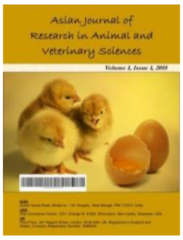

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Determination of Vertebral Index in Thoracic Roentgenographs of the Rabbit (*Oryctolagus cuniculus)*

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Authors' contributions

This work was carried out in collaboration of the three authors. Author ROU designed and wrote the draft manuscript, supervised the research and reviewed literature. Authors ROU and JII carried out all the radiographic and darkroom procedures. Authors JII and EYT made all the radiographic measurements and data analyses. All three authors jointly read and approved the submission of the final manuscript.

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ABSTRACT

Aim: There are numerous thoracic cage malformations that variably affect the contour and volume of the thorax in both humans and animals. Common thoracic congenital disorders are *pectus* deformities, and objective measures delineating the limits of normal and deformation are yet to be defined in the New Zealand White (NZW) rabbit. This research was aimed at establishing values of vertebral index (VI) of clinically normal NZW rabbit, for reference purposes.
Materials and Methods: Ten healthy NZW rabbits were acquired for this investigation. A right lateral (RtL) thoracic roentgenograph of each research animal was made. The sternovertebral distance and diameter of the tenth thoracic vertebra (T_{10}) were evaluated in centimetres in each of the radiographs. The quotient of the vertebral diameter and sum of the same vertebral diameter and

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the sternovertebral distance was then obtained from each experimental radiograph as the VI for the rabbit concerned.
Results: Mean plus or minus standard error of mean (M±SEM) VI was 0.1±0.01, and the difference between male and female VIs was statistically insignificant.
Conclusion: VI is clinically, objectively, and easily applicable in radiographic investigation of the thoracic shape and depth.

Keywords: Radiographic measurement; right lateral thoracic view; deformation index; rabbit.

1. INTRODUCTION

There are numerous congenital and acquired thoracic cage deformities that variably affect the contour and volume of the thorax. The most common thoracic cage anomalies in both man and animals include *pectus* deformities [1-11]. Congenital deformities of the sternum, ribs, and thoracic spine are frequently encountered clinically, radiographically, and incidentally [1]. In cats, majority of these malformations involve these thoracic skeletal elements, in order of decreasing frequency: sternum, spine, and ribs [2]. *Pectus excavatum* compresses thoracic organs causing cardio-respiratory distress such as disturbed comprehensive inspiration, tachycardia, cardiac palpitations, etc. These disorders lead to impaired neonatal and infantile development and exercise intolerance [6,10,12].

Changes in chest wall bones constitute the main anatomic component of thoracic deformities, and so radiological examination enables assessment of thoracic condition, deformation degree, and shape. Distortion of thoracic spine may present as scoliosis (right or left lateral bowing or kinking of the spine), lordosis (an abnormal ventral curvature of the spine in the dorsoventral plane as viewed in a lateral radiograph), kyphosis (an abnormal dorsal spinal arching), or a combination of any of these anomalies, and may result in myelopathy depending on the extent of spinal canal distortion and stenosis. Such abnormalities may be congenital, idiopathic, or related to another spinal deformity [2-4]. In people, it is claimed that depressed thoracic wall influences affected children’s psychological state, which, in turn, inflicts psychosomatic disturbances and physical exercise limitations [13,14]. Cosmetic indications for surgical correction gained more importance after minimally invasive and better result-oriented Nuss operation for *Pectus excavatum* was introduced [15-17].

Pectus excavatum (funnel chest) and *Pectus carinatum* (chicken or pigeon chest) are the most common types of congenital ventral thoracic wall deformities. *Pectus excavatum* is a sternal deformity that typically involves the caudal vertebrae and costal cartilages (chondrosternal depression) attributed to excess traction of the diaphragm during the early stages of late intrauterine or early neonatal development [18,19]. There are varying degrees of local and regional concavity, and this inward sternebral displacement alters the shape of the caudoventral aspect of the thoracic cavity secondarily, resulting occasionally in clinical signs referable to cardiac or pulmonary displacement and or depression. Surgical correction of funnel chest is predicted on the severity of clinical signs [20,21]. Radiographic indicators of *Pectus excavatum* are a marked dorsal deviation of the caudal aspect of the sternum (resulting in abnormal sternovertebral distance at the affected part), acute angulation of the associated costal cartilages, and dorsal displacement of the heart in lateral views; lateral heart displacement is often pronounced in ventrodorsal projections [22,23]. In severe cases, the sternum is superimposed on the heart in lateral projection [5]. *Pectus carinatum* anomaly results in a laterally compressed thorax secondary to ventral (outward) displacement of the caudal aspect of the sternum [5]. When viewed laterally, the vertical diameter of the thorax is increased in the affected animal. The ventral aspect of the diaphragm is often straighter than normal, and the diaphragm on the whole is more vertically oriented [2]. Congenital syndromes associated with *pectus* deformities in both man and animals include osteogenesis imperfecta, osteodysplasty, foetal alcohol syndrome (in man), mucopolysaccharidosis (especially in cats), spondyloepiphyseal dysplasia congenita, and homocystinuria [2, 24,25].

However, only a few patients, be they people or animals, experience respiratory disorders unless the condition is accompanied by primary cardiac or pulmonary defects due to severe deformities. The patients usually undergo an operation because of cosmetic and (in man) psychological reasons [1,26]. The severity of these deformities is measured by various parameters including vertebral index and sternovertebral distance [26,27]. Various parameters have been proposed to measure the severity of these deformities before operation. Plain thoracic radiography, computed tomography, pulmonary function test, and cardiac investigation can be used for assessment of *pectus* deformities. However, routine thoracic radiography often yields enough information to permit assessment of the thoracic region [6,28,29].

Indices derived from relationships of cardiac and thoracic dimensions measured in preoperative and postoperative thoracic radiographs have been employed to quantitatively assess the degree of surgical correction in patients with *pectus* disorders [7,26,28]. Lateral radiographic measurements are more valuable than dorsoventral views in patient assessment because the main effect of *pectus* repair operation on the anatomy of thoracic cavity is dorsoventral effect rather than a transverse effect [30-33].

Precise roentgenographic evaluation parameters differentiating between normal and deformed thorax in the NZW rabbits are yet to be documented. The authors aim to generate measurement values of the sterno-thoracic relationship in the healthy NZW rabbit.

2. MATERIALS AND METHODS

2.1 Location of the Study

The study was carried out in the Department of Veterinary Surgery & Radiology, Michael Okpara University of Agriculture, Umudike. Umudike lies in the tropical rainforest zone of South-eastern Nigeria between latitudes 5° 29'N and longitudes 7° 33'E at the elevation of 122 m above sea level with annual rainfall of 1245 mm and a temperature range of 22.4° to 30.6°C.

2.2 Experimental Animals and Adaptation

Ten NZW rabbits comprising equal number of both sexes (average body weight = 2.25 kg; ranging from 1.65 to 2.55 kg) were bought from local breeders and used for this project. The rabbits were kept separately in well ventilated pens for two weeks to acclimatise. The experimental animals were given feed and clean drinking water *ad libitum* and the feed was a mix of concentrates and forages [34]. The animals were identified with numbered ear-tags. At the end of adaptation period, the animals were examined generally and their vital parameters were all within the normal values documented for the NZW rabbit, and so the animals were considered suitable for the radiographic study.

2.3 Radiographic Procedures

The animals were controlled for radiographic exposure with a sedative, xylazine hydrochloride (XYL-M2^R, by VMD Belgium), given i.m. at 30mg/kg [35]. An inspirational plain right lateral thoracic projection was obtained of each experimental rabbit. The x-ray field was centred at the middle of the 4th intercostal space and the beam was collimated to capture the entire thorax from cranial end of T_1 to the caudal end of L_1 as described by Ettinger and Suter [36] and Douglas et al. [37]. Each x-ray film was identified with lead markers, processed, and kept in a labelled envelope. Using a viewer, the parameters measured in the radiographs were: the maximum vertical depth of thorax from the dorsal border of the sternum to the ventral border of the vertebral column at the level of the 10th thoracic vertebra (sterno-vertebral distance SVD), and the sagittal diameter of the vertebral body measured from the ventral board to the dorsal board of the vertebra in line with SVD (Vertebral diameter VD) [38].

Results of the study were presented as means plus or minus standard errors of means (M±SEM). Variables were compared using t-test, Durbin Watson test, simple linear regression, and Pearson's product moment correlation coefficient statistics. A probability value less than five percent was considered statistically significant.

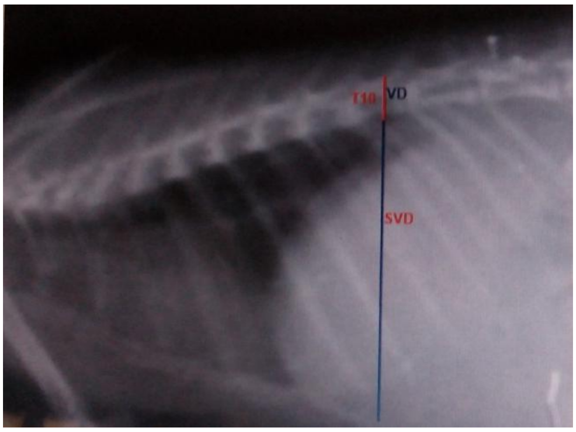

Plate I. Method of determining vertebral index (VI)

VI = VD/VD+SVD; KEY: T_{10} = 10th Thoracic vertebra, VD = Vertebral Diameter, SVD= sternovertebral distance

3. RESULTS

3.1 Right Lateral View of the NZW Rabbit

A test of difference between male sex mean (0.094), female sex mean (0.098), pooled mean (0.096), SEM (0.002), and a t-test of 0.013, confirms that there is no significant difference between the sex means (Table 3).

The Regression Table below (Table 4) is the test of relationship between Sex and VI using Simple Linear Regression Model. The result shows that there is no significant relationship between Sex and VI. A Durbin Watson test was also carried out to determine the strength of the correlation between Sex and VI and a value of 2.584 shows there is no correlation between VI and Sex.

4. DISCUSSION

Vertebral index is the relationship between the breadth of the tenth vertebra (T10) and the sternovertebral distance. In other words, VI is the ratio of T10 sagittal diameter to sum of the T10 diameter and sternovertebral distance measured in line with the sagittal diameter of the tenth vertebra. Radiological assessment is greatly useful for evaluation of indications for surgical treatment of sternal deformation of the thorax. In the present work and in the experimental radiographs, the mean VI value was 0.10 (ranging from 0.08 to 0.11).

Table 1. VI in the right lateral views of the NZW rabbits

S/N	Sex	VD(cm)	SVD(cm)	VI(VD/VD+SVD)
1	F	0.90	7.70	0.11
2	F	0.70	5.70	0.11
3	F	0.70	6.10	0.10
4	F	0.60	6.20	0.09
5	F	0.60	6.90	0.08
6	M	0.80	6.50	0.11
7	M	0.70	6.40	0.10
8	M	0.70	7.10	0.09
9	M	0.50	6.40	0.08
10	M	0.70	6.80	0.09
Total	10	6.90	65.80	0.96
Average		0.69	6.58	0.10
Mean				0.10
SEM				0.01

Mean = 0.10 ± 0.01

Table 2. The Male and Female VIs of NZW rabbits

	Males			Females		
S/N	VD(cm)	SVD(cm)	VI(VD/VD+SVD)	VD(cm)	SVD(cm)	VI(VD/VD+SVD)
1	0.80	6.50	0.11	0.9	7.70	0.11
2	0.70	6.40	0.10	0.7	5.70	0.11
3	0.70	7.10	0.09	0.7	6.10	0.10
4	0.50	6.40	0.08	0.6	6.20	0.09
5	0.70	6.80	0.09	0.6	6.90	0.08
Total	3.40	33.20	0.47	3.5	32.60	0.49
Average	0.68	6.64	0.10	0.7	6.52	0.10
Mean			0.10			0.10
SEM			0.01			0.01

Mean = 0.10 ± 0.01; Mean = 0.10 ± 0.01; Mean sex difference in VI (P< 0.05) not significant

Table 3. t- Test comparing the VIs of male and female NZW rabbits

Variables	Sex Mean	Pooled Mean	SEM	df	t-Test
Females	0.098	0.096	0.002	1.000	0.013
Males	0.094				

† Mean VI sex difference not significant (P< 0.05)

Table 4. Determination of the influence of Sex on VI of NZW rabbits

Variables	B	SD Error	t	Significance
Constant	0.098	0.085	1.148	0.284
Sex	0.120	0.121	0.994	0.349
R^2	0.110			
F-factor	0. 988			0.349
Durbin Watson				2. 584

No significant relationship between Sex and VI (P<0.05)

The mean VI value (0.10) obtained in this study for the NZW rabbit is similar to published human vertebral indices of 0.25 [38] and 0.26 [27], that have successfully been used in the assessment of thoracic wall malformation and surgical treatment of children and other patients with *pectus* deformities. There was no significant sex index difference observed in the present work. The medical researchers also recorded an insignificant difference between male and female index values. Before the publication of the medical indices, the assessment of patients with sternovertebral distortion was carried out only subjectively, without a reference guide, during clinical inspection.

In cases of moderate thoracic cage depression with no clinical sign of thoracic organ compression, indications for surgery can be determined by the size of deformity visualized in thoracic radiographs, and or computed tomography (CT) [39]. *Pectus carinatum* (a congenital deformity in which the sternum bulges caudoventrally and protrudes) and lordosis are the causes of less than normal VI values while *pectus excavatum* (a congenital deformity in which the sternum and caudal ribs are concave and depressed towards the spine reducing thoracic cavity space) and kyphosis will result in VI values greater than normal [2,4,40].

Radiologic examination is also useful in planning surgery, predicting its results and treatment outcome [29,41]. Lateral and dorsoventral thoracic radiographs (frontal i.e., posteroanterior or PA view in man) reveal the severity of deformity, but for comprehensive study, however, thoracic CT scanning is necessary to see not only the shape but also the exact topography of thoracic organs; thoracic symmetry and thickness or flatness can only be evaluated tomographically [39,42,43]. The CT scanning should be performed in the most concave level of the thorax both on inspiration and expiration in order to diminish error due to chest wall excursion during breathing.

5. CONCLUSION

Radiographic evaluation of thoracic contour in the rabbit is feasible. Experienced radiologists employ subjective determination of thoracic radiographs in the analysis of cardiothoracic anomalies. But measurement of thoracic structures is more accurate when a clinician with limited experience is involved, and in subtle cases of sterno-thoracic contour malformation. The VI is an easy method to apply; it allows effective measurement of *pectus* deformation, determination of surgical treatment plan, and provides an efficient comparison between preoperative evaluation and postoperative outcome of the surgical correction. Surgical correction is indicated if the deformation index of VI>0.11 is obtained in the NZW rabbit.

CONSENT

It is not applicable.

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the authors. The housing, environment, and management of the research animals were as stipulated in the Guide for the Care and Use of Laboratory Animals, 8th Edition, National Research Council, USA, downloaded from the National Academic Press, Washing D.C. www.nap.edu

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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