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# PROPOSED SIMPLE METHOD FOR ELECTROCARDIOGRAM RECORDING IN FREE-RANGING ASIAN ELEPHANTS (*ELEPHAS MAXIMUS*)

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*Abstract:* Electrocardiography represents a relevant diagnostic tool for detecting cardiac disease in animals. Elephants can present various congenital and acquired cardiovascular diseases. However, few electrophysiologic studies have been reported in captive elephants, mainly due to challenging technical difficulties in obtaining good-quality electrocardiogram (ECG) tracings, and no data are currently available for free-ranging Asian elephants (*Elephas maximus*). The purpose of this pilot prospective study was to evaluate the feasibility of using a simple method for recording ECG tracings in wild, apparently healthy, unsedated Asian elephants ($n = 7$) in the standing position. Successful six-lead recordings (I, II, III, aVR, aVL, and aVF) were obtained, with the aVL lead providing the best-quality tracings in most animals. Variables measured in the aVL lead included heart rate, amplitudes and duration of the P waves, QRS complexes, T and U waves, and duration of the PR, QT, and QU intervals. A negative deflection following positive P waves, representative of an atrial repolarization wave (Ta wave), was observed for five out of the seven elephants.
*Key words:* Asian elephant, electrocardiography, *Elephas maximus*, free-ranging, Ta wave, U wave.

## INTRODUCTION

Electrocardiography consists of recording electrical cardiac activity over time, and providing a graphic record, known as an electrocardiogram (ECG), of the sequential, electrical depolarization–repolarization patterns of the heart. Electrocardiography is a valuable noninvasive method for monitoring heart rate, arrhythmias, and conduction abnormalities and also may provide information regarding cardiac chamber enlargement and hypertrophy. It is therefore commonly used as a complementary exam to assess small and large animals with acquired and congenital heart diseases.[22,23]

Reports have indicated that elephants may present various cardiovascular diseases, potentially leading to sudden death or death from congestive heart failure.[2,17] Noninfectious acquired cardiovascular diseases, including dilated or hypertrophic cardiomyopathies and arteriosclerosis lesions mainly involving the aorta, the coronary arteries, and the aortic branches have been described.[2,17] Virally induced myocarditis also has been reported, related to *Picornaviridae* or West Nile virus infections.[2,17] Electrocardiography (ECG) is therefore an appropriate diagnostic tool to detect the electrophysiologic alterations associated with such cardiac issues. However, ECGs are not recorded routinely in elephants, as acquiring good-quality tracings represents a technical challenge owing to the large size of these animals, their skin thickness, frequent movement-induced artifacts, and the low-amplitude electric signals. Few electrophysiologic studies have been reported in

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elephants, and to date, all involved captive African (*Loxodonta africana*) or Asian (*Elephas maximus*) elephants.[2,3,8,9,11–13,15–17,24]

The Elephant Valley Project (EVP) is a sanctuary established specifically for Asian elephants in the eastern Cambodia province of Mondulkiri. Its main aim is provision of an alternative approach to caring for elephants in their natural environment, and to retire and rehabilitate working elephants. Many of these animals enter the center dehydrated, emaciated, and overworked. In the EVP, they are provided with a large area of forest isolated from human activity and given supportive medical care as needed.

The objectives of the present study were therefore to evaluate the feasibility of using a simple method for ECG recording on free-ranging nonsedated Asian elephants housed at the EVP, and to describe the corresponding ECG patterns and values.

## MATERIALS AND METHODS

Seven free-ranging Asian elephants (1 male, 6 females) were involved in the study. Their ages (mean ± SD: 46.86 ± 8.84 yr) ranged from 38 to 61 yr. All the animals had a history of being overworked, although at the time of the study, all were apparently healthy based on a physical examination. Tuberculosis tests (DPP® VetTB Assay for Elephants, Chembio Diagnostic Systems, Inc., Medford, New York 11763, USA) were negative but the elephants had been neighbors to a positive animal, which since has been isolated. All examinations were carried out in the elephants' natural environment of the Mondulkiri forest. The animals were kept calm and steady by a mahout, and optimal stillness was maintained by feeding bananas during the ECG recordings. All recordings were performed on nonsedated animals in standing position.

ECGs including six-lead recordings (I, II, III, aVR, aVL, and aVF) were obtained using an automatic recorder (Cardimax FX-7202, Fukuda Denshi, Bunkyo-ku, Tokyo 113-8483, Japan), standardized at 20 mm = 1 mV with a chart speed of 25 mm/sec. Four alligator clip electrodes (Hirschmann Test and Measurement, Hirschmann 09366 Niederdorf, Germany), similar to those used for ECG recording in medium- to large-breed dogs, were placed on areas where the skin was thinnest as follows: two on the cranial ventral thorax just caudal to the forelimbs, and two immediately cranial of the hind limbs attached to the inguinal folds (Fig. 1). A thick layer of ultrasound gel (Aquasonic® 100 Ultrasound Gel, Parker Laboratories Inc. Fairfield, New Jersey 07004, USA) was applied in each area after the placement of the alligator clip to ensure adequate clip-to-skin contact. The electrodes could be easily removed after the procedure by pulling on the attached cables, and no signs of secondary skin lesions or irritation were apparent. The standard nomenclature and methods of ECG interpretation were adopted.[22,23] As the aVL lead provided the best-quality tracings in most elephants, three well-defined cardiac cycles were selected in aVL for each animal in the study with the average of three values calculated for each ECG variable. If three consecutive beats could not be analyzed, owing mostly to artifacts due to animal movements, a nonconsecutive beat was substituted. The amplitude and duration of the P, QRS complexes, T, and U waves, as well as the duration of the PR, QT, and QU intervals were assessed using calipers. Amplitude of QRS was calculated by adding the absolute values of positive and negative deflection voltages of the QRS complexes. Lastly, three consecutive heartbeats were used to calculate the mean heart rate.

Data are expressed as mean ± SD and ranges. Descriptive statistical analyses were performed using the computer program Microsoft Excel (Microsoft Corporation, Redmond, Washington 98052, USA).

## RESULTS

Six-lead ECG recordings (I, II, III, aVR, aVL, and aVF) were collected successfully from all seven elephants included in the study, with the aVL lead providing the best-quality tracings. All elephants displayed a normal sinus rhythm (26–37 beats/mim) with a mean of 33 ± 4 beats/min. All animals showed a positive U wave of variable amplitude (0.01–0.1 mV) following a positive T wave. Typical morphologic patterns of P–QRS–T–U deflections obtained in aVL were recorded (Fig. 2). Means ± SDs and ranges of amplitude and duration of the P, QRS, T, and U waves, as well as the duration of the PR, QT, and QU intervals in aVL were measured (Tables 1, 2). Additionally, a negative deflection following positive P waves, representative of an atrial repolarization wave (Ta wave), was observed for 5 out of the 7 elephants (Fig. 2A, B).

## DISCUSSION

Electrocardiographic examinations are performed infrequently on Asian elephants. To date no data have been available on such animals in

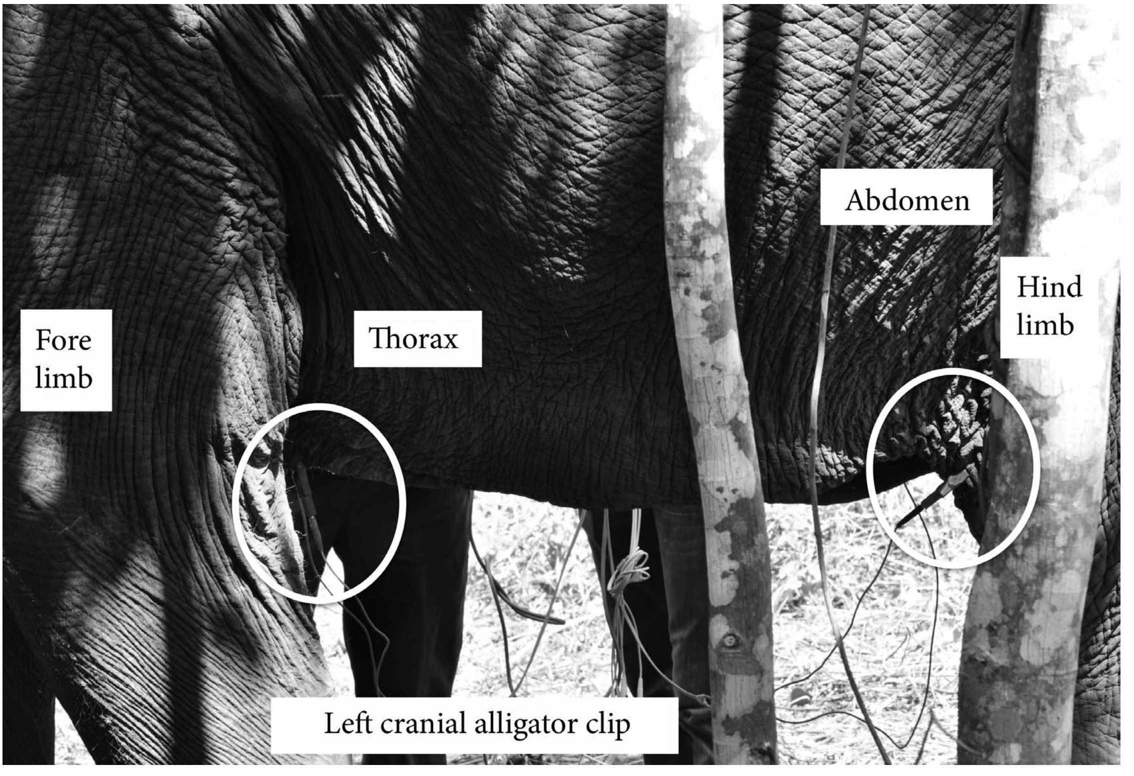


**Figure 1.** Position of the left alligator clips attached to cranio-ventral skin folds and inguinal folds in a standing, nonsedated, free-ranging 55-yr-old female Asian elephant (*Elephas maximus*) for measurement of EKG tracings.

their natural environment, due both to technical challenges and to the difficulties of restraining these animals without potential handler risk. The present pilot study shows that high-quality ECG tracings can be obtained in nonsedated free-ranging elephants by simply using alligator clips coated with a large amount of ultrasound gel and attached ventrally to thin skin folds at inguinal

**Table 1.** Age, body weight, and electrocardiogram (ECG) variables (mean of three values) of the six female (F) and one male (M) apparently healthy nonsedated free-ranging Asian elephants (*Elephas maximus*) in the standing position.

| Elephants | F1 | F2 | F3 | F4 | F5 | F6 | M1 |
|---|---|---|---|---|---|---|---|
| Age (years) | 52 | 55 | 43 | 36 | 60 | 40 | 42 |
| Approximate body weight (kg) | 3,250 | 2,700 | 3,600 | 3,200 | 3,450 | 2,480 | 3,540 |
| Heart rate | 35 | 26 | 33 | 26 | 37 | 35 | 36 |
| ECG variables | | | | | | | |
| P-wave duration (msec) | 0.20 | 0.16 | 0.19 | 0.18 | 0.18 | 0.16 | 0.16 |
| P-wave amplitude (mV) | 0.01 | 0.09 | 0.05 | 0.05 | 0.15 | 0.10 | 0.05 |
| PR-interval duration (msec) | 0.40 | 0.32 | 0.40 | 0.36 | 0.35 | 0.33 | 0.41 |
| QRS duration (msec) | 0.12 | 0.16 | 0.12 | 0.18 | 0.11 | 0.16 | 0.15 |
| QRS amplitude (mV) | 0.15 | 0.50 | 0.25 | 0.48 | 0.45 | 0.57 | 0.45 |
| QT-interval duration (msec) | 0.64 | 0.65 | 0.68 | 0.68 | 0.68 | 0.68 | 0.59 |
| T-wave duration (msec) | 0.22 | 0.23 | 0.28 | 0.22 | 0.26 | 0.20 | 0.23 |
| T-wave amplitude (mV) | 0.20 | 0.15 | 0.10 | 0.23 | 0.13 | 0.075 | 0.10 |
| U-wave duration (msec) | 0.20 | 0.20 | 0.20 | 0.20 | 0.24 | 0.24 | 0.20 |
| U-wave amplitude (mV) | 0.010 | 0.075 | 0.025 | 0.075 | 0.083 | 0.075 | 0.054 |
| QU-interval duration (msec) | 1.38 | 1.89 | 1.20 | 1.16 | 1.03 | 1.16 | 1.16 |

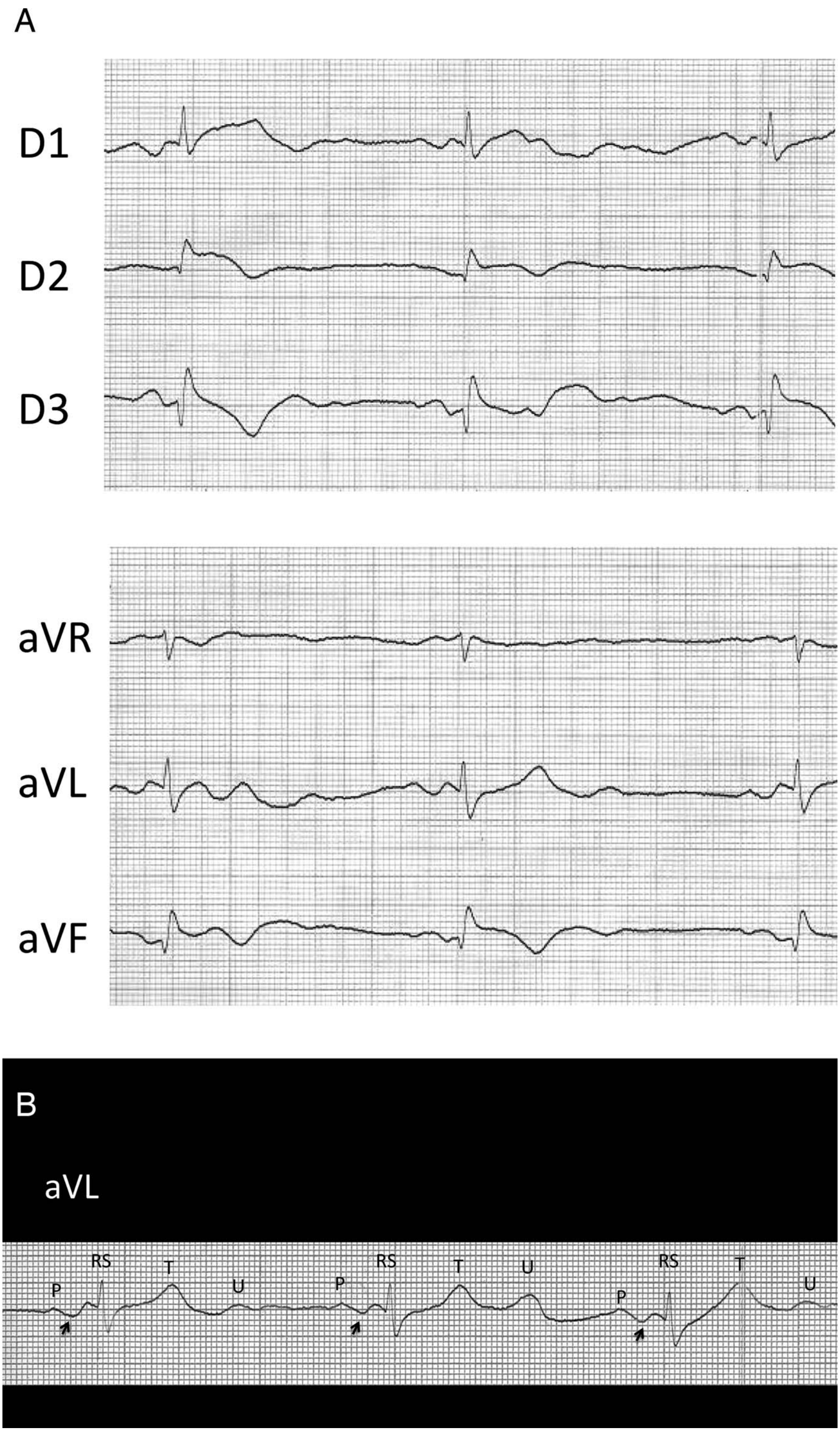


**Figure 2.** Electrocardiogram (six leads and aVL, **A** and **B**, respectively) recorded from a standing, nonsedated, free-ranging, 36-yr-old female Asian elephant (*Elephas maximus*) demonstrating a normal sinus rhythm and U wave (20 mm = 1 mV; 25 mm/sec). The arrows indicate negative deflections representative of Ta waves. Note the RS configuration (i.e., absence of negative Q wave, presence of positive R wave and negative S wave only) on aVL lead.

**Table 2.** Electrocardiogram (ECG) variables (durations, amplitudes and heart rate) measured on lead aVL from seven apparently healthy nonsedated free-ranging Asian elephants (*Elephas maximus*) in the standing position. Each variable was calculated 21 times (three measurements per elephant, seven elephants).

| ECG variables | Mean ± SD | Minimal–maximal values |
|---|---|---|
| P-wave duration (msec) | 0.175 ± 0.014 | 0.14–0.20 |
| P-wave amplitude (mV) | 0.073 ± 0.035 | 0.010–0.150 |
| PR-interval duration (msec) | 0.37 ± 0.033 | 0.30–0.40 |
| QRS duration (msec) | 0.14 ± 0.02 | 0.10–0.18 |
| QRS amplitude (mV) | 0.41 ± 0.12 | 0.150–0.575 |
| QT-interval duration (msec) | 0.66 ± 0.027 | 0.58–0.68 |
| T-wave duration (msec) | 0.23 ± 0.023 | 0.20–0.28 |
| T-wave amplitude (mV) | 0.14 ± 0.04 | 0.075–0.225 |
| U-wave duration (msec) | 0.21 ± 0.017 | 0.18–0.26 |
| U-wave amplitude (mV) | 0.056 ± 0.024 | 0.010–0.100 |
| QU-interval duration (msec) | 1.28 ± 0.20 | 1.00–1.92 |
| Heart rate (beats/min) | 33 ± 4 | 26–37 |

folds caudally and ventral thorax caudal to the forelimbs.

A previously published standardized procedure on 27 nonsedated captive Asian elephants used large Quick-Grip Handi-Clamp 20 curved bar clamps that had been modified to collect high-quality ECG tracings.[3] Such modified clamps are suitable for captive elephants, whereas the alligator clips used in the present study seem better adapted for free-ranging elephants, for which the material needs to be as light as possible and easier to use in field conditions.

Three animal positions were compared in the previously published report: standing position, and right and left lateral recumbencies.[3] As also demonstrated in dogs,[19] the animal's position was found to have a significant effect on several ECG variables, including both waveform amplitudes and interval durations. For example, lower heart rates, with U waves of lower amplitude, but P waves and QRS complexes of higher amplitude, were obtained when the animal was standing, rather than in lateral recumbency.[3] The two lateral positions could not be used in the present study of free-ranging elephants examined in their natural environment, so only the standing position was feasible to obtain ECG recordings.

In the previously published report, it was found that lead I consistently provided the best-quality tracings, whatever the animal's position, whereas the lead of choice in the current study was aVL.[3] This discrepancy between the two studies may be explained by differences between the types and locations of the cranial electrodes used for the ECG recordings.

Comparison of ECG values obtained on lead aVL in free ranging elephants with those measured in lead I for the captive elephants in the standing position revealed similar values for the six ECG durations (i.e., P wave, PR interval, QRS complex, QT interval, T wave, and U wave). In the free-ranging values, QU interval also was measured. Conversely, the amplitudes of all the ECG deflections apart from T wave (i.e., P wave, QRS complex, and U wave), were smaller in the free-ranging study as compared to those published for the captive elephants.[3] For example, the mean ± SD QRS amplitude was 0.84 ± 0.02 mV in lead I for captive elephants[3] versus 0.41 ± 0.12 mV in aVL for the free-ranging elephants in the present study. Similarly, the U-wave amplitude was 0.10 ± 0.04 mV in lead I for captive elephants[3] versus 0.056 ± 0.024 mV in aVL reported here. Again, the discrepancies between the two studies may be explained by the differences between both the types and locations of the electrodes used for the ECG recordings.

In captive Asian elephants, the standing position provided U waves of lower amplitude than left lateral recumbency.[3] Although all ECG tracings were recorded in the standing position, a positive U wave following a positive T wave in aVL was clearly identified in all seven elephants in the present study. The U wave was first described in humans by Einthoven in 1906, and is defined as a diastolic deflection following ventricular depolarization (QRS complex) and repolarization (T wave).[6,7,20] These waves have already been reported in captive African and Asian elephants measured in different positions, as well as in humans and other animals.[3,9,21] The precise origin of the U wave is still debated.[1,5,20,21] The initially suggested hypotheses were that this deflection would correspond either to a delayed repolarization of the subendocardial Purkinje fibers, prolonged repolarization of the midmyocardial cells, or an "after-potential."[1,5,21] One of the most widely accepted current explanations is that the T and U waves form a continuum, being the resultant of the same process of repolarization of the total ventricular myocardium.[20] Normal U waves usually have the same polarity as T waves, as was the case in the present study with both positive on aVL.

Lastly, as described in domestic horses (*Equus ferus caballus*), a negative deflection following positive P waves, representative of a Ta wave, was observed for five out of the seven elephants.[14] Ta waves are generated by the atrial repolarization process and are usually small in amplitude, so are hidden by the following QRS complex, and not detected using surface ECG tracings in most animal species and in humans.[4,10,18] These waves have never been reported in elephants before.

In conclusion, good-quality ECG tracings can be obtained in nonsedated free ranging Asian elephants using the simple method described here. Further prospective studies are needed to test the method in a larger number of free-ranging animals and provide the corresponding reference intervals.

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