RESEARCH ARTICLE

Evaluation of Radiographic Measurements of Liver in Deep Chested Dogs

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Abstract

Dog's health is major concern while liver health plays key role to keep dogs healthy. The aim of this research work was to determine radiographic measurements of liver, *i.e.,* radiographic liver length, thoracic depth, thoracic width, radiographic liver volume and radiographic T11 vertebrae length in deep chested dogs. A total 89 numbers of 6 deep chested dog breeds (German Shepherd, Belgium Shepherd, Golden Retriever, Dobermann, Great Dane and Siberian Huskey) of one year and above age, and different body weights were included in this study. Radiographic liver length, thoracic depth and T11 vertebrae length was measured from right lateral radiograph and thoracic width was measured from ventro-dorsal view of radiograph. Then the radiographic liver volume was calculated. The radiographic liver length was recorded 14.62±0.27 cm, thoracic depth was 19.04±0.27 cm, thoracic width was 18.74±0.24 cm, radiographic liver volume was 820.63±28.18 cm^3 and radiographic length of T11 vertebrae was 2.40±0.02 cm. The age, sex, breed and body weight of dog influenced these measurements, particular the thoracic depth, thoracic width, and radiographic liver volume, were higher in 6-9 years age group, in male, in Red Dane, and in dogs of higher (>30 kg) body weight, but was not influence by the neutering status. It was concluded that radiographic measurements can be set as a quantitative index of radiographic liver size and allow accurate assessment of liver size, shape and position, excluding evaluation of parenchymal changes unless any radio-opaque content is present.

Key words: Dogs, Radiographic liver length, Radiographic liver volume, Thoracic depth, Thoracic width,.

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Introduction

Dogs are domesticated for a set of social-cognitive abilities that enable them to communicate with humans in unique ways (Hare *et al.*, 2002). Liver measurements play an important role to establish differential diagnosis for suspected hepatic diseases. Radiography, ultrasonography, scintigraphy, computed tomography (CT) and magnetic resonance imaging (MRI) are used for evaluation of normal liver size in dogs. CT and MRI are not compatible without anaesthesia and use of CT and MRI is still limited in veterinary practices (Kim *et al.*, 2018). Radiography is economic and easy to use for diagnosis of various affections. Survey abdominal radiographs (lateral and ventro-dorsal view) are useful to evaluate the morphologic abnormalities in size, shape, position and density of the liver (Kumar *et al.*, 2012). The radiographic appearance of the hepatic silhouette is influenced by the thoracic conformation, in narrow with deep-chested dogs; the ventral lobes appear small, upright and lie within the costal arch (Wrigley, 1985; Cha *et al.,* 2018). The size and delineation of liver shadow is influenced by the positioning of dog and it is said that the liver shadow looks larger (Suter, 1982) and is better delineated in right lateral recumbency (Lee and Leowijuk, 1982; Cha *et al.,* 2018). The position of liver margins relative to the costal arch may also be affected by nonpathological conditions such as the patient's age, size, weight, breed, conformation, volume of gastric contents and degree of inspiration (Partington and Biller, 1995; Lee *et al.,* 2019).

Liver diseases are frequently encountered in the veterinary clinical practices. Dogs primarily present with parenchymal pathologies such as hepatitis (Watson, 2004; Center, 2009). The estimated frequency of canine hepatitis depends on the investigated population and accounts for 1-2% of clinics'

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referral population and up to 12% in a general population (Watson *et al.,* 2010). Potential causes of canine hepatitis include micro-organisms, toxins and drugs and immune-mediated reactions. Disorders of copper metabolism account for roughly 30% of chronic canine hepatitis cases (Favier, 2009). Liver affections, *i.e.,* hepatomegaly, microhepatica, liver cyst and abscess, neoplasia and mineralization of liver etc. are commonly observed (Negasee, 2021). Radiographic diagnoses of liver affections are excellent modules for clinical practice as well as research in dogs. Hence, the present systemic study was planned to evaluate normal radiographic measurements of liver and the influence of demographic factors on them in deep chested dogs.

Materials and Methods

The research work was carried out on clinical cases of deep chested dogs (n=89) with good general body conditions, no history of chronic illness and systemic disease, presented at the Veterinary Clinical Complex and Department of Veterinary Surgery and Radiology, PGIVER, Jaipur (Rajasthan, India) from October 2023 to March 2024. Dogs one year and above age of 6 deep chested breed of different body weights were included in this study. Thoraco-abdominal radiography was done in all dogs, using 500 mA X-Ray machine (EP-CORSA 40kw, Epsilon Health Care Solutions Pvt. Ltd.). A complete radiographic examination was done in right lateral (RL) and ventro-dorsal (VD) views. Following radiographic measurements were taken.

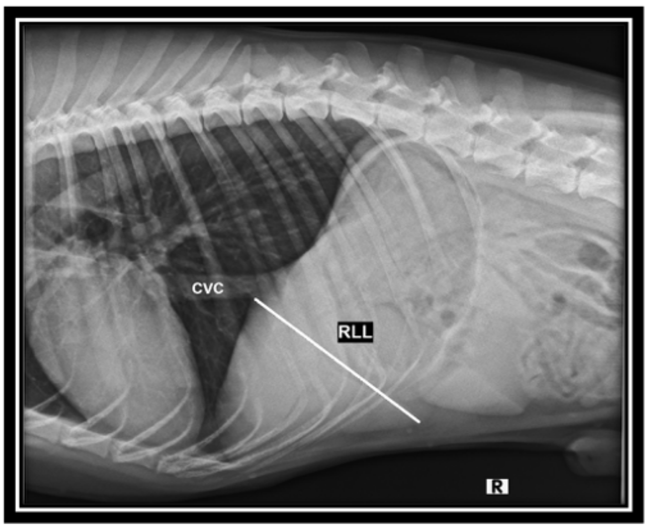

Fig. 1: Radiograph showing site for radiographic measurement of radiographic liver length

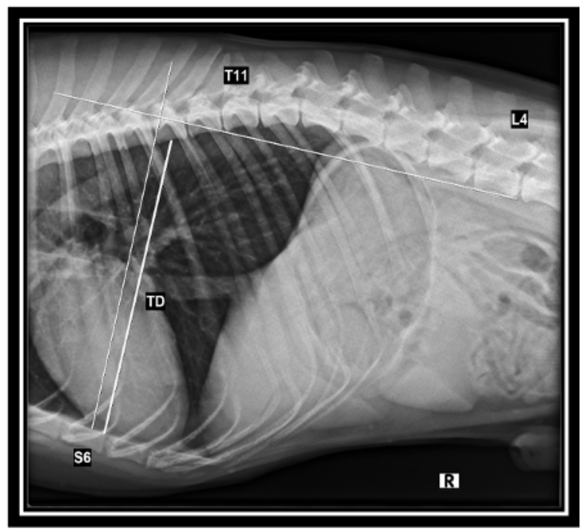

Fig. 2: Radiograph showing site for radiographic measurement of thoracic depth

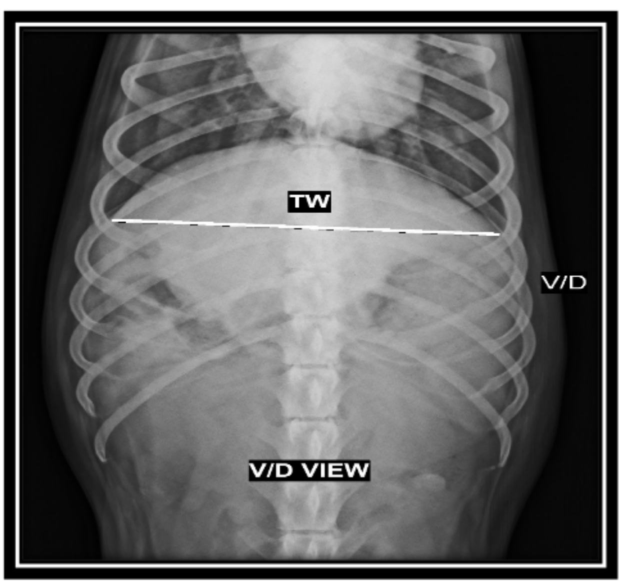

Fig. 3: Radiograph showing site for radiographic measurement of thoracic width

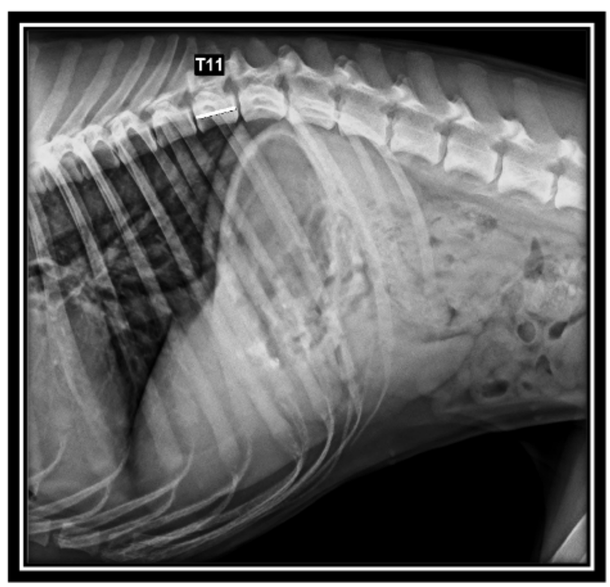

Fig. 4: Radiograph showing site for radiographic measurement of T11 vertebrae length

Radiographic liver length (RLL) was measured as the length of the axis from ventral border of caudal vena cava to the apex of hepatic caudal border (Fig. 1). *Thoracic depth* was measured as the length from the caudal tip of the sixth sternebrae up to ventral border of thoracic vertebra which is perpendicular to the axis between the ventral border of T11 vertebra and the ventral border of the fourth lumbar vertebra (Fig. 2). *Thoracic width* was measured by drawing a line between the costophrenic recesses on radiographic ventro-dorsal view (Fig. 3). *Radiographic liver volume (RLV)* was calculated with formula: Liver volume = 11.62 + 0.154 (liver length × thoracic depth × thoracic width). *Radiographic T11 vertebrae length* was measured at the level of the midpoint parallel to the long axis of the vertebral body (Fig. 4).

The age of dogs was classified in 4 groups, *i.e.,* 1-3 year, 3-6 year, 6-9 year and 9-12 year; sex in 2 groups *i.e.,* male and female; body weight was categorised in 4 groups, *i.e.,* 10-20 kg, 20-30 kg, 30-40 kg and 40-50 kg; the breed in 6 groups, *i.e.,* German Shepherd, Belgium Shepherd, Doberman, Golden Retriever, Great Dane and Siberian Huskey, and the status of neutering was put in 2 groups, *i.e.,* castrated/spayed and intact. The data generated was presented as Mean plus/minus standard errors, and analysed statistically using 't' test, one way ANOVA and Duncan's *post hoc* test to see the differences at $p<0.05$ (Snedecor and Cochran, 1994).

Results and Discussion

The overall mean (±SE) radiographic liver length recorded for all dogs was 14.62±0.27 cm, thoracic depth was 19.04 ± 0.27 cm, thoracic width 18.74±0.24 cm, radiographic liver volume calculated was 820.63±28.18 cm^3, and radiographic length of T11 vertebrae was 2.40±0.02 cm. Cha *et al.* (2018) measured thoracic height in purpose-bred Beagles that was 18.77±0.52 cm and 18.59±0.5 cm at maximal inspiration and maximal expiration, respectively. Kinoshita *et al.* (2023 and 2024) calculated liver volume 722.2 ± 281.2 cm^3 and 813.8 ± 326.5 cm^3 in dogs without hepatic diseases with computed tomography. However, Kim *et al.* (2018) measured radiographic liver volume in normal liver size groups of dogs as 126.40±10.80 CC. Lee *et al.* (2019) reported radiographic liver volume 159.69±96.00 cm^3, 89.81±68.42 cm^3 and 219.57±110.81 cm^3 in normal group, microhepatia and hepatomegaly group of small breeds of dogs. Kinoshita *et al.* (2024) measured T11 vertebrae length as 2.14 ± 0.35 cm in dogs without hepatic diseases with computed tomography. Contrary to it, Cha *et al.* (2018) reported T11 vertebrae length 1.74 cm and 1.77 cm on food withheld and gastric distension at maximal expiration in 12 purpose-bred Beagles, respectively. The normal radiographic liver length was concluded 6.09 times of T11 vertebrae length in deep chested dogs by Karir *et al.* (2024).

The mean (± SE) values of various measurements recorded according to age and sex, body weight and neutering status, and breed are presented in Tables 1 to 3, respectively. The influence of age of dogs had a significant influence only on thoracic width, the measurement being highest in 6-9 years age group and the lowest in 1-3 years age group. Moreover, though the values of radiographic liver length, radiographic liver volume and T11 vertebral length were highest in age group 6-9 years, did not differ from other age groups. In contrast, male dogs had significantly higher values of all measurements, except radiographic liver length (Table 1). Similar findings have been reported by Choi *et al.* (2013), who observed that radiographic liver size can vary across age groups but often shows greater correlation with body weight than chronological age. Cha *et al.* (2018) also reported higher thoracic and hepatic measurements in male Beagles compared to females under standardized radiographic

Table 1: Age and sex-wise mean ± SE values of different radiographic measurements of liver of dogs

Radiographic measurements	Age				Sex	
	1-3 year	3-6 year	6-9 year	9-12 year	Male	Female
RLL (cm)	14.33±0.34	15.28±0.58	16.24±0.56	13.90±0.62	14.98±0.43	14.36±0.34
TD (cm)	18.93±0.34	19.03±0.58	19.45±0.86	19.86±1.11	19.87^{a}±0.42	18.44^{b}±0.33
TW (cm)	18.38^{A}±0.27	18.99^{AB}±0.59	20.93^{B}±1.06	18.92^{AB}±0.76	19.37^{a}±0.39	18.27^{b}±0.29
RLV (cm^3)	799.2±34.32	800.47±76.36	1027.46±69.89	811.88±51.33	912.91^{a}±44.18	751.87^{b}±33.78
T11 L (cm)	2.38±0.03	2.43±0.05	2.53±0.05	2.34±0.12	2.47^{a}±.04	2.35^{b}±0.03

RLL= radiographic liver length, TD= thoracic depth, TW= thoracic width, RLV= radiographic liver volume, T11L= radiographic length of T11 vertebrae. Means having different superscripts within a row differ significantly for age groups or sex ($p<0.05$)

Table 2: Body weight and neutering status-wise mean ± SE values of different radiographic measurements of liver of dogs

Radiographic measurements	Body weight				Neutering status	
	10-20 kg	20-30 kg	30-40 kg	40-50 kg	Castrated	Intact
RLL (cm)	11.73^{a}±0.36	14.49^{b}±0.28	16.47^{c}±0.46	18.40^{c}±0.60	13.96±0.7	14.75±0.29
TD (cm)	17.44^{a}±0.75	18.69^{ab}±0.29	20.56^{bc}±0.52	22.40^{c}±0.30	18.83±0.65	19.09±0.3
TW (cm)	16.31^{a}±0.29	18.47^{b}±0.24	20.58^{c}±0.46	22.40^{c}±0.60	18.01±0.42	18.88±0.27
RLV (cm^3)	526.14^{a}±28.87	762.91^{b}±23.29	1082.47^{c}±43.97	1432.28^{d}±27.31	736.95±43.67	836.25±32.21
T11 L (cm)	2.19^{a}±0.05	2.37^{b}±0.07	2.55^{c}±0.04	2.90^{d}±0.20	2.41±0.07	2.40±0.03

RLL= radiographic liver length, TD= thoracic depth, TW= thoracic width, RLV= radiographic liver volume, T11L= radiographic length of T11 vertebrae. Means having different superscripts in a row differ significantly ($p<0.05$).

conditions. In addition, Lee *et al.* (2019) confirmed that sex-based variations should be considered when establishing reference intervals for hepatic size in dogs. The normal radiographic liver length was concluded 6.09 times of T11 vertebrae length in deep chested dogs by Karir *et al.* (2024). Similar validation was reported in cats, where the LL/T11 ratio strongly correlated with CT liver volume, supporting its use as a reliable index of hepatic size (An *et al.,* 2019).

The mean values of all radiographic measurements of liver in dogs under study were found to increase gradually and significantly with increasing body weight from 10-20 kg to 40-50 kg group, although statistically the values of RLL, TD and TW were same between body weight groups 30-40 kg and 40-50 kg. However, there was no any influence of neutering status of dogs, since all the measurements were alike between castrated or spayed and intact dogs (Table 2). Kinoshita *et al.* (2024) emphasized body weight as a reliable standardization factor for computed tomography (CT)-derived liver volume in healthy dogs, supporting the present findings. Similarly, Lee *et al.* (2019) demonstrated significant correlation of radiographic liver area with body size in small-breed dogs, confirming that hepatic measurements must be interpreted relative to weight. Comparable observations were made by Choi *et al.* (2013), who reported minimal effect of neutering on radiographic liver size when body size and conformation were controlled. Thus, body weight, rather than neutering status, should be considered the key determinant of radiographic hepatic measurements.

Breed-wise analysis of data revealed that the all the measurements were highest in Great Dane, with significant differences in thoracic depth, thoracic width and radiographic liver volume, and the lowest in Doberman and Siberian Husky (Table 3). Choi *et al.* (2013) demonstrated significantly different radiographic liver dimensions in Pekingese dogs compared to other breeds, underlining the importance of breed-specific baselines. Similarly, Cha *et al.* (2018) highlighted how thoracic conformation directly affects radiographic liver assessment in Beagles, which may be extrapolated to other breeds with distinct morphologies. Recent advances in CT hepatic volumetry further support these observations. Kinoshita *et al.* (2023) demonstrated that CT-derived liver volumetry provides an accurate and reproducible method for liver size assessment in dogs, reducing observer variability. Moreover, Kinoshita *et al.* (2024) established that body weight is the most reliable normalization factor for hepatic volume, confirming that breed- and size-related variations must always be considered when interpreting hepatic measurements.

In small animals (Carlson, 1976; Suter, 1982; Wrigley, 1985) as well as in humans (Gelfand, 1975) survey radiographic measurements provide an imprecise estimation of hepatic sizes (Bree and Sackx, 1987). Evaluation of the size of liver by means of diagnostic imaging is important to identify hepatic abnormalities. Liver size is a significant prognostic indicator of survival with compensated cirrhosis and hepatic failure (Sekiyama *et al*., 1994). Small animal radiologists are confronted with the problem of different breeds, sizes and thoracic conformation. Even in medical atlases of roentgenographic measurements, parameters about normal liver size are lacking (Lusted and Keats, 1976). However, liver could be measured successfully through the thoraco-abdominal radiography by lateral and ventro-dorsal view in German Shepherd, Belgium Shepherd, Golden Retriever, Doberman, Great Dane and Siberian husky breeds of dogs. The exact position of caudo-ventral tip of the liver is appreciated in the lateral projection (Lee and Leowijuk, 1982). A substantially enlarged or reduced liver size is a reliable sign of disease (Suter, 1982).

Changes in liver size are frequent indicators of hepatic diseases (Carlson, 1976; Wrigley, 1985). Liver affections lead either increase or reduce size which can be diagnosed with the help of radiographic measurements of liver. Increased values of radiographic measurements may confirm hepatomegaly/increased liver size whereas decreases values to microhepatia in dogs.

Conclusion

From the findings of the present study, it is concluded that radiographic measurements are set as a quantitative index of radiographic liver size and allow accurate assessment of liver size, shape and position whereas excluding evaluation of parenchymal changes unless any radio opaque content is present. The age, sex, breed and body weight of dog influence these measurements, particular the thoracic depth, thoracic width, and radiographic liver volume, being higher in 6-9 years age group, in male and in dogs of higher

Table 3: Breed wise mean ± SE values of different radiographic measurements of liver of dogs

Radiographic measurements	Breed					
	German Shepherd	Belgium Shepherd	Doberman	Golden Re-triever	Great Dane	Siberian Husky
RLL (cm)	14.88±0.38	14.92±0.75	13.00±0.61	14.85±0.53	15.47±1.13	13.02±1.05
TD (cm)	19.75^{bcd}±0.32	18.5^{abd}±0.77	19.63^{bd}±0.78	16.45^{a}±0.29	20.25^{d}±0.93	17.43^{ac}±1.68
TW (cm)	18.36^{ab}±0.32	19.47^{bc}±0.56	17.54^{a}±0.54	19.72^{bc}±0.66	21.23^{c}±0.56	18.18^{ab}±0.92
RLV (cm^3)	838.45±39.17	848.74±82.41	692.59±27.09	770.26±54.05	1054.79±129.88	689.76±145.87
T11 L (cm)	2.44±0.03	2.38±0.05	2.24±0.05	2.35±0.06	2.48±0.16	2.32±0.06

RLL= radiographic liver length, TD= thoracic depth, TW= thoracic width, RLV= radiographic liver volume, T11L= radiographic length of T11 vertebrae. Means having different superscripts in a row differ significantly ($p<0.05$).

body weight. The current findings are expected to help further researchers as well as canine practitioners for a better comprehension of diagnosis of liver affections while endeavouring for better health care of dogs.

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