Intracardiac electrophysiological conduction parameters in adult dogs

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ABSTRACT

Background: Invasive electrophysiology study (EPS) is one of the most important adjunct tests for the evaluation of arrhythmias in human medicine. However, EPS is neither well known nor widely used in veterinary medicine.

Objective: To define the values for intracardiac conduction parameters determined during invasive EPS in dogs.

Animals and methods: The study included 16 admitted dogs of various breeds, sex and ages and 6 control Beagles. In the Beagles, EPS was performed twice at 6-month intervals in order to verify the reproducibility of the results.

Results: No significant differences were found between the results of the baseline and repeated EPS performed in the Beagles. We found retrograde conduction in 13 (59%) out of 22 dogs and including 4 (31%) animals with concomitant ‘jumps’ in the atrioventricular node conduction curve, pointing to the presence of dual conduction in this node. The mean values of the AV and retrograde VA Wenckebach points equaled to 220 and 360 ms, respectively, suggesting that the capability of the descending route is higher than that of the ascending route.

Conclusion: The values determined in this study may be helpful in early detection of abnormalities in the electrical conduction system of the heart.

KEYWORDS

Dog; canine; arrhythmia; invasive electrophysiology; conduction system

Abbreviations

| Abbreviation | Definition |
|--------------|------------|
| AERP | atrial effective refractory period |
| AH | interval between the right atrium and His bundle |
| AV | anterograde, atrio-ventricular |
| AVNERP | atrioventricular nodal effective refractory period |
| CSNRT | corrected sinus node recovery time |
| EPS | electrophysiology study |
| ERP | effective refractory period |
| HRA-LA | interatrial conduction time |
| HRA-LA 150 | interatrial conduction time at an imposed rhythm 150 bpm |
| HV | interval between the His bundle area and ventricle |
| LA-HRA 150 | retrograde interatrial conduction at an imposed rhythm 150 bpm |
| PA | intraatrial conduction time |
| RF | radiofrequency |
| SNRT | sinus node recovery time |
| VA | retrograde, ventriculo-atrial |
| VERP | ventricular effective refractory period |

1. Introduction

Invasive electrophysiology study (EPS) is one of the adjunct tests performed routinely in humans with arrhythmia. EPS allows determination of an arrhythmia’s background, blockade of conduction at a critical site for a given rhythm disorder, and identification of abnormal electrical connection between the atria and ventricles (Josephson, 2002; Wellens, 2004, 2008). Conduction time, the principal parameter determined during EPS, enables analysis of the electrical impulse conduction velocity between various areas of the heart and the sequence of their depolarization. EPS requires specialist equipment, involvement of several appropriately trained professionals and, in the case of animals, anesthesia that results in greater invasiveness of the procedure and higher risk of complications. Probably due the aforementioned factors, EPS is not routinely performed in animals with a suspected arrhythmia. However, the progress in veterinary cardiology is reflected by a growing demand for additional diagnostic tests that might be a useful tool in patients with a suspected arrhythmia in whom routine, widely available procedures, such as resting electrocardiography, Holter electrocardiography, or long-term monitoring with a loop recorder, proved insufficient. Therefore, EPS might be a useful diagnostic option for veterinary patients with sporadic loss of consciousness, paroxysmal dyspnea, or a decrease in physical capacity of unknown origin. EPS is also very useful to further investigate and to monitor treatment of rhythm...
disturbances. In many species, such as pigs, goats, and dogs, EPS is performed in an experimental setting (Wright et al. 1996; Vos et al. 1998; Gepstein et al. 1999; Toshida et al. 2001; Coronel et al. 2002; Hocini et al. 2002; Wijffels et al. 2007; Nishida et al. 2011). Usually, EPS is performed to evaluate abnormalities of the electrical conduction system of the heart, to test the influence of various chemicals and medicines on this system, and to develop novel methods or improve existing protocols of non-pharmacological treatments of arrhythmia. In the case of dogs, apart from experimental purposes, EPS is usually performed in order to choose an appropriate (pharmacological or non-pharmacological) treatment or prior to, radiofrequency (RF) ablation (Santilli et al. 2006, 2010a, 2010b, 2011, 2012, 2013; Perego et al. 2012). To the best of our knowledge, determination of the electrophysiological conduction parameters for selected electrophysiological parameters of dogs was a subject of only few studies (Landmark & Amlie, 1976; Pickoff et al. 1983; Huerta et al. 1984; Sassine et al. 1984; Young et al. 1986; Timour et al. 1987; Traunecker, 1988; Wright et al. 1996). Contrary to human cardiology, detailed guidelines regarding indications for EPS in animals are lacking. Similarly, no standardized protocols of the initial physical examination and anesthesia regimen prior to EPS have been developed. This precludes comparative analysis of the data reported by various authors. Furthermore, the EPS procedures performed prior to RF ablation in dogs are simplified and differ markedly depending on the type of underlying arrhythmia.

The aim of this study was to define intracardiac conduction parameters in adult dogs determined during invasive EPS.

2. Animals and methods

2.1. Animals

The study included 22 dogs (six Beagles as a control group and 16 admitted dogs referred for cardiological examination due to arrhythmia found on auscultation by the referring veterinarian). All the dogs recruited to EPS were free from cardiovascular diseases and other conditions potentially affecting the electrical conduction system of the heart, e.g. thyroid and kidney disorders, diabetes mellitus, acute inflammation (especially myocarditis), and abnormal blood concentrations of electrolytes. In order to exclude these abnormalities, EPS was preceded by determination of a complete blood count, activity of ALT and AST, concentrations of urea, creatinine, glucose, magnesium (Mg²⁺), sodium (Na⁺), chloride (Cl⁻), potassium (K⁺), calcium (Ca²⁺), C-reactive protein, Troponin I (cTnI), Tₐₐₙ free Tₐₜ, and cholesterol as well as by resting electrocardiography, Holter electrocardiography, and echocardiography. In the case of six Beagles, EPS was performed twice at 6-month intervals in order to test the reproducibility of the results. In the case of the remaining dogs, EPS was performed once. However, in the 16 admitted dogs resting electrocardiography, Holter electrocardiography, and EPS did not reveal arrhythmias.

The protocol of the study was approved by the 2nd Local Bioethics Committee in Wroclaw (decision no. 7/2012 of 20 February 2012).

2.2. EPS technique

EPS was performed under general anesthesia. Self-adhesive electrodes were placed in order to obtain standard ECG records. The animals were premedicated with midazolam (0.2–0.5 mg/kg BW i.v.; Polfa, Warsaw Poland), and then general anesthesia was induced with propofol (6–8 mg/kg BW i.v.; ScanVet Poland, Gniezno, Poland) and maintained with inhalation isoflurane (1.5%–2% vol.; Baxter Poland, Warsaw, Poland). After the anesthesia was induced and the dog was placed in a supine position, the right and left external jugular veins and one femoral vein were accessed percutaneously with a modified Seldinger technique (Ching et al. 2007). Invasive EPS was performed with a LABSYSTEM PRO (BARD Electrophysiology, Lowell, Massachusetts, USA). The 6F quadripolar electrode catheters with various curvatures: Cournand Curve and Josephson Curve (BARD Electrophysiology, Lowell, MA, USA) were introduced into the veins by 6F vascular introducer sheaths (Johnson & Johnson, Cordis, Milpitas, CA, USA). Under fluoroscopic guidance and intracardiac potential control, three quadripolar catheters were inserted via vascular sheaths to the right atrium, coronary sinus, His bundle area, and right ventricle. A Josephson Curve electrode (BARD Electrophysiology, Lowell, Massachusetts, USA) was placed via the femoral vein in the His bundle area, and later replaced to right atrium. Josephson Curve electrodes (BARD Electrophysiology, Lowell, MA, USA) were placed in the coronary sinus and right ventricle via the left and right external jugular veins. Electrical potentials from the main leads of standard ECG (I, II, III, aVR, aVL, aVF) were recorded during EPS, along with intracardiac potentials from the intracardiac electrode catheters. The study comprised a passive stage, during which the intracardiac potentials from the right atrium, coronary sinus, His bundle area, and right ventricle were recorded at the patient’s own rhythm and at dynamic stage, i.e. stimulation of the selected cardiac regions.

2.3. EPS protocol and parameters

The following parameters were determined during the passive stage: HRA-LA – from the electrode catheters placed in the right atrium and coronary sinus, and PA,
AH, and HV intervals from the catheters inserted into the right atrium and His bundle area. HRA-LA, i.e., interatrial conduction time, was defined as the conduction time from the high right atrium to the distal coronary sinus. PA interval was determined as the interval between the onset of the P wave recorded from lead II of the standard electrocardiogram and the intrinsic deflection of the atrial electrogram on the bundle recording catheter. AH interval was measured as the interval between the intrinsic deflection of the atrial electrogram and the earliest onset of the His potential, and HV interval as the interval between the intrinsic deflection of the His potential and the earliest onset of ventricular activation on the intracardiac electrogram.

The following pacing protocols were used during the dynamic stage of the EPS. (1) Atrial pacing at progressively shorter cycle length, to determine the anterograde (AV) Wenckebach point, along with the ventricular pacing with retrograde (ventriculoatrial) conduction, in order to identify the retrograde (VA) Wenckebach point. The anterograde (AV) Wenckebach point is defined as the lowest atrial pacing rate at which atrioventricular block is observed, usually in the form of Wenckebach periodicity. The retrograde (VA) Wenckebach point is defined as the ventricular pacing rate at which the loss of 1:1 ventriculoatrial conduction occurs. (2) Continuous 30-second atrial pacing at a 400 ms cycle length in order to determine sinus node recovery time (SNRT), defined as the interval between the delivery of last atrial stimulus and the first spontaneous atrial depolarization. Additionally, the corrected sinus node recovery time (CSNRT) was determined as the difference between SNRT and regular spontaneous cycle length measured from the mean of five consecutive cycles length. (3) Programmed atrial and ventricular pacing with a single premature impulse at progressively shorter coupling interval was used in order to determine atrial (AERP), atrioventricular nodal (AVNERP), and ventricular (VERP) effective refractory periods. The atrial effective refractory period was defined as the longest coupling interval (S1–S1) of the premature atrial stimulus (S2) that did not result in a premature atrial depolarization. Atrioventricular nodal effective refractory period was determined as the longest S1–S2 interval that did not result in a His bundle depolarization. VERP was defined as the longest S1–S2 interval that did not result in ventricular capture. The refractory periods were determined at the natural rhythm and at imposed rhythms of 130 beats per min (460 ms cycle length), 150 beats per min (400 ms cycle length), and additionally at 180 beats per min (330 ms cycle length) for the purpose of VERP determination, in an 8 + 1 system, i.e., with 8 impulses at an imposed rhythm and a single premature impulse at progressively shorter coupling interval. (4) Short-term continuous atrial pacing at 400 ms to determine the interatrial conduction time at an imposed rhythm (HRA-LA 150/16.1 min), along with the short-term coronary sinus pacing in order to examine the retrograde interatrial conduction at an imposed rhythm (LA-HRA 150/min).

All the intracardiac conduction parameters were expressed in milliseconds. The electrode catheters and vascular sheaths were removed after completing the EPS recording, prior to patient’s recovery. The sites of vascular access were compressed for 15 min to stop bleeding and prevent hematoma formation. The results of EPS were used to define the values for the intracardiac conduction parameters.

2.4. Statistical analysis

The mean and range were calculated for each parameter measured as well as the standard deviation (SD) and 95% CI. The significance of intergroup differences in normally distributed data was verified with the Student’s t-test for independent variables. Correlations between pairs of variables were analyzed on the basis of the Spearman’s R-coefficients. Only univariate statistical analyses were performed. The threshold of statistical significance for all the tests was set at $P < 0.05$. For all electrophysiology parameters in the group of six control Beagles also the coefficients of variation were calculated.

3. Results

We examined 22 dogs of various breeds (6 Beagles, 12 crossbreeds, 1 German Shepherd, 1 Munsterlander, 1 Golden Retriever, 1 Fox Terrier), sex (15 females and 7 males), and body weight (6.7–31 kg, mean 16.1 ± 8.9 kg). The age of the dogs ranged between 18 months and 12 years (mean 5.2 ± 3.3 years). There were no differences in average body weight (females 16.8 ± 10.8 versus males 16.5 ± 9.5 kg) and age (females 5.6 ± 3.6 versus males 6.2 ± 1.3 years) between males and females. We did not find significant differences between the results of the baseline and repeated EPS performed in six Beagles. Furthermore, no significant differences between the Beagles and the 16 admitted dogs were detected.

The coefficient of variation for almost all parameters was under 20%, except CSNRT where it reached 39%. The lowest values were: AV Wenckebach – 3.6%, AH – 4%, and HV – 6%. The values for the analyzed parameters of intracardiac conduction, determined on the basis of the examination of all 22 dogs, are presented in Tables 1 and 2. To create range values, only the results of the first study have been taken, to avoid the amplification of the data.

We found significant differences in the values of the anterograde Wenckebach point for male and female dogs. Mean values of the AV Wenckebach point in females and males amounted to 232 ± 28.9 ms and 211 ± 13.4 ms, respectively ($P = 0.048$). A total of 13
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Table 1. The mean values and range of electrophysiological parameters in the current study based on the examination of all 22 dogs. All the parameters are expressed in milliseconds (ms).

| Parameter       | Mean | Minimum | Maximum |
|-----------------|------|---------|---------|
| PA              | 10   | 6       | 17      |
| AH              | 55   | 40      | 83      |
| HV              | 34.5 | 22      | 54      |
| SNRT            | 581  | 414     | 734     |
| CSNRT           | 60   | 17      | 128     |
| HRA-LA          | 39.5 | 13      | 46      |
| HRA-LA 150      | 45.5 | 22      | 77      |
| LA-HRA 150      | 49   | 21      | 74      |
| AV Wenckebach   | 220  | 180     | 290     |
| VA Wenckebach   | 360  | 260     | 430     |
| AERP            | 130  | 80      | 170     |
| AERP 130        | 130  | 110     | 180     |
| AERP 150        | 130  | 110     | 180     |
| AVNERP 130      | 150  | 120     | 200     |
| AVNERP 150      | 155  | 110     | 220     |
| AVNERP 150      | 155  | 110     | 210     |
| VERP            | 150  | 130     | 180     |
| VERP 130        | 160  | 140     | 210     |
| VERP 150        | 160  | 140     | 180     |
| VERP 180        | 150  | 130     | 200     |

Notes: PA, the interval between the onset of the P wave and the intrinsic deflection of the atrial electrogram on the bundle recording catheter; AH, interval between the intrinsic deflection of the atrial electrogram and the earliest onset of the His potential; SNRT, sinus node recovery time; CSNRT, corrected sinus nod e e recovery time; HRA-LA, interatrial conduction time from the high right atrium to the distal coronary sinus; HRA-LA 150, interatrial conduction time at an imposed rhythm of 150 beats per min; LA-HRA 150, retrograde interatrial conduction time from the distal coronary sinus to the high right atrium at an imposed rhythm of 150 beats per min; AV Wenckebach, ventricular pacing rate at which the loss of 1:1 atrioventricular conduction occurs; VA Wenckebach, ventricular pacing rate at which the loss of 1:1 ventriculoatrial conduction occurs; AERP, atrial effective refractory period at an own rhythm; AERP 130, 150, atrial effective refractory period at an imposed rhythm of 130 beats per min and 150 beats per min; AVNERP, atrioventricular nodal effective refractory period at an own rhythm; AVNERP 130, 150, atrioventricular nodal effective refractory period at an imposed rhythm of 130 beats per min and 150 beats per min; VERP, ventricular effective refractory period at an own rhythm; VERP 130, 150, 180, ventricular nodal effective refractory period at an imposed rhythm of 130 beats per min, 150 beats per min, and 180 beats per min.

(59%) dogs showed evidence of retrograde conduction as based on univariate statistical analysis.

Furthermore, in 13 dogs, during determination of atrial and the atrioventricular node refractory periods inhibition of conduction in the AVN and atria occurred simultaneously. We were unable to determine AERP and AVNERP in two dogs, as well as VERP at a 460-ms cycle length in another four animals, since their own rhythms were faster or equal to 130 beats per min. In the case of five dogs, programmed atrial pacing with a premature impulse at progressively shorter coupling interval induced a short-term non-permanent atrial fibrillation. This arrhythmia was observed during the pacing with a premature impulse S2 at a coupling interval <160 ms. The duration of the longest documented episode of atrial fibrillation was 1.8 s. The arrhythmia resolved spontaneously in all the cases. One dog showed a single retrograde excitation during the programmed atrial pacing with a premature impulse at progressively shorter coupling interval, at S1 coupling interval of 460 ms and premature impulse S2 at 170–140 ms, and at a 400-ms coupling interval and premature impulse S2 at 170–140 ms. Four dogs showed evidence of ‘jumps’ in the atrioventricular node conduction curve, corresponding to switching from fast to slow conduction pathway.

4. Discussion

Although the electrophysiological parameters of canine heart have been reported previously in a few studies, all of them analyzed the effects of various antiarrhythmic agents and other substances on the conduction parameters, usually under pentobarbital anaesthesia (Landmark & Amlie, 1976; Pickoff et al. 1983; Huerta et al. 1984; Sassine et al. 1984; Young et al. 1986; Timour et al. 1987; Traunecker, 1988). As pentobarbital is known to affect the intracardiac conduction, the parameters determined in the aforementioned studies should not be used for diagnostic purposes. Due to its vagolytic effect, pentobarbital enhances sympathetic tone, which may be reflected by changes...
in the parameters of intracardiac conduction (Young et al. 1986). To the best of our knowledge, there is only one report on the electrophysiological parameters in dogs where more parameters were measured and larger amount of dogs were used (Wright et al. 1996). Wright et al. (1996) determined the range values for parameters, such as AH, HV, and PA intervals, SNRT, CSNRT, VERP, AERP, AVNERP, AV, and VA Wenckebach points. Wright’s study used 15 adult dogs, of both sexes, from 12 to 25 kg, so very similar to our study. The results of this study and the range values of parameters determined in our dogs are presented in Table 3. All the parameters determined by Wright et al. (1996) differed from those documented in our study. This may result from different protocols of anesthesia used in these two studies, with Wright et al. (1996) using butorphanol, diazepam, thiamylal, and isoflurane. Moreover, the two studies differed in terms of the methodology of the refractory period determination. Both the values of electrophysiological parameters determined by Wright et al. (1996) and the values documented in our study are closer to normal values for children than to the reference limits for adults (Ward & Camm, 1987; MacDonald, 2006). Similar to children, dogs present with higher heart rate than adults; also the size of canine heart resembles that of a child’s heart. Moreover, a role of the autonomic nervous system should be considered, as it was shown to exert stronger effect on the sinoatrial and atrioventricular nodes in children and dogs than in adult humans (Wright et al. 1996).

The coefficient of variation for almost all parameters were under 20% but in CSNRT reached 39% which is moderate, not like other parameters. Assessment of sinoatrial node function is very challenging in human as well as in veterinary medicine. Diagnosis of sinus node dysfunction, SNRT has a sensitivity of approximately 50%. SNRT depends on many factors like local neurohormonal and autonomic nervous system influences, also the proximity of the pacing catheter to the sinus node, the SACT (sinoatrial conduction time), and presence or absence of SA entrance block. CSNRT measurements should be more accurate, but in dogs have wide variation, both in present study and the study presented by Wright et al. (1996). There are large fluctuations in cycle length in dogs like physiological sinus arrhythmia, and as CSNRT depends on mean cycle length it could be the main reason of moderate CV. The electrophysiologic tests of sinus node function are not very specific nor sensitive, that is why such test results should not be relied on when making clinical decisions regarding diagnosis or treatment. This variation can decrease after pharmacologic inactivation of the sinus node using a β-blocker and atropine. In this case, these measurements may be more useful in making a definitive diagnosis.

As many as 18% of our dogs (n = 4) showed ‘jumps’ in the atrioventricular node conduction curve, pointing to the presence of dual conduction in this node. This phenomenon has been observed in 7% of healthy humans, more often in children than in adults (Cohen et al. 1997; Zimetbaum & Josephson, 2009). Typically, dual fast and slow pathway conduction is observed within the atrioventricular node. Conduction via the fast pathway is associated with short AH interval and long refractory period, and conduction via the slow pathway is reflected by long AH interval and short refractory period. Usually, the fast pathway is the preferred route of conduction, and the slow pathway is activated no earlier than after refraction of the fast one. The electrographic evidence of the ‘jump’ reflects switching from the fast to the slow pathway. Usually, the ‘jump’ can be induced by atrial pacing with a single premature impulse, and sometimes also by continuous atrial pacing. Dual physiology of the atrioventricular node constitutes the reason behind atrioventricular nodal reentry tachycardia.

While retrograde conduction is not universally observed on standard electrocardiograms, it can be easily documented during ventricular pacing in the course of intracardiac or transesophageal EPS. Identification of this phenomenon becomes of vital importance in patients with tachyarrhythmia, dual physiology of the atrioventricular node, or implantable cardiac pacemakers. We found the retrograde conduction in 13 (59%) dogs; this group included 4 (31%) animals with concomitant ‘jumps’ in the atrioventricular node conduction curve, pointing to the dual physiology of the atrioventricular node. Wright et al. (1996) found the evidence of ventriculotriatal conduction in 46% of the examined dogs; according to various

| Parameter | Present study | Wright et al. (1996) |
|-----------|---------------|---------------------|
| PA (ms)   | 6–17          | 0–30                |
| AH (ms)   | 40–83         | 54–116              |
| HV (ms)   | 22–54         | 30–44               |
| SNRT (ms) | 414–734       | 480–1710            |
| CSNRT (ms)| 17–128        | 20–488              |
| AV Wenckebach (ms) | 180–290 | 180–540 |
| VA Wenckebach (ms) | 260–430 | 280–510 |
| AERP (ms) | 80–170        | 110–210*            |
| AVNERP (ms)| 120–200      | 150–300*            |
| VERP (ms) | 130–180       | 150–240*            |

* Determined at a 450-ms cycle length.

Notes: PA, the interval between the onset of the P wave and the intrinsic deflection of the atrial electrogram on the bundle recording catheter; AH, interval between the intrinsic deflection of the atrial electrogram and the earliest onset of the His potential; HV, the interval between the intrinsic deflection of the His potential and the earliest onset of ventricular activation on the intracardiac electrogram; SNRT, sinus node recovery time; CSNRT, corrected sinus nodal recovery time; AV Wenckebach, ventricular pacing rate at which the loss of 1:1 atrioventricular conduction occurs; VA Wenckebach, ventricular pacing rate at which the loss of 1:1 ventriculotriatal conduction occurs; AERP, atrial effective refractory period at an own rhythm; AVNERP, atrioventricular nodal effective refractory period at an own rhythm; VERP, ventricular effective refractory period at an own rhythm.
authors, the incidence of this phenomenon in human ranges between 20% and 90% (Hayes & Furman, 1983; Westveer et al. 1984; Inoue et al. 1985; Ciemniewski et al. 1990; Kazmierczak et al. 1993; Militianu et al. 1997). Retrograde conduction is more frequent in younger individuals; McCormack et al. (1988) found this phenomenon in all the examined neonates, but in only 27% of adult dogs, which is consistent with the evidence from human studies (Ward & Camm, 1987).

Although we did not find an association between age and the incidence of retrograde conduction, this might reflect insufficient number of dogs representing various age categories. In our study all dogs were fully grown, which may also affect comparisons. We determined the values of the VA Wenckebach point in animals with the evidence of retrograde conduction. The reference bracket for this parameter turned out to be relatively broad, which may inter alia reflect a small number of dogs examined in our study. Nevertheless, the values of the VA Wenckebach point were markedly higher than the values of the anterograde Wenckebach point. The mean values of the AV and retrograde VA Wenckebach points equaled to 220 and 360 ms, respectively, which suggests that the capability of the descending route is higher than that of the ascending route.

We were unable to determine AERP and AVNERP in two dogs, as well as VERP at a 460-ms cycle length in another four animals, since their own rhythms were faster or equal to 130 beats per min. Moreover, 13 (59%) dogs showed simultaneous block of the atrioventricular nodal and atrial conduction during the AVNERP and AERP determination. The sinoatrial node (45%), followed by the atrium (40%), are the primary sites in which the conduction block is observed during the refractory period determination in most humans (Akhtar et al. 1975). AERP is achieved earlier than AVNERP, especially at a slow own rhythm or excess sympathetic tension. Noticeably, the hereby-documented reference values for the refractory periods of canine atria, atrioventricular node and ventricles differ markedly from the respective values for humans (Akhtar et al. 1975; Josephson, 2002). The refractory periods of dogs turned out to be markedly shorter than those of humans.

The major limitation of the study was the small amount of examined dogs. This made it difficult to determine all significant associations between the analyzed parameters. Further studies should be conducted on a larger number of dogs of variable body weight and age with an equal sex distribution.

5. Conclusions

We showed that EPS is an accurate test providing additional information on the function of the electrical conduction system of the heart. The range values determined in this study may be helpful in establishing of an accurate diagnosis and implementation of effective treatment.

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