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Retrospective analysis of indications and complications related to implantation of permanent pacemaker: 25 years of experience in 31 dogs

Agnieszka Noszczyk-Nowak[1], Marcin Michałek[1], Karolina Kapturska[2], Alicja Cepiel[1], Adrian Janiszewski[3,6], Robert Pasławski[4], Piotr Skrzypczak[5], Urszula Pasławska[1]

[1]Department of Internal Medicine with Clinic of Diseases of Horses, Dogs, and Cats, Faculty of Veterinary Medicine, Wrocław University of Environmental and Life Sciences, 50-366 Wrocław, Poland
[2]Student of Faculty of Veterinary Medicine, Wrocław University of Environmental and Life Sciences, 50-375 Wrocław, Poland
[3]Centre for Experimental Diagnostics and Biomedical Innovations, Faculty of Veterinary Medicine, Wrocław University of Environmental and Life Sciences, 50-366 Wrocław, Poland
[4]Department and Clinic of Internal and Occupational Diseases and Hypertension, Wrocław Medical University, 50-556 Wrocław, Poland
[5]Department and Clinic of Surgery, Faculty of Veterinary Medicine, Wrocław University of Environmental and Life Sciences, 50-366 Wrocław, Poland
[6]Department of Internal Diseases and Veterinary Diagnosis, Faculty of Veterinary Medicine and Animal Sciences Poznań University of Life Sciences, 60-637 Poznań, Poland
m.michalek@outlook.com

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Abstract

Introduction: Pacemaker implantation is the only effective symptomatic treatment for life-threatening bradyarrhythmias. Major complications observed after implantation of cardiac pacemakers include lead dislocation, loss of pulse generator function, and inadequate stimulation. The aim of this retrospective single-centre study was to analyse the indications for pacemaker implantation and the incidence and types of complications associated with this procedure in dogs treated for symptomatic bradyarrhythmia. **Material and Methods:** The retrospective analysis included 31 dogs with symptomatic bradyarrhythmia, implanted with permanent cardiac pacemakers in 1992–2017. The list of analysed variables included patient age, breed, sex, indication for pacemaker implantation, comorbidities, and the incidence of procedure-related complications along with the type thereof. **Results:** The most common indication for pacemaker implantation was 3rd degree AVB, followed by SSS, advanced 2nd degree AVB, and PAS. Pacemaker implantation was associated with a 35% overall complication rate and 6.45% periprocedural mortality. There were no significant differences in terms of procedure-related complications with regard to age, sex, breed, indications for pacemaker implantation, or comorbidities. **Conclusions:** Cardiac pacing is the only effective treatment of symptomatic bradycardia, but as an invasive procedure, may pose a risk of various complications, including death.

Keywords: dog, pacemaker, bradyarrhythmia, atrioventricular block, complication.

Introduction

Arrhythmias, occurring in up to 40% of cardiological patients, constitute a significant and frequent cause of veterinary consultations (8, 18, 21, 30). In dogs, tachyarrhythmias occur markedly more often than bradyarrhythmias (42.97% *vs*. 12.32%) (21); both may lead to a critical decrease in cardiac output below the level, which is necessary for adequate perfusion of the brain (4, 22). Sick sinus syndrome (SSS), atrioventricular blocks (AVBs), ventricular tachycardia (VT), and atrial fibrillation (AF) may manifest clinically as syncope (5, 22), but the 2nd and 3rd degree AVBs comprise the largest proportion of canine syncopal episodes (24). In many cases (approximately 10%), bradycardia is detected

accidentally during evaluation of congestive heart failure or cardiological examination before a surgical procedure (30). Supraventricular bradycardia may occur as a primary arrhythmia (as a manifestation of SSS) or develop secondarily to another condition (*e.g.* increased vagal tone or hypothyroidism) or drug intoxication (*e.g.* with digitalis). The aetiology of syncopal episodes can be established using Holter monitoring (18) or implantable loop recorders (ILRs). The latter can be particularly useful, since conventional Holter monitoring not infrequently interferes with the normal physical activity of the patient which cuts the likelihood of another syncopal episode; moreover, the time of Holter recording is relatively short, between 24 and 72 hours, whereas monitoring with ILRs can be continued up to 36 months (15).

The most common causes of canine bradyarrhythmias that require permanent pacing are 2nd and 3rd degree AVBs (occurring in 3.58% and 6.74% of arrhythmic patients, respectively), sinus node dysfunction (SSS), and persistent atrial standstill (PAS) (18, 19, 24, 25, 30). RR pauses caused by sinus arrest or AVB represent nearly 28% of canine arrhythmias (18). Frequently, patients present with mixed arrhythmias, *e.g.* sinus bradycardia with 2nd degree AVB (21). Higher-degree blocks may be idiopathic or associated with fibrosis within the cardiac conduction system and/or cardiomyocytes, or may have an inflammatory origin (12, 18, 24).

Implantation of an artificial cardiac pacemaker is the only permanent and effective treatment in patients with symptomatic bradyarrhythmia. The first pacemaker implantation procedure in a human took place in 1952, and 15 years later a cardiac pacemaker was implanted in a canine patient for the first time; the first transvenous implantation procedure was performed in 1976 (8). Nowadays, most canine patients are qualified for transvenous pacing with a pacemaker lead implanted to the right ventricular apex (RVA) under fluoroscopic guidance. The popularity of this procedure is primarily associated with its simplicity and high success rates; however, a transthoracic approach is still required in some cases (27, 30). The recommended method is transvenous implantation of a lead, with the pacemaker placed within subcutaneous tissue of the neck or more caudally, between the scapulae (in dogs < 4 kg body weight) (8, 19, 27). Typically, single-chamber pacemakers are used due to the shorter time of the implantation procedure, lower risk of intraprocedural complications, and better outcomes (27). Implantation of a cardiac pacemaker may be associated with both minor and major life-threatening complications, the incidence of which usually correlates inversely with the number of these procedures performed annually at a given centre (4). According to some authors, the risk of intraprocedural mortality may reach 5% (8). The most significant complication is lead dislodgement, usually occurring during the patient's recovery from anaesthesia; the risk of this complication after implantation of active- and passive-fixation leads is essentially the same (19, 25, 30). Other major complications include pacemaker malfunction resulting from an inadvertent disconnection of a lead from the pulse generator, or inappropriate pacing caused by a lead's rupture or insulation failure due to mechanical injury (19, 25, 30). Insertion of a pacemaker lead to the ventricle and activation of the device are associated with a particularly high risk of major complications, such as life-threatening arrhythmias, including asystole, and right ventricular perforation with resultant pericardial tamponade and death (10). However, the benefits of artificial cardiac pacing markedly outweigh the risks associated with post-implantation complications. Cardiac pacing may prevent secondary congestive heart failure or at least significantly delay the onset of this condition, and protects patients against sudden cardiac death due to bradyarrhythmia (27).

The aim of this retrospective single-centre study was to analyse the indications for pacemaker implantation and the incidence and types of complications associated with this procedure in dogs treated for symptomatic bradyarrhythmia.

Material and Methods

The retrospective analysis included 31 patients with symptomatic bradyarrhythmia, qualified for implantation of a cardiac pacemaker at the Department of Internal Medicine with Clinic of Diseases of Horses, Dogs and Cats, Faculty of Veterinary Medicine, Wrocław University of Environmental and Life Sciences in 1992–2017. The patients were qualified for pacemaker implantation based on a history of syncopal episodes, results of clinical examination, laboratory testing (complete blood count, ALT, AST, urea, creatinine, K^+, Mg_2^+, Ca_2^+, Cl^-, Na^+, fT4 and T4 levels), echocardiography (Aloka 4000, Aloka F37 or Aloka Alpha 7 with 5 MHz and 7.5–10 MHz transducers, Hitachi Healthcare, Japan), electrocardiography (EKG BTL-08; BTL Industries, U.K.), and/or long-term Holter monitoring (AsPEKT 702, Aspel, Poland or Medilog AR12 Plus, Schiller, Switzerland).

The list of analysed variables included patient age, breed, sex, indication for pacemaker implantation, comorbidities, and incidence of procedure-related complications along with the type thereof. Moreover, concomitant cardiovascular diseases other than arrhythmia, which might have had an effect on survival and treatment outcome, were considered in the analysis. Procedure-related complications were classified as minor or major and early (up to three months post-implantation) or late. Major complications were defined as life-threatening events or conditions that required repeated surgical intervention; all other morbidities were qualified as minor complications.

Statistical analysis of the results was performed using Prism 5 computer software (GraphPad, USA). The significance of intergroup difference was evaluated using the Mann–Whitney or non-parametric Kruskal-Wallis test with a *post-hoc* Dunn's test. The threshold of statistical significance for all tests was set at $P \leq 0.05$.

Results

A total of 31 dogs were implanted with cardiac pacemakers over a 25-year period. The majority were males (61.29%), predominating among both large and small breeds (69.23% and 55.56%, respectively). Mean age at the time of pacemaker implantation was 7.36 years. Age was unknown in the case of three dogs found in the street and taken in by their owners or adopted from a shelter. The largest proportion of the patients were Labrador Retrievers (n = 6, 19.35%) (Table 1). The most common indication for pacemaker implantation was 3rd degree AVB (70.97%), followed by SSS (16.13%), 2nd degree AVB (9.68%), and PAS, (3.23%), which was found to be statistically significant ($P < 0.0001$) (Table 2).

In 15 out of 31 dogs, symptomatic bradyarrhythmia co-existed with other conditions, most often (53.33%) cardiovascular diseases. Degenerative mitral valve disease and dilated cardiomyopathy (DCM) were each found in 16.13% of patients. One dog was diagnosed with tricuspid regurgitation. Other comorbidities, found in 9.68% of the patients, included diseases of the kidneys and spleen (splenomegaly, changes in parenchymal echogenicity, and proliferative lesions without splenomegaly). Two patients presented with neoplastic lesions. In 19.35% of dogs, bradyarrhythmia co-existed with more than one comorbidity. In 2 out of 3 patients with hypothyroidism, this condition co-existed with degenerative mitral valve disease.

The largest number of implantation procedures (n = 4) was conducted in 1999. The number of implantations in the remaining years amounted to three (1996, 1999, 2010, 2015, and 2017), two (2012, 2013, and 2016), and one annually (1992–2014). Until 2010, all dogs were implanted with passive-fixation leads (18 implantations of single-chamber leads), and starting from 2011, with active-fixation leads (13 procedures, including 12 implantations of single-chamber leads and one implantation of a dual-chamber pacemaker). Procedure-related complications were documented in 11 out of 31 (35.48%) dogs; three patients presented with multiple morbidities: cranial vena cava syndrome with echocardiographic evidence of a hyperechoic "cuff" around the lead (n = 1), tricuspid insufficiency (regurgitation wave velocity > 2.7 m/s) with right ventricular dilation (n = 1), and purulent infection of post-implantation wound and hyperechoic "cuff" around the lead visible on echocardiography (n = 1). Two dogs (6.45%) died of procedure-related complications, namely cardiac tamponade caused by right ventricular wall perforation by an active-fixation electrode. Other two dogs (6.45%) needed repeated surgical intervention due to mechanical injury of the lead and preterm exhaustion of the pacemaker battery (Table 3).

There were no significant differences in terms of procedure-related complications with regard to age, sex, or breed. Moreover, no statistically significant differences were found between the complication rate in dogs implanted with passive-fixation leads and the rate in dogs with the active.

Table 1. Breeds of dogs included in the study

Large breeds	Number	Small breeds	Number
Labrador Retriever	6	Dachshund	3
Golden Retriever	3	West Highland White Terrier	2
Standard Schnauzer	2	Miniature Schnauzer	2
Siberian Husky	1	Yorkshire Terrier	1
Boxer	1	Standard Poodle	1
Polish Lowland Sheepdog	1	Beagle	1
Dalmatian Dog	1	Mixed breed (up to 15 kg)	3
German Shepherd	1		
Polish Hunting Dog	1		
Bavarian Mountain Hound	1		
Total	18		13

Table 2. Age and sex of the patients, overall, and stratified according to the indication for pacemaker implantation

Indication for pacemaker implantation	Number	Age (years)		Sex	
		Mean ± SD	Median	Females	Males
3rd degree atrioventricular block	22	7.74 ± 3.67	8	7	15
Sick sinus syndrome	5	5.8 ± 4.92	4	3	2
2nd degree atrioventricular block	3	9.17 ± 3.88	8	2	1
Persistent atrial standstill	1	2.5	2.5	0	1
Total	31	7.36 ± 3.93	8	12	19

Table 3. Complications related to cardiac pacemaker implantation in the patients

Early complications (n = 5)	Late complications (n = 10)
- purulent infection of post-implantation wound (n = 2)	- hyperechogenic "cuff" around the electrode (n = 3)
- right ventricular perforation and death (n = 2)	- tricuspid insufficiency (n = 2)
- episodic dyspnoea due to phrenic nerve stimulation (n = 1)	- right ventricular dilation (n = 1)
	- cranial vena cava syndrome (CVCS) (n = 1)
	- lead rupture (n = 1)
	- preterm exhaustion of pacemaker battery (n = 1)
	- endocardial fibrosis triggered by insertion of pacemaker lead (found on necropsy) (n = 1)
Minor complications (n = 9)	**Major/life-threatening complications (n = 6)**
- hyperechogenic "cuff" around the electrode (n = 3)	- right ventricular perforation and death (n = 2)
- purulent infection of post-implantation wound (n = 1)	- lead rupture (n = 1)
- right ventricular dilation (n = 1)	- preterm exhaustion of pacemaker battery (n = 1)
- episodic dyspnoea due to phrenic nerve stimulation (n = 1)	- cranial vena cava syndrome (CVCS) (n = 1)
- endocardial fibrosis triggered by insertion of pacemaker lead (found on necropsy) (n = 1)	- purulent infection of post-implantation wound (n = 1)
- tricuspid insufficiency (n = 2)	

Discussion

Various aspects of cardiac pacemaker implantation in dogs, including complications related to this procedure, have been discussed for years in global veterinary literature. The first Polish implantation of canine pacemaker was carried out at our centre in 1992; 25 years later, we summarised the treatment outcomes and compared them with those reported from other centres abroad.

Indications and survival time. Labrador Retrievers constituted the largest proportion of dogs qualified for pacemaker implantation at our centre, which is consistent with the statistics presented by other authors (11, 19). According to literature, other breeds that frequently need pacing are West Highland White Terriers (in our series n = 2) and Miniature Schnauzers (n = 2), in which a primary indication for pacemaker implantation is syncopal episodes associated with SSS (16). The most common indication for pacemaker implantation in our series was 3rd degree AVB (70.97% of the cases) followed by SSS (16.13%); similar indications for cardiac pacing were reported previously by other authors (3, 11, 19, 25). The mean age of our patients at the time of pacemaker implantation was 7.36 years (range 1–14 years) and was similar to the results of two previous studies (11, 25), in which cardiac pacing was started at a mean age of 7 years 2 months and 9 years, respectively (range 6 months to 16 years). According to literature, mean survival time of dogs implanted with cardiac pacemakers ranges between 16.9 and 33.6 months, but may vary considerably from patient to patient, with some animals dying immediately after the procedure and others surviving nearly seven years (10, 14, 25, 28). The survival time was shown to be markedly shorter in older dogs as well as in patients with episodes of ventricular tachycardia or decreased systolic function; concomitant cardiovascular diseases may contribute to even a five-fold increase in the risk of sudden cardiac death (11, 14). Published evidence shows that up to 86% of canine patients survive one

year after pacemaker implantation, and 3- and 5-year survival rates amount to 65% and 39%, respectively (11). Due to incompleteness of follow-up documentation (three owners did not bring their dogs to our centre for a pacemaker check-up), we were unable to determine the exact survival times in all patients, but the proportion of dogs that survived at least one year post-procedure was 90.3% (n = 28). All dogs treated at our centre were implanted with transvenous leads. However, it needs to be emphasised that nowadays complication rates and survival times after the implantation of transvenous and epicardial leads are essentially the same, which makes the latter option an alternative in small and miniature breeds (27).

Cardiac pacing modes. Pacemakers used in the study group were set in one of two different pacing modes. Single chamber pacing devices were set in VVI mode, with the electrode placed in the right ventricular apex. The ventricle was paced, sensed, and the pulse generator was inhibited by a sensed ventricular event. Dual chamber systems were set in DDD mode, so that one electrode was placed in the right atrium and the other at the right ventricular apex, and the pacemaker was capable of pacing and sensing both chambers. In all but one dog included in our series, cardiac pacemakers were set in VVI mode, which is presently the most commonly used setting in veterinary medicine (10); one patient was implanted with a dual-chamber pacemaker set in DDD mode. Physiological pacing in DDD mode is recommended in humans with 2nd or 3rd degree AVBs due to its stronger beneficial effect on cardiac output, blood pressure, exercise tolerance, and quality of life. However, dual-chamber pacemakers are rarely used in dogs (10) because of different cardiac and vascular dimensions, and the longer duration of the implantation procedure. One study demonstrated that the mean implantation time for dual-chamber pacemakers was markedly longer (133.4 ±51.3 min) than for single-chamber devices (94 ±37.0 min) (9). Moreover, duration of the implantation procedure was shown to increase with each additional lead (102.3 ± 51.1 min for one lead, 114.9 ±24.8 min for two leads, and 158.2 ±8.5 min for three leads) (9).

Complications. Although in our series, complications related to pacemaker implantation were most common in dogs with 3rd degree AVB, this might be at least in part associated with the fact that this was the most frequent indication for cardiac pacing in this group. Up to 77.28% of dogs with 3rd degree AVB did not have any or had only minor complications (n = 1), primarily associated with impaired healing of the post-implantation wound. Overall morbidity rate in our series was 35%, which is higher than those reported recently from other centres abroad (11). However, it needs to be emphasised that most complications observed in our patients were minor. Early studies analysing the outcomes of cardiac pacing in dogs documented high morbidity rates (between 33% and 55%) after implantation of epicardial and passive-fixation transvenous (non-tined) leads, which were frequently dislodged (3, 11, 25). The results presented in our paper were collected over a 25-year period, and thus a large proportion of the patients were implanted with older, passive-fixation leads. Complication rates reported by authors who used solely newer, active-fixation (tined) leads are markedly lower (11). Nowadays, major and minor complications occur in 13%–14.42% and 11%–22.11% of dogs, respectively. These rates are similar to those reported in human patients 18 years earlier (11, 13, 30). Noticeably, complication rates in dogs implanted with dual-chamber pacemakers may be slightly higher. According to Hildebrandt *et al.* (10), major life-threatening and minor complications occurred respectively in 27% and 36% of dogs fitted with dual-chamber pacing. However, in another study, major complications were observed in 11% of dogs paced in DDD mode and in 20% paced in VVI mode, and the difference was not statistically significant. This implies that the mode of pacing may not influence the risk of major life-threatening complications (9, 14). In the study conducted by Oyama *et al.* (19), the incidence of major complications was 33%, but decreased considerably to 17% if an experienced operator conducted the implantation procedure. According to literature, an operator can be considered experienced after performing more than 12 implantation procedures in a one-year period (19, 25). Significantly higher rates of major life-threatening events or complications that required pacemaker replacement were also reported after implantation of epicardial leads in large breed dogs (27).

Another factor which may exert an effect on post-procedural morbidity is time of the day when the implantation was carried out. One study showed that emergency procedures carried out after hours resulted in major complications more than three times as often as the scheduled implantations performed in the normal business hours of the clinic (28% *vs*. 9%). Postoperative bacterial infections were also documented solely in patients treated after hours (28). All procedures performed at our clinic were planned in advance, and hence the relatively high morbidity rates observed in our series cannot be explained as a consequence of implantation in an emergency setting.

According to literature, the most common perioperative complications during pacemaker implantation are hypothermia and hypotension (23). Importantly, many patients qualified for the implantation procedure are assessed to the American Society of Anaesthetists (ASA) class III or IV (23). In such patients, mortality associated with anaesthesia is similar to mortality due to other causes. In our series, perioperative deaths due to right ventricular perforation and cardiac tamponade occurred solely in two dogs from ASA classes III and IV, and the overall perioperative mortality rate (6.45%) was similar to that in previous studies (4.76%–5.2% mortality within the

initial 48 h post-procedure) (8, 23). The occurrence of no perioperative mortality in other dogs included in our series should probably be attributed to anaesthesiologists' experience and appropriate perioperative care.

Minor complications. The most common complication documented in our series (observed in 9.68% of patients) was echocardiographic evidence of a hyperechoic "cuff" around the pacemaker lead placed in the right ventricle, probably representing clotted blood. All these cases were classified as minor late complications, since the "cuffs" were visualised during control echocardiography performed more than three months post-implantation. Plausibly, blood clotting along the pacemaker lead may also occur in the anterior vena cava, which in extreme cases may impair or completely block blood flow within this vessel (17, 26). Six months after pacemaker implantation, Hildebrandt *et al.* (10) found blood clots in the right atrium in 6% of dogs given dual-chamber pacing.

Two patients included in our series (6.45%) developed superficial infections of the post-implantation wound. The proportion of post-implantation wound infections was similar to those described by other authors (3%–15%), but still higher than in human patients (0.5%–5.1%). However, published evidence suggests that post-implantation wound infection rates in dogs can be as low as in humans (10, 19, 25, 30). Contamination with environmental microflora typically occurs during the implantation procedure or shortly thereafter. According to Oyama *et al.* (19), the dogs that did not respond adequately to antibiotic therapy may have required replacement of pacemaker components due to potential risk of their bacterial contamination. Sisson *et al.* (25) demonstrated that the occurrence of post-implantation wound infections decreased with the use of perioperative antibiotic therapy. Other studies showed that aside from prophylactic administration of antibiotics, the infection rates can be substantially reduced if the implantation procedure is conducted strictly according to the protocol, and operative time is not too long. Finally, postoperative glucocorticoid therapy was identified as a risk factor for post-implantation wound infection (19). All patients included in our series received prophylactic antibiotic therapy (enrofloxacin or amoxicillin with clavulanic acid), but this did not prevent post-implantation wound infection in two cases. Nevertheless, the infections were superficial and did not spread into the pacemaker site. This is quite important, since according to some authors, in patients in whom a purulent effusion accumulated at the pacemaker site, further antibiotic therapy may be unsuccessful (8, 19).

Some authors reported seroma formation as a common (present in 2.85%–17.30% of patients) early (observed within up to 10 days post-procedure) or late (after 24 months) spontaneously resolving complication of pacemaker implantation (10, 11, 30). However, we did not find this complication in any of our patients.

Major complications. The most serious complication related to pacemaker implantation is perforation of the right ventricle in its apical part, usually occurring during insertion of the lead (1). This complication occurred in two patients from our series. Autopsy showed that in one case perforation was associated with reduced thickness of right ventricular wall, down to 1 mm. In both patients, ventricular perforation resulted in pericardial tamponade and cardiac arrest within 3 h after the implantation of active-fixation lead. Usually dislodgement of the lead occurs during patient's recovery from anaesthesia, but has been also observed up to 24 months post-procedure (8, 11, 19, 25, 30). Implantation of active-fixation leads is associated with lower likelihood of dislodgement (up to 6% in the case of dual-chamber pacing), but with greater risk of ventricular perforation (10, 25). In dogs, lead dislodgement occurs more often than in humans due to differences in the anatomical structure of the right ventricular lumen and markedly greater motor activity after the procedure (19, 25). The incidence of lead dislodgement tends to decrease with greater operator experience (25). However, according to Oyama *et al.* (19), in veterinary medicine the effect of operator experience on the risk of lead dislodgment has not been so evident as in human medicine, since the number of adequately experienced centres that could serve as a reference is too small. Pacemaker lead dislodgement is a major complication and potential cause of sudden death (30). However, Achen *et al.* (1) presented a case of a patient in whom problems with sensing caused by lead dislodgement and right ventricular perforation were detected accidently during administration of anaesthesia seven weeks after the implantation of a passively-fixed electrode (1). Regular control of pacemaker function allows for early detection of lead malposition and for implementation of appropriate preventive measures to avoid further dislodgement (6).

The list of major late complications observed in our series included lead rupture (about one year after the implantation), premature battery exhaustion (after five years), and cranial vena cava syndrome, with the former two requiring urgent surgical intervention. According to other authors, pacemaker malfunction of unknown aetiology is a rare complication of cardiac pacing in dogs (~2%) (11, 30). Equally rare is a malfunction due to a mechanical injury, *e.g.* neck biting by another dog or twiddler's syndrome (11).

Cranial vena cava syndrome. The dog with cranial vena cava syndrome (CVCS) probably developed this condition secondarily to thrombosis and stenosis of the vessel triggered by presence of pacemaker lead (7, 17, 20). According to literature, thrombosis is a rare complication after cardiac pacemaker implantation in dogs (<1%), but owing to

a recent increase in its incidence, should be considered by clinicians as a potential morbidity cause (7, 11, 17, 19, 26). CVCS manifests with facial, neck, and forelimb swelling, hydrothorax, and recurrent chylothorax (17, 20). Potential risk factors for CVCS include dual-chamber pacing, DCM, periprocedural infection, and lead rupture (17). According to some authors, formation of a thrombus around a pacemaker lead and its further fibrosis may predispose the patient to outflow tract stenosis (17). To the best of our knowledge, only four cases of CVCS associated with pacemaker implantation have been reported thus far in canine patients, typically 3–4 years post-procedure (7, 17, 26). In our patient, CVCS developed 2.5 years after pacemaker implantation. Other rare complications associated with insertion of transvenous leads include ventricular fibrillation or premature ventricular contraction at the time of implantation, right atrioventricular stenosis, and carcinogenesis (fibrosarcoma) (10, 11). In turn, implantation of an epicardial lead may be associated with early neurological dysfunction, temporal loss of sensing function due to improper sensing threshold, and pyloric obstruction (2, 29). Severe mitral regurgitation and enlargement of the left atrium with concomitant atrial fibrillation has also been reported 20 months after implantation of a pacemaker set in DDD mode (10). Although some dogs from our series presented structural and functional cardiac abnormalities, these pathologies were generally mild and seemed to be associated with age-related degenerative processes typical for older dogs.

To summarise, we showed that the most common indication for cardiac pacing in the studied group was 3rd degree AVB. It was proved that cardiac pacing, the only effective treatment of symptomatic bradycardia, not only attenuates the symptoms of this condition, but may also improve quality of life and prolong survival time in the vast majority of canine patients. Most of the complications associated with the procedure were minor, and the procedure itself may be considered safe. However, pacemaker implantation poses a risk of major complications, including death.

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