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Smart Phone Based Electrocardiography in Dogs – A Newer Concept in Veterinary Cardiology

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ABSTRACT

With the advancements in veterinary cardiology, ECG has become a basic diagnostic aid and its role in primary diagnosis is becoming more and more important. Though there are multiple conventional electrocardiograms available with different specifications and price, use of smart phone based technology in recording ECGs in veterinary patients is a welcomed technology. This device is simple, handy and provides information that helps in assessment of heart rate, rhythm, conduction abnormalities and arrhythmias. In the present study, the smart phone device was used to trace ECG by placing onto the back of an iPhone or any android phone and / or by placing the phone close to the electrodes and recorded a single lead ECG for 30 seconds. Elevated R wave amplitude, deep S wave, deep Q wave, elevated T wave amplitude, electrical alterans, atrial fibrillation, bradycardia, ventricular tachycardia, ventricular premature complex, deep Q and elevated R wave, wide P wave, low voltage QRS complexes, absence of P wave, wide QRS, ST coving, fine atrial fibrillation, bradycardia with low voltage QRS complexes, deep T wave were the significant abnormal tracings recorded using smartphone based ECG device. Hence, it may be concluded that the smartphone base ECG device might be an alternative for conventional ECG with cables to record various abnormalities and cardiac arrhythmias.

HIGHLIGHTS

- Present study signifies the clinical utility of Smartphone based ECG device in dogs.
- The device evaluates various heart abnormalities including arrhythmias in dogs.

Keywords: Smart phone based electrocardiography, Dogs

Diagnosis and management of various cardiovascular diseases in pet animals is still a difficult task in the face of the veterinarian (Haritha *et al.,* 2017a). 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. Electrocardiography is a basic, non invasive tool for diagnosis of heart diseases in dogs which is currently carried out by the standard ECG units with associated cables and electrodes (Bhonge *et al.,* 2001; Haritha *et al.,* 2017a). The smart phone based ECG device is economical (Rs. 9000/- approximately) and compact that can be carried easily and may be very useful to small animal practitioners for rapid cardiac evaluation, particularly heart rate and rhythm abnormalities. The application of smart phone technology for ECG recording has been demonstrated among various species from various parts of the world (Mueller and Orvalho, 2013;

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Vezzosi *et al.,* 2016; Vezzosi *et al.,* 2018; Bonelli *et al.,* 2019; Smith *et al.,* 2016), but currently no studies have put on record from India.

MATERIALS AND METHODS

Dogs of various breed and gender that were referred to Veterinary Clinical Complex of College Veterinary Science, Rajendranagar, Hyderabad with signs suggestive of cardiac involvement were considered for electrocardiographic assay using smart phone based ECG. Unlike the traditional machine, the smart phone based ECG (sECG), the AliveCor Veterinary Heart Monitor is a plastic case with two metal electrodes (Fig. 1) that can either be fixed onto the back of an iPhone or any android phone or can be used separately by placing the phone close to the electrodes (Fig. 2A). The left cardiac area (between 3-5 ICS) is trimmed, moistened with conduction gel or alcohol and the smart phone device was positioned on the left chest wall, just caudal to the olecranon (precordial area), with a slightly dorso-cranial-ventro-caudal orientation (Fig. 2B). A single lead sECG was recorded for 30 seconds in an unsedated dog either on right lateral recumbancy or in standing position, at 25 mm/s. The recorded sECGs were automatically digitised by the device and stored as a PDF, which can subsequently be analysed on a computer and interpreted as described by Tilley and Goodwin, (2001).

Fig. 1: Smart phone based ECG device

RESULTS AND DISCUSSION

A total of 250 dogs were presented at cardiology ward, Veterinary Clinical Complex of the College of Veterinary Science, Rajendranagar, with the signs suggestive of cardiac disease viz., exercise intolerance, lethargy, dyspnoea at rest, nocturnal cough, ascites / pedal edema and cyanosis. Out of which 187 dogs of various breed and gender has shown different abnormal tracings on a smartphone-based ECG device. There was no resistance from the patient as there is no physical restraining procedure involved.

Table 1: Number and percentage of cases showing abnormal ECGs recorded using smart phone based device

Sl. No	ECG finding	No of Cases (n=187)	% of Cases
1	Elevated R wave amplitude	31	16.57
2	Deep S wave	20	10.69
3	Deep Q wave	17	9.09
4	Ventricular tachycardia	15	8.02
5	Deep Q and elevated R wave	15	8.02
6	Low voltage QRS complexes	12	6.41
7	Electrical alterans	11	5.88
8	Elevated T wave amplitude	10	5.34
9	ST coving	8	4.27
10	Ventricular premature complex	7	3.74
11	Wide QRS	7	3.74
12	Atrial fibrillation	7	3.74
13	Ventricular premature complexes with atrial enlargement	6	3.20
14	Wide P wave	5	2.67
15	Fine atrial fibrillation	4	2.13
16	Absence of P wave	4	2.13
17	Conduction blocks	3	1.60
18	Bradycardia	3	1.60
19	Deep T wave	2	1.06

Further, the patient resistance associated with the trauma caused by crocodile clamps (modified) is absolutely absent as the device is simply placed on the cardiac area, which was easy and comfortable for both the patient and the examiner. The various electrocardiographic abnormalities detected on a smartphone-based device in the present study are shown in Fig. 3 to Fig. 5 that include, elevated R wave amplitude, deep S wave, deep Q wave, elevated T wave amplitude, electrical alterans, atrial fibrillation, bradycardia, ventricular tachycardia, ventricular premature complex, deep Q and elevated R wave, wide P wave, low voltage QRS complexes, absence of P wave, wide QRS, ST coving, ventricular premature complexes with atrial enlargement, fine atrial fibrillation, conduction blocks and deep T wave (Table 1). The ECG tracings obtained in the present study by smart phone- device were adequate enough for accurate assessment of heart rate, rhythm and common arrhythmias and represents a simplified, compact additional tool in the diagnosis of arrhythmias in dogs, but

Fig. 2: Recording of sECG; **(A)** Placing the phone close to the device that is placed at the cardiac area; **(B)** Placing the phone that is already fixed with the device

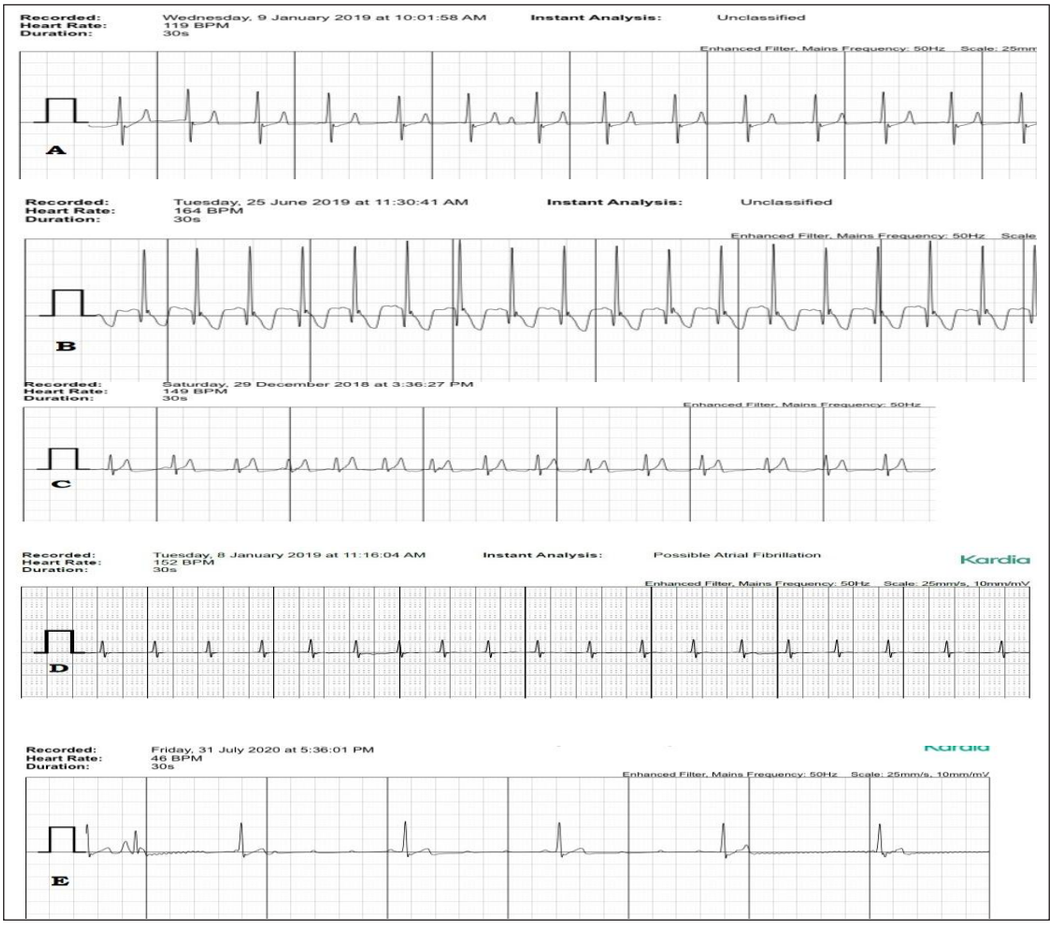

Fig. 3: Various ECG abnormalities recorded using smart phone device; **(A)** Deep S wave (>2 mv) and absence of P wave; **(B)** Elevated R wave amplitude (>2.5 mv) and tachycardia; **(C)** Elevated T wave; **(D)** Fine atrial fibrillation; **(E)** Third degree AV block with junctional escape

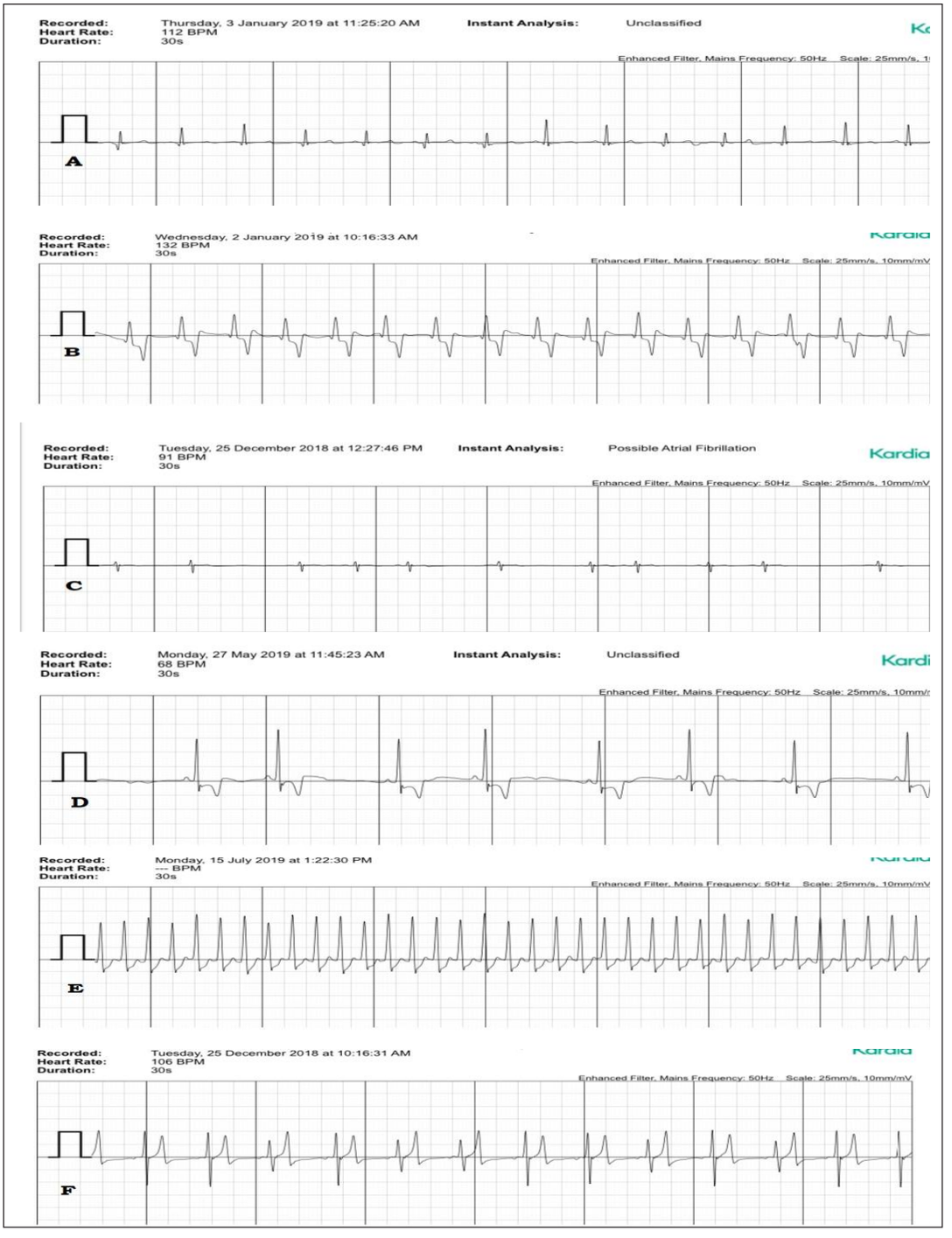

Fig. 4: Various ECG abnormalities recorded using smart phone device; **(A)** Wavy pattern of R wave amplitude -Electrical alterans; **(B)** Deep T wave and ST coving; **(C)** Low voltage QRS complexes; **(D)** ST coving or Kinking of ST segment; **(E)** Ventricular tachycardia (HR > 280 bpm); **(F)** Ventricular bigemini of right ventricle origin

may not be a substitute for a 6-lead ECG. However, various underlying cardiac disorders were further confirmed on echocardiography.

The different electrocardiographic tracings detected in the present study using a smart phone based device was similar to those documented using a conventional electrocardiogram by various authors (Haritha *et al.,* 2017a). Elevated R wave amplitude more than 3 mv is suggestive of left ventricular enlargement, is a feature of dilated cardiomyopathy in dogs. Whereas, ST slurring or coving could be associated with myocardial injury. Deep S wave characterized by the increased S wave amplitude is associated with right ventricle enlargement commonly seen in heart failure of right side origin. Increase in the amplitude of P wave more than 0.5 mv and R wave amplitude more than 3.0 mv is associated with atrio-ventricular enlargement (Martin, 2002). Deep Q waves or Q dip are characterized by Q wave amplitude more than 0.5 mv and indicates right ventricle enlargement and whereas, increased R wave amplitude with increased Q wave amplitude is suggestive of biventricular enlargement. The heart rate is usually normal and the rhythm is irregular due to the premature P wave that disrupts the normal P wave rhythm. The ectopic P wave is premature and its configuration is different from that of the sinus P waves. It may be negative, positive, diphasic or superimposed on the previous T wave (Tilley and Goodwin, 2001). The author suggested that this ECG abnormality can be associated with atrial enlargement secondary to chronic atrioventricular valvular insufficiency. Wide P wave also termed as P mitrale is characterized by the presence of P wave with duration more than 0.04 s and is suggestive of left atrial enlargement and animals showing this abnormality may also be associated with the signs of left sided heart failure (Tilley and Goodwin, 2001). Dukes McEwan (2000) reported that P mitrale could be seen in chronic mitral valve insufficiency and dilated cardiomyopathy.

R wave amplitude less than 0.5 mv also termed as low voltage QRS complexes is accompanied by pericardial / pleural effusion or ascites (Martin, 2002). Ventricular tachycardia is associated with enlargement and failure of biventricles more commonly in Doberman Pinchers and Boxer breed dogs (DeFrancesco, 2002). Yamaki *et al.* (2007) reported that ventricular extra systoles and ventricular tachycardia were the common ECG abnormality detected in dogs with idiopathic dilated cardiomyopathy. Absence of P wave also termed as atrial stand still or silent atrium is associated with mitral valve insufficiency (Jeyaraja *et al.,* 2004 and Haritha *et al.,* 2017a). Wide QRS is characterized by increased width of QRS complex greater than 0.08 sec and a positive R wave. This abnormality is associated with dilative form of cardiomyopathy (Tilley and Goodwin, 2001). Shifting of the pacemaker between the SA node and AV junction causes a gradual change in the configuration of the P wave, which becomes positive, biphasic, iso-electric and negative. P pulmonale, which is characterized by a tall P wave whose amplitude is more than 0.4 mv and indicates right atrial enlargement. Whereas, increased both amplitude and duration of P wave indicates biatrial enlargement. Dogs with right atrial enlargement are associated with the signs of right sided heart failure like ascites and hepatomegaly (Ristic, 2004). Ajit Kumar *et al.* (2003) and reported a case of Cor pulmonale in which the ECG abnormality was increased P wave amplitude and elevated ST segment. Hyperkalemia (more than 5.5 mEq/l) is suggestive of T wave amplitude more than 25 % of the R wave (Jeyaraja *et al.,* 2004; Hanton *et al.,* 2007), with myocardial infarction as was diagnosed in a Pomeranian dog (Changkija *et al.,* 2006).

Presence of multiple wave shaped Ps between consecutive QRS complexes is termed as fine atrial fibrillation. Atrial fibrillation is a common arrhythmia in dogs and is accompanied by ventricular tachycardia (Noszczyk *et al.,* 2008). Junctional premature complexes recorded in the present study is characterized by irregular rhythm associated with premature P waves, negative P waves and is associated with mitral valve insufficiency (Haritha *et al.,* 2017). Ventricular premature complexes are characterized by bizarre shaped QRS complexes, usually accompanied by a tall T wave and absence of P wave. Ventricular premature complexes originate from the ventricles and are commonly seen in chronic mitral valve insufficiency and dilated cardiomyopathy. Gupta *et al.* (2005) documented ventricular premature complexes with bizarre QRS complexes in dogs suffering with congestive heart failure. Deep T wave characterized by large negative T wave whose amplitude is more than 25 % of R wave and is associated with left sided congestive heart failure and left ventricle enlargement (Bhonge *et al.,* 2001).

The findings in the present study are in accordance with Haritha *et al.* (2017), who opined that ECG showing

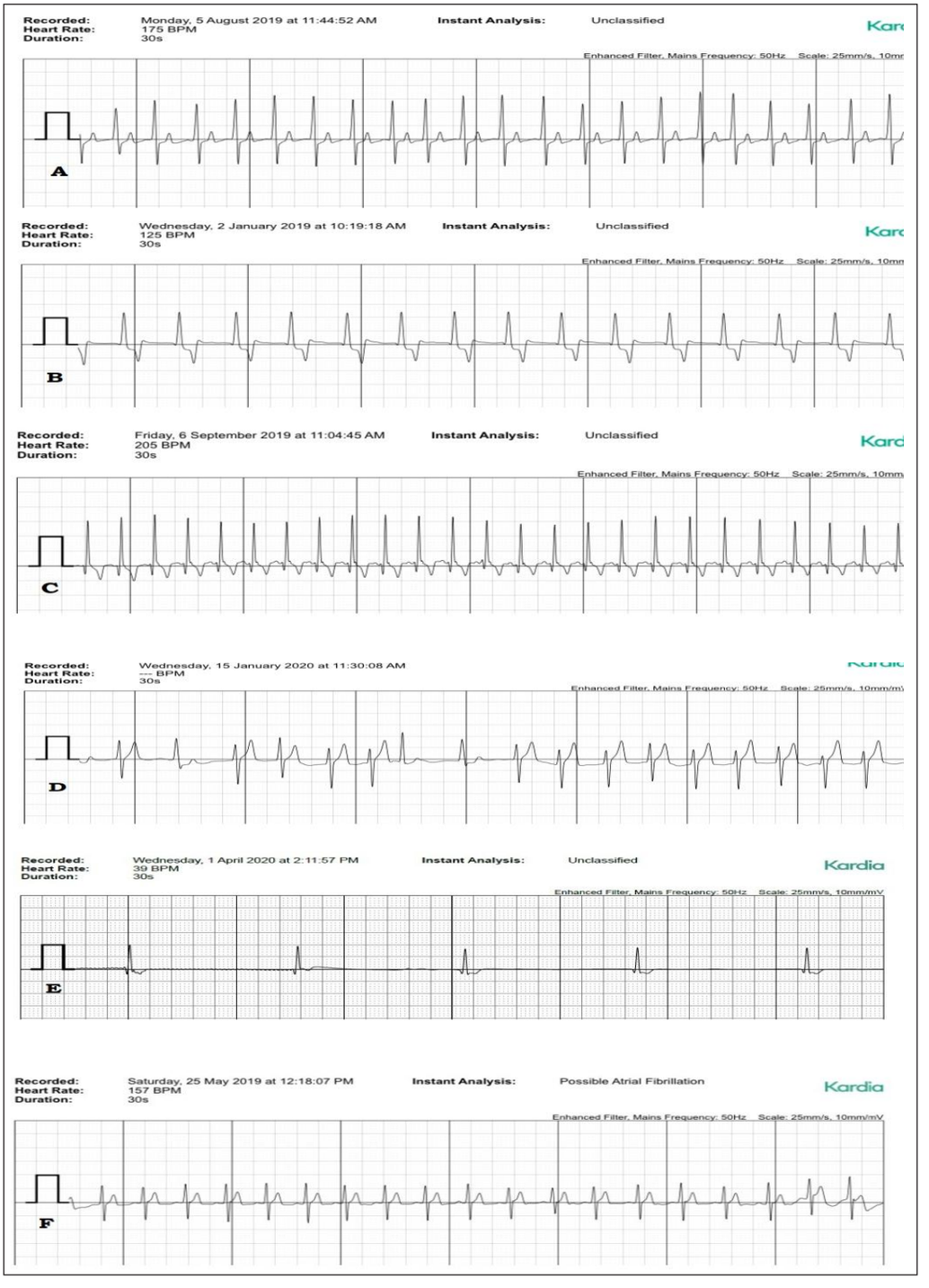

Fig. 5: Various ECG abnormalities recorded using smart phone device; **(A)** Deep S (>1 mv) and tachycardia; **(B)** Unclear or absence of P wave - Sick sinus; **(C)** Ventricuar tachycardia and Electrical alterans; **(D)** Ventricular premature complexes; **(E)** Bradycardia with possible atrial fibrillation; **(F)** Deep S wave with tachycardia

chamber enlargement and ventricular premature complexes are the common findings in heart failure dogs that are commonly recorded using conventional ECG machine. Some arrhythmias may be considered to be quite benign and may represent physiological variants. Such rhythms include sinus bradycardia and second degree atrio-ventricular block in healthy dogs. Other arrhythmias like ventricular fibrillation or asystole can be rapidly fatal. Arrhythmias may be significant in their ability to compromise cardiac function or as indicators of an underlying disease. Brady arrhythmias may lead to a heart rate so low that homeostatic mechanisms are unable to increase stroke volume sufficiently to compensate. When the heart rate is pathologically elevated as in tachyarrhythmia, the heart rate may be increased above a level where the ventricle is able to fill normally. The decreased periods of time spent in diastole results in compromised ability of the ventricle to fill, leading to a fall in stroke volume. The marked increase in heart rate increases the myocardial oxygen demanding a situation where the myocardial perfusion is reduced. So a chronically elevated heart rate causes a "cardiomyopathy of arrhythmia". Ventricular arrhythmias may compromise stroke volume when the ventricle no longer depolarizes in the normal pattern. When the ventricle is depolarized from an ectopic focus, ventricle is not able to contract efficiently, ultimately leading to a fall in cardiac output. The findings in the present study are in accordance with Rao *et al.* (2007) and Haritha *et al.* (2017) who reported that increased amplitude of R wave, deep Q/S wave, sinus tachycardia, ventricular premature complexes and atrial fibrillation were the most common ECG abnormalities in dogs with DCM associated CHF dogs.

CONCLUSION

ECG tracing recorded in the present study using smart phone based device revealed various abnormalities that are suggestive of cardiac disease among dogs which were previously documented using a conventional ECG machine. Further, it may be concluded that the tracings of a smart phone device is easy, simple and of same diagnostic quality in dogs. Hence, the device can be used for hassle free evaluation of heart rate, rhythm, dilatation of various chambers and conduction abnormalities like AV blocks.

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