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Morphological variation of electrocardiogram: A boon in diagnosis of canine cardiac disorders

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Abstract
The study was conducted on 137 client owned dogs presented to Veterinary Clinical Complex, College of Veterinary Science & A.H., Jabalpur, Madhya Pradesh, with the objective to diagnose different types of cardiac abnormalities in dogs. Evaluation of cardiac disorders was made based on complete history, clinical signs, physical examination, auscultation, electrocardiography, thoracic radiography, echocardiography, haemoglobin and serum electrolytes. Various types of electrical wave formation in majority found in electrocardiogram were abnormal configuration of P wave (59.38%), low voltage QRS complex (36.00%) and tall T-wave (23.81%) in P-wave, QRS complex and T wave morphology, respectively. Auscultation along with palpation of cardiac area and electrocardiography are the basic and primary prerequisite for early diagnosis of cardiac disorders.

Keywords: cardiac disorder, ECG, electrical wave morphology

Introduction
Cardiac diseases in canines are an extensively studied phenomenon all over the world but meager information has been reported in India (Hoque *et al*. 2019) [4]. According to studies, cardiac failure is believed to be the third most common cause of death in dogs next to the cancer. Even though, cardiac disorders are progressive and chronic in nature, they occur as acute form wherein the clinician has to respond quickly both in its diagnosis and treatment. As there is no single test to detect the heart failure, electrocardiography is a basic, non invasive tool for its diagnosis. The electrocardiography is the voltage time graph of the electrical activities of the heart and widely used for monitoring heart rate, cardiac rhythm, conduction integrity for diagnosis of cardiac disorders in dogs. The present paper discusses the various electrocardiographic abnormalities associated with different cardiovascular disorders in dogs. The ECG was interpreted as alterations in the morphology of P wave, QRS complex and T wave.

Materials and Methods
A total of 137 dogs had clinical signs suspected for cardiac disorders were subjected to thorough investigation for confirmation. Evaluation of cardiac disorders was made based on complete history, clinical signs, physical examination, cardiac auscultation and palpation, electrocardiography, thoracic radiography, echocardiography, haemoglobin and serum electrolytes. However, thorough electrocardiographic recordings were done for interpretations of various cardiac conduction anomalies.
The electrocardiogram was recorded with Cardiart 8408 View (BPL Limited) machine by placing the dog in right lateral recumbency on a non-conducting table. Three bipolar limb leads (lead I, lead II and lead III) were used. ECG was recorded with a paper speed of 50 mm/sec. Before each recording, a one millivolt standardization pulse was made. A longer rhythm strip was run on lead II and four or five beats were recorded on each lead. Tilley's (1985) [13] guidelines for measuring complexes and intervals were followed for the interpretation of electrocardiograms.

Results and Discussion
P-wave morphology in electrocardiogram in canine cardiac disorders
The various types of cardiac disorders were detected on the basis of ECG when focused on

P-wave morphology. Abnormal configuration of P wave was noticed in maximally (59.38%), although absence of P wave and widening of P wave was reported in similar frequency (18.75%). Tall P wave was documented in one case only *i.e.* 03.13%.

Table 1: P-wave morphology in electrocardiogram canine cardiac disorders

P- wave morphology	No. of dogs	Distribution (%)
Absence of P wave	06	18.75
Wide P- wave	06	18.75
Abnormal configuration of P- wave	19	59.38
Tall P-wave	01	03.13

Absence of P wave was recognized with a flat baseline. The findings are in accordance with Kumar (2013) [8] who reported absence of P wave (4.16%). There is no minimum height or duration for P wave. P wave may be absent in atrial fibrillation and atrial standstill. P waves may be superimposed on other waveforms in ventricular tachycardia and supraventricular tachycardia (SVT). Wide P wave was identified with increased duration i.e. greater than either 0.04 second or 0.05 second (in giant breeds) and termed as P mitrale and is suggestive of left atrial enlargement and dogs showing this abnormality may also be associated with the signs of left sided heart failure (Tilley, 1992) [14]. Wide P wave (4.94%) is reported similar to present study by Kumar (2013) [8]. According to Sahoo *et al*. (2021) [12], wide P wave (P-mitrale) is indicative of mitral valve disease leading to haemodynamic problems to the left atrium that injures and destroys some cells. The increased volume load and/ or pressure lead to cellular hypertrophy along with atrial dilatation which results in the death of some atrial cells with replacement *i.e.* fibrosis.

Abnormal configuration of P wave was interpreted as variation in shape of P wave. This is may be due to shifting of the pacemaker within the SA node. High vagal tone allows the exact pacemaking site within the SA node is a normal feature of canine ECG called wandering pacemaker (WPM; Fig. 3). The amplitude of the P wave may also vary between tracings due to changes in the position of the heart and of the ECG clips (Tilley, 1992; Ettinger and Feldman, 2010) [14, 2]. Kumar (2013) [8] reported abnormal configuration of P wave in lesser percentage (5.72%) as compared to the findings of present study. Tall P wave was recognized with the increased amplitude of P wave i.e. more than 0.4 mV and termed as P-pulmonale. The present findings were in accordance to Martin (2002) [10].

QRS complex morphology in electrocardiogram in canine cardiac disorders

Different kinds of cardiac disorders were detected electrocardiographically in QRS complex morphology i.e. low voltage complex 36.00% (09/25), deep Q- wave 28.00% (07/25), absence of Q-wave 20.00% (05/25), deep S-wave 8.00% (02/25), wide QRS complex 4.00% (01/25) and tall R wave 4.00% (01/25) affected with cardiac disorders.

Table 2: QRS complex morphology in electrocardiogram in canine cardiac disorders

QRS complex morphology	No. of dogs	Distribution (%)
Absence of Q wave	05	20.00
Deep Q wave	07	28.00
Tall R wave	01	04.00
Deep S wave	02	08.00
Low voltage QRS complex	09	36.00
Wide QRS Complex	01	04.00

Absence of Q wave was interpreted on ECG graph by a flat baseline. Deep Q wave was recognized by negative deflection of Q wave with enlarged amplitude i.e. greater than 0.5 mV (Ettinger and Feldman, 2010) [2] and it is suggestive of right ventricular enlargement. Deep Q wave was reported in 5.21% cases by Kumar *et al.* (2011) [7] which is less than that reported in present study (28%). Tall R wave which is suggestive of left ventricular enlargement was recognized as increased amplitude of R wave (4 mV) i.e. more than 3.0 mV. The present study is supported by Tilley (1985) [13], Mike (2007) [11], Kumar (2012) [6] and Kumar (2013) [8]. Sahoo *et al.* (2021) [12] and Mahendran *et al.* (2021) [9] suggested that increased amplitude of R wave may be due to hypertrophy or dilatation of left ventricle. Thus QRS complex is delayed or altered in conduction that leads to endocardial ischaemic changes. These myocardial ischaemic changes may be due to neoplasia, renal disorders, blood parasites, immune mediated haemolytic anaemia, myocardial infarction and mitral valve insufficiency.

Wide QRS complex was recognized by increased duration of QRS complex i.e. greater than 0.05 second. Low voltage QRS complexes, with R wave amplitude less than 0.5 mV (Fig. 1) is accompanied by pericardial/ pleural effusion (Martin, 2002) [10]. Low voltage QRS complex was diagnosed as generalized low R wave amplitude/ QRS complexes i.e. less than 0.5 mV; swinging motion of the beating heart within a distended, fluid filled pericardial sac and the corresponding redirection of electrical impulses toward and away from an ECG lead stays fixed and the heart swings to and fro (Ettinger and Feldman, 2010) [2]. Present findings are higher in number to those reported by Kumar *et al.* (2011) [7] who found low voltage QRS complexes in 15.15% cases. The higher percentage of low voltage QRS complex in present study correlate well with clinical signs as almost all dogs showed low voltage were found to be affected with ascites or pericardial effusion. Deep S wave was recognized as negative deflection of S wave with amplitude more than 0.35 mV suggestive of right ventricular hypertrophy. Similar findings were reported by Kumar *et al.* (2011) [7], who concluded deep S wave in 6.51% cases.

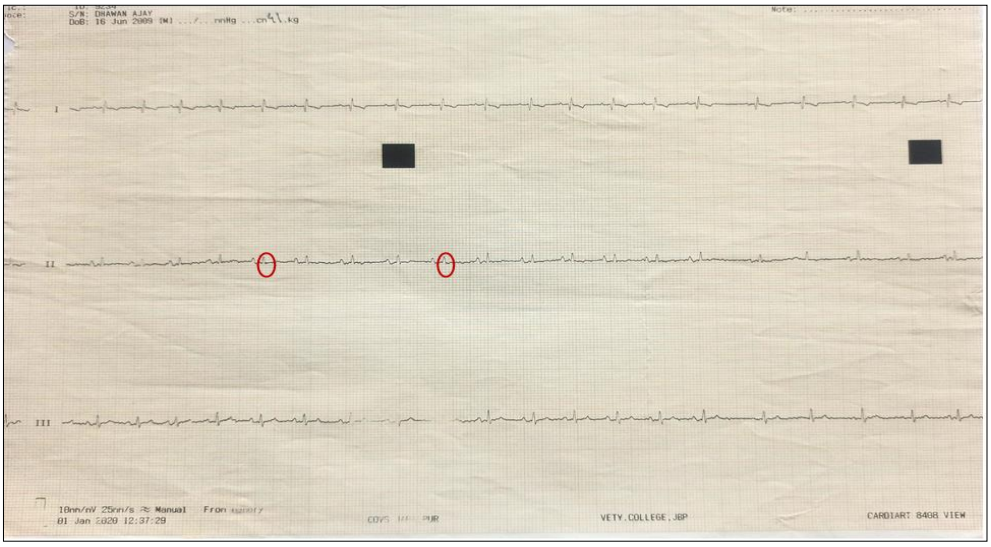

Fig 1: ECG showing abnormal QRS complex morphology (Low voltage QRS complex)

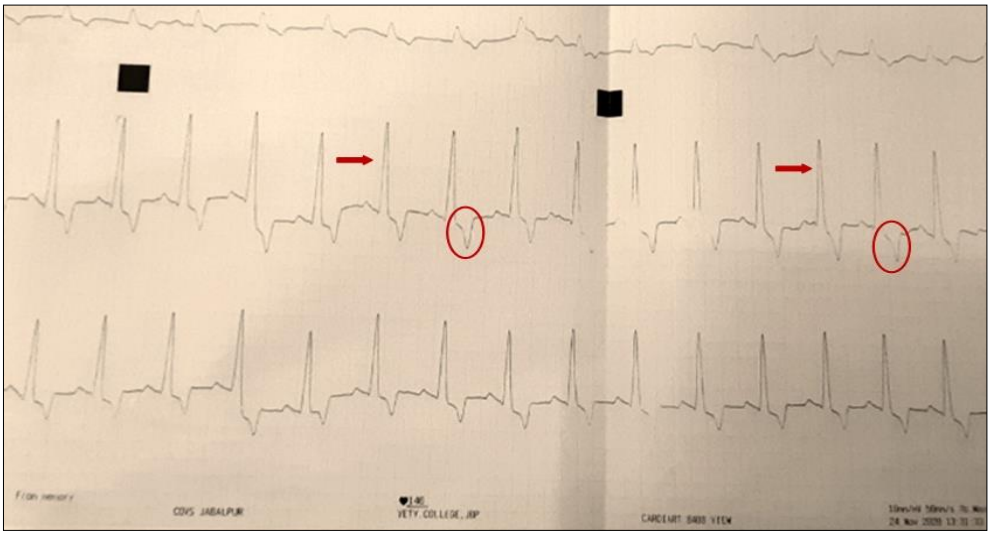

Fig 2: ECG showing abnormal morphology of R wave (tall R complex) and S-T segment depression (S-T coving)

T-wave morphology in electrocardiogram in canine cardiac disorders

The various types of cardiac disorders were detected electrocardiographically in T-waves i.e. tall T wave (23.81%), ST coving (19.05%), deep T wave (19.05%), ST segment depression (16.67%), biphasic T wave (14.29%) and absence of T wave (9.52%) in dogs.

Table 3: T-wave morphology in electrocardiogram in canine cardiac disorders

T-wave morphology	No. of dogs	Distribution (%)
Absence of T wave	04	09.52
Tall T wave	10	23.81
Deep T wave	08	19.05
ST coving	08	19.05
Biphasic T wave	06	14.29
ST segment depression	07	16.67

Absence of T- wave was recognized by a flat baseline. Biphasic T wave was recognized as deflection of T wave in either direction. Tall T wave (Fig. 3) was recognized by amplitude of T wave more than R/4 (i.e. 25% of R wave) amplitude and it is associated with hyperkalemia (more than 5.5 mEq/L). Similar finding were reported by Kumar (2012) [6] who documented it in 16.66% cases. Current findings are also relevant to that of Jeyaraja *et al.* (2004) [5] and Hanton *et al.* (2007) [3]. Deep T wave was recognized as negative deflection of T wave with amplitude more than 25% of R wave and is associated with left ventricle enlargement (Bhojne *et al.*, 2001) [1]. ST coving was diagnosed as a delayed return to baseline in the ST segment or an oblique or curved terminal upstroke of S wave or displacement of the ST segment in the opposite direction of QRS deflection. In volume overload both wall thickness and cavity size increases; wall thickness may be only moderately increased but the cavity size is the main dimension contributed to ventricular muscle mass (Sahoo *et al.*, 2021) [12]. Due to the increased muscle mass in hypertrophy or enlargement, the height of the R wave is increased, the QRS complex is delayed or altered in conduction, and the ST segment is depressed i.e. endocardial ischaemic change. (Tilley, 1992; Ettinger and Feldman, 2010) [14, 2]. ST segment depression was identified by depression of ST segment 0.2 mV or more.

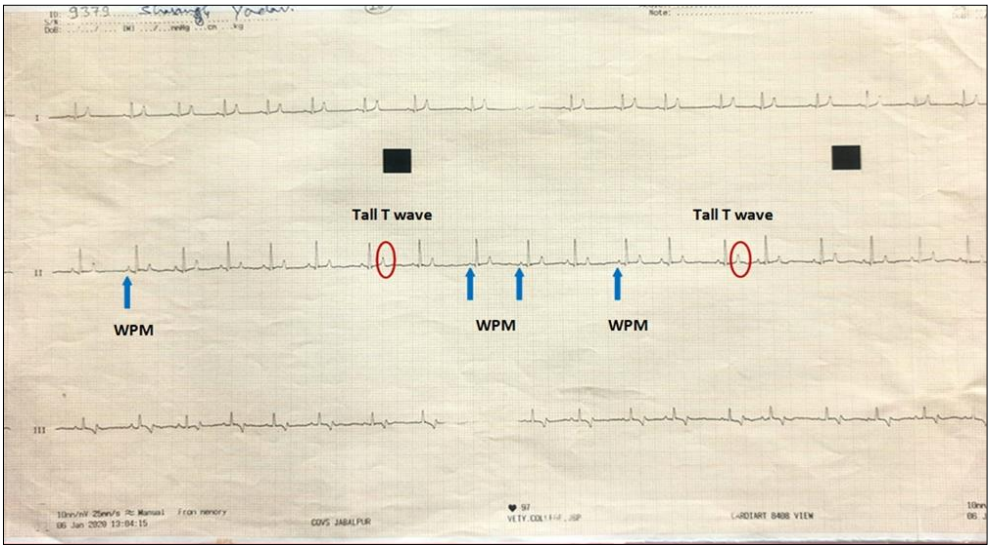

Fig 3: ECG showing abnormal morphology of P wave (WPM; blue arrow) and Tall T wave (red circle)

Conclusion

Electrocardiography is a basic, non invasive tool for diagnosis of cardiac disorders. Maximum cases of abnormal configuration of P-wave was noticed (59.38%), followed by low voltage QRS complex 36.00% in QRS complex morphology and tall T-wave (23.81%) was found predominantly in T-waves morphology. Cardiac disorders are often omitted by clinicians and pet parents in our country due to lack of awareness. As there is no single test to diagnose cardiac disorders, ECG along with auscultation of heart can be beneficial tools for early detection of cardiac conduction defects in canines.

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