donnelly, 2012). Similarly, while congenital abnormalities of the vertebral column, such as transitional vertebrae, hemivertebrae, wedge vertebrae, block vertebrae, atlantoaxial malformations and spina bifida have been recognised (Newitt et al., 2008; Westworth and Sturges, 2010), and their prevalence described in dogs, cats and ferrets (Morgan, 1968; Newitt et al., 2008; Proks et al., 2015), few studies exist detailing these in rabbits. Congenital vertebral anomalies in rabbits include spina bifida, hemivertebrae and thoracic vertebra with asymmetrical or rudimentary ribs (Crary et al., 1966; Greenaway et al., 2001; Hunt, 2014); scoliosis, lordosis and kyphosis have been described as both congenital and acquired diseases (Drescher and Loeffler, 1996).

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**Table 1**  
Breed distribution of rabbits included in this study (n = 330).

Breed	Number	Vertebral formula	Number with each vertebral formula	Number with congenital anomalies
Giant breeds	2			
Flemish Giant	1	C7/Th12/L7/S4	1	0
Moravian Blue	1	C7/Th13/L7/S4	1	0
Large breeds	3			
English Lop	1	C7/Th12/L7/S5	1	0
French Lop	1	C7/Th12/L7/S4	1	0
Silver Fox	1	C7/Th13/L7/S4	1	0
Medium breeds	293			
Mixed breed	243	C7/Th11/L7/S4	1	33
		C7/Th12/L7/S6	1	
		C7/Th12/L6/S4	5	
		C7/Th13/L7/S4	4	
		C7/Th12/L7/S5	2	
		C7/Th12/L8/S4	2	
		C7/Th12/L7/S4	195	
Czech Spot	12	C7/Th12/L6/S4	1	3
		C7/Th13/L7/S4	1	
		C7/Th12/L8/S4	1	
		C7/Th12/L7/S4	6	
Big Marten	8	C7/Th12/L6/S4	1	1
		C7/Th12/L7/S5	1	
		C7/Th12/L7/S4	5	
Havana	9	C7/Th12/L6/S4	1	1
		C7/Th12/L7/S4	7	
Smoke Pearl	7	C7/Th12/L6/S4	1	0
		C7/Th12/L7/S4	6	
Siamese Sable	5	C7/Th13/L7/S4	1	0
		C7/Th12/L7/S4	4	
Silver Little	9	C7/Th12/L6/S4	1	1
		C7/Th12/L7/S4	7	
Small breeds	32			
Netherland Dwarf	7	C7/Th12/L7/S4	4	3
Mini Lop	13	C7/Th12/L6/S4	1	5
		C7/Th12/L7/S4	7	
Mini Lionhead	7	C7/Th12/L6/S4	1	3
		C7/Th12/L7/S4	3	
Mini Satin	5	C7/Th12/L7/S4	5	0
Total	330		280	50

In this study, we sought to estimate the prevalence of different vertebral formulae of the axial skeleton in rabbits, to determine the position of anticlinal vertebra and to evaluate the radiographic prevalence of congenital vertebral anomalies in this species.

**Table 2**  
Frequency (%) of different formulas of the vertebral column and anticlinal vertebra in rabbits included in this study (n = 330).

Vertebral formula	Female	Male	Total	Anticlinal vertebra				
				Th10 <sup>a</sup>	Th11 <sup>a</sup>	Th10 <sup>b</sup>	Th11 <sup>b</sup>	Not established
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Thoracolumbar variants								
C7/Th11/L7/S4	1 (0.3)	0	1 (0.3)	0	0	0	1 (0.3)	0
C7/Th12/L6/S4	5 (1.5)	6 (1.8)	11 (3.3)	8 (2.4)	3 (0.9)	0	0	0
C7/Th12/L7/S4	132 (40)	120 (36.4)	252 (76.4)	156 (47.3)	32 (9.7)	1 (0.3)	63 (19.1)	0
C7/Th12/L8/S4	1 (0.3)	2 (0.6)	3 (0.9)	1 (0.3)	1 (0.3)	0	1 (0.3)	0
C7/Th13/L7/S4	5 (1.5)	3 (0.9)	8 (2.4)	3 (0.9)	5 (1.5)	0	0	0
Sacral variants								
C7/Th12/L7/S5	2 (0.6)	2 (0.6)	4 (1.2)	1 (0.3)	2 (0.6)	0	1 (0.3)	0
C7/Th12/L7/S6	1 (0.3)	0	1 (0.3)	0	0	0	1 (0.3)	0
Without congenital abnormalities	147 (44.5)	133 (40.3)	280 (84.8)	169 (51.2)	43 (13.0)	1 (0.3)	67 (20.3)	0
Congenital abnormalities	19 (6)	31 (9.4)	50 (15.2)	16 (4.9)	16 (4.9)	0	14 (4.2)	4 (1.2)
Total	166 (50.3)	164 (49.7)	330 (100)	185 (56.1)	59 (17.9)	1 (0.3)	81 (24.5)	4 (1.2)

<sup>a</sup> Anticlinal vertebra determined as the vertebra with the spinous process perpendicular to the long axis.

<sup>b</sup> Anticlinal vertebra determined where spinous process angles diverged.

## Materials and methods

### Image selection

The picture archiving and communication system (PACS) of the Department of Diagnostic Imaging of the University of Veterinary and Pharmaceutical Sciences, Brno, Czech Republic, was searched for radiographs of pet rabbits examined from 2007 to 2016. All radiographs were acquired with computed radiography (FCR, Capsula XL) in sedated animals and stored on the picture archiving and communication system (PACS) in digital imaging and communications in medicine (DICOM) format. Breed, sex and clinical history were available for all rabbits included in the study. We included radiographs in which we could visualise the cervical, thoracic, lumbar and sacral segments of the vertebral column and at least the four most cranial vertebrae of the caudal vertebral column (tail). Additionally, we had to be able to visualise all ribs to at least the level of costochondral junction. We required at least two orthogonal views of the vertebral column. Given that many of vertebral column segments reviewed were from survey radiographs of head, thorax and lateral abdomen, both ventrodorsal (VD) and dorsoventral (DV) projections of the vertebral column were acceptable. Images were viewed on a PACS Workstation DICOM viewer (JiveX, Visus Technology Transfer GmbH) by two observers. The number of vertebrae in each segment of the vertebral column was recorded, along with the type and localisation of any congenital abnormalities; the rib morphology and spinal curvature (scoliosis) of the vertebral column in each rabbit were evaluated subjectively and a consensus opinion was recorded. The location of the anticlinal vertebra was recorded. Transitional vertebrae were recorded as a type of vertebra and block vertebra were identified as two vertebrae when vertebral formula was calculated.

### Classification of anomalies

Vertebral congenital anomalies were defined as any defect in vertebral body formation as defined by Westworth and Sturges (2010), Gutierrez-Quintana et al. (2014) and Flückiger et al. (2009). A hemivertebra was defined as ventral, lateral or ventrolateral aplasia of the vertebral body, a wedge vertebra was defined as ventral or lateral hypoplasia of the vertebral body and a butterfly vertebra was defined as ventral and median aplasia of the vertebral body. A short vertebra was defined as symmetrical hypoplasia of the vertebral body and a block vertebra was defined as failure of vertebral

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