# CHAPTER 1 INTRODUCTION

## 1.1 Research Background

Chronic kidney disease (CKD) is characterized as a sustained decline in kidney function over at least 3 months. It is a heterogeneous condition resulting in loss of functional renal mass. Congenital or acquired disorders in veterinary patients may lead to CKD development. Acute kidney damage (single or recurrent episodes) secondary to urinary obstruction, nephrotoxins, pyelonephritis, or ischemic injury may also lead to CKD. The disease syndrome is a significant cause of morbidity and mortality in cats (Finch *et al*., 2016). Chronic kidney disease is the end result of a broad range of primary disorders that cause irreversible nephron damage, leading ultimately to a decreased glomerular filtration rate (GFR). A particular underlying cause can be found in a minority of cases, such as neoplasia, polycystic renal disease, renal amyloidosis, hypercalcaemic nephropathy. However, no primary cause can be identified in the majority of cases (Cannon, 2016). Clinical signs usually become multisystemic as the illness progresses (Saftencu and Solcan, 2016).

Estimation of the overall prevalence of feline CKD ranged from 1% to 3% to 50%, indicating variations in patient populations, such as age and diagnostic criteria. Though many cats with CKD are likely to die of non-renal causes, 4% of cats dying at 1 to 5 years of age and 17% of cats dying at 11 years of age were the cause of death during a necropsy study of renal disease. Mortality was due to renal disorders in 12.1% of cats in a review of longevity in companion animals in the United Kingdom, with this diagnosis being the most common, 13.6%, reported cause of mortality in cats at or after 5 years of age. Feline CKD is a regular condition brought to a veterinarian for review in clinical practice and is the most common metabolic disorder in cats (Brown *et al*., 2016). Furthermore, a study has been conducted and revealed that 81.1% mortality rate of cats diagnosed with CKD from the year 2016 until 2017 in Malaysia (Manoraj, 2018).

Since the kidneys play a pivotal role in regulating body fluids, electrolytes and acid-base balance, CKD is likely to lead to several disorders, including hyperkalaemia, metabolic acidosis and hyperphosphatemia, resulting in serious complications such as muscle wasting, bone mineral disease/disorder, vascular calcification and mortality (Dhondup and Qian, 2017). The kidneys are involved in homeostasis of the entire body, so CKD affects many organ systems, are associated with many metabolic disorders, and affects general well-being (Bartges, 2012). In addition, CKD is associated with a significantly increased risk of cardiovascular events and mortality (Kestenbaum *et al*., 2007).

Recent studies and ongoing researches have shown that patients with kidney problems begin to develop cardiac problems, scientifically known as the Cardio Renal Syndrome (CRS), which in the last stages of their diseases can lead to a sudden cardiac arrest (Rahman *et al*., 2019). Number of tests can be used to easily predict the CKD nowadays. Therefore, the affected kidney can also be found by detecting the presence of CKD using the electrocardiogram (ECG) signals and then the computed tomography (CT) scan images. The dynamic changes in CKD patients can be observed by the ECG (Arulanthu and Perumal, 2019).

The ECG can be used to measure the magnitude of electrolyte imbalances and to determine whether severe arrhythmias are likely to occur (Ecgwaves.com, 2020). Due to their function in muscle contraction, nerve conduction and water balance, alterations in electrolyte concentrations can have important implications. Significantly increased concentrations of serum potassium can lead to cardiac arrhythmias. Dehydration and shock can result from excessive loss of sodium and chloride (Ruotsalo and Tant, 2017).

The ECG provides a description of the electrical activity of the heart and is an integral part of a clinical assessment. Thus, in small animal practice, the ECG is widely used to diagnose conduction irregularities such as cardiac arrhythmias. During the production of the electrical impulse, these disorders are major changes and can occur in the face of specific cardiac conditions such as valve, ischemic, or traumatic diseases, cardiomyopathies, systemic diseases (electrolytic, neurological, and gastrointestinal abnormalities), as well as in patients with systemic infections (Camacho *et al*., 2010).

The invention of ECG recordings had led to human findings that cardiac conduction and repolarization depend on serum electrolyte concentrations. Today, electrolyte abnormalities have well-known effects on ECG recordings, including hypokalaemia, hyperkalaemia, hypocalcaemia, hypermagnesemia and others, and may cause extreme rhythm disruptions and death. Nevertheless, no big, systematic study has so far connected electrolyte concentrations with particular ECG intervals in the general population (Olshansky and Bhattacharya, 2019).

Based on the elaboration given, the author decided to do this research on the electrocardiography (ECG) evaluation on chronic kidney disease (CKD) in cats. Nevertheless, this may allow veterinarians to detect or recognize patients with CKD that shows any abnormalities in the ECG readings.

## 1.2 Problem Statement

Does the chronic kidney disease (CKD) affect the electrocardiography (ECG) reading in cats?

## 1.3 Research Objective

The purpose of this research is to evaluate the electrocardiography (ECG) reading changes on cats with chronic kidney disease (CKD).

## 1.4 Research Benefits

### 1.4.1 Theoretical outcome

This research is expected to provide useful information to readers regarding the benefit of using of electrocardiography (ECG) machine in evaluation on chronic kidney disease (CKD) in cats.

### 1.4.2 Practical outcome

It is expected that this study will be:

a. Use of help in treating chronic kidney disease as well as detecting kidney diseases thus proper management will be given to cats.
b. To increase awareness to practicing veterinarians in incorporating ECG in small animal practices.

## 1.5 Theoretical Basis

Both in health and sickness, the cardiovascular and renal systems interact in a complicated way. The pathogenic connections between these two organ systems in humans are becoming more and more in need of classification, characterization, and explanation. Cardiorenal syndrome (CRS), a pathophysiological disorder of the heart and kidneys in which acute or chronic failure in one organ adversely affects the other, is caused by a variety of multifactorial mechanisms that are not limited to hemodynamic parameters (extracellular fluid volume, cardiac output, arterial pressure, and so on) (Kingma *et al*., 2017). Based on Pouchelon *et al*. (2015), there are five subdivisions of CRS as shown in Table 1.1.

| CRS subdivisions | Definition |
|---|---|
| Type 1 | Acute worsening of heart function leading to kidney injury, such as in patients with acute congestive heart failure (CHF) |
| Type 2 | Chronic heart disease leading to kidney injury, that occurring in patients with chronic heart failure |
| Type 3 | Acute worsening of kidney function which leads to heart injury, as seen in patients with acute kidney injury (AKI) |
| Type 4 | Involves chronic kidney disease (CKD) which then leads to heart injury |
| Type 5 | Involving systemic disease(s) that can leads to a simultaneous injury of both heart and kidney organs, such as sepsis, systemic hypertension or amyloidosis |

**Table 1.1** CRS sub-division and its definition

Currently, in veterinary industry, the CRS is defined as cardiovascular-renal disorders (CvRD) by the CRS Consensus Group (Martinelli *et al*., 2016). The CvRD is defined as disease, toxin or drug-induced structural and/or functional damage to the kidney and/or cardiovascular system, leading to disruption of the normal interactions between these systems, to the ongoing detriment of one or both. Table 1.2 shows there are few subgroups in CvRD. These three categories can be further subdivided into stable disease (S) or unstable disease (U) based on the patient's clinical presentation (Pouchelon *et al*., 2015).

| CvRD subgroups | Definition |
|---|---|
| $CvRD_H$ | Kidney injury or dysfunction emanating from a primary disease process involving the cardiovascular system |
| $CvRD_K$ | Cardiovascular injury or dysfunction emanating from a primary disease process involving the kidney. |
| $CvRD_O$ | Kidney and cardiovascular injury or dysfunction emanating from either a primary disease process outside the two systems or instances in which primary kidney and cardiovascular diseases coexist |

**Table 1.2** CvRD subgroups and its definition

Pouchelon *et al*. (2015) also stated that although renal and heart illness are well-known causes of morbidity and mortality in domestic dogs and cats, the veterinary profession has yet to clearly identify and describe the relationship between the two systems. Based on the experience in cardiovascular and renal illness, the clinical manifestations of CvRD in dogs and cats are expected to be incredibly varied among individuals and between species, precluding their description as a single clinical syndrome. Despite the absence of precise information on the pathophysiology of CvRD in veterinary medicine, the research currently accessible points to the likelihood that the pathophysiology of CvRD in animals exhibits some similarities to the pathophysiology of CRS in humans.

On the other note, a good ECG recording technique is very important as interference/artifact can hinder diagnosis and, at worst, causes misinterpretation. Electrical interference, such as clippers, or movement may cause artefacts. Patient should be as relaxed as possible to optimize the recording. The gold technique standard notes that the patient should be on a padded bed in right lateral recumbency, with the limbs kept slightly apart to prevent movement artefacts as shown in Figure 1.1. Positioning is not as critical in cats, it has been suggested, which may help improve patient compliance. If the patient is dyspnoeic, sternal recumbency should be used, so as not to further compromise respiratory effort. The electrodes should be positioned on all four limbs as stated in Table 1.3, behind the elbows and in front of the stifles. In fact, this is not always practical if a cat has an intravenous catheter bandage. It may be sufficient to attach the electrodes close to the limbs in cases like these. Poor contact between the patient and the electrodes is a common cause of artefacts. It is possible to use different types of electrodes, such as crocodile clips (should be filed down to avoid causing pain), comfortable clips (no teeth but merely adhere to the skin) or sticky adhesive pads. Selection should be driven by patient comfort and ease of use. In order to enhance contact, a conduction agent such as electrode gel or surgical spirit should be used. The surgical spirit works faster and is easier to clean, but if defibrillation is needed, it is flammable (Pace, 2020).

The number of cables varies with the ECG machines, most usually 3, 4, or 5, but some may have more. Electrodes create a triangle of leads in the heart muscle that measure electrical potential. If there are only three electrodes and cables in a machine, then the trace of the ECG can only be seen in one of those leads, as the third electrode behaves like the earth. For instance, the operator can select lead I, II or III on a multi-parameter anaesthetic system, but not display all three at the same time. If the system has four or more electrodes, however, the trace of ECG can be viewed simultaneously in three leads (I-III) or in six leads (aVR, aVL and aVF) since the fourth cable functions as the earth. It is recommended to record the trace as such if the machine has 6 lead capabilities, so that a more in-depth interpretation is possible if needed (Pace, 2020). Figure 1.2 shows an illustration of an animal showing the three bipolar frontal plane leads (I, II and III) and Einthoven's triangle (red). In lead I, the right foreleg (RA) is negative and the left foreleg (LA) is positive. In lead II, the right foreleg (RA) is negative and the left hind leg (LL) is positive. In lead III, the left foreleg (LA) is negative and the left hindleg (LL) is positive. The net depolarization moving through the ventricles (green arrow) is normally oriented toward the left hind leg (the positive pole of lead II) in dogs and cats, and thus the QRS complex is predominantly positive in lead II. When using ECG machines that utilize four electrodes, the electrode placed on the right hind leg is the ground (it is not part of any of the leads) (Sleeper, 2020).

Kidneys play a crucial role in regulating body fluids, electrolytes and acid-base balance, CKD and end-stage renal disease (ESRD) are likely to contribute to several disorders, including hyperkalaemia, metabolic acidosis and hyperphosphatemia, leading to severe complications, including muscle wasting, bone-mineral disorder, vascular calcification and mortality. Therefore, with gradual loss of kidney function, electrolyte and acid-base distortions eventually occur and lead to poor patient outcomes (Dhondup and Qian, 2017).

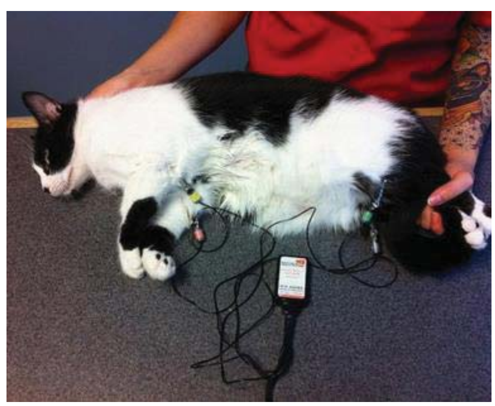

**Figure 1.1** Gold standard of ECG position (Brewer *et al*., 2019)

| Electrode | | Colour | |
|---|---|---|---|
| | | British machines | American machines |
| Right | Forelimb | Red | White |
| | Hindlimb | Black | Green |
| Left | Forelimb | Yellow | Black |
| | Hindlimb | Green | Red |

**Table 1.3** Electrode placements (Pace, 2020)

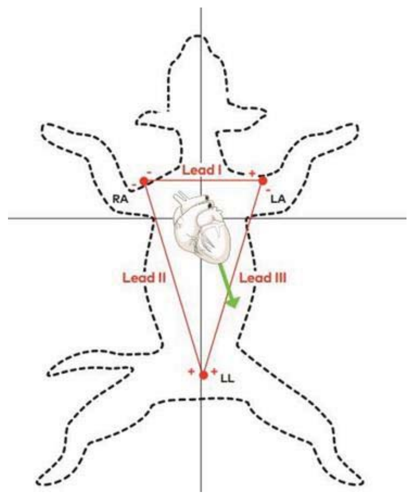


**Figure 1.2** Three bipolar frontal plane leads (I, II and III) and Einthoven's triangle (red) (Sleeper, 2020)