Clinically evident bradyarrhythmias that are unresponsive to medical treatment remain the most common indication for artificial cardiac pacing in dogs.1,2 Third-degree atrioventricular block is the most common of these bradyarrhythmias in dogs, followed by sinus-node dysfunction (sick sinus syndrome).1–3 Dogs with sick sinus syndrome that have normal atrioventricular node function can be treated by AAI implantation where the pacing stimulus is delivered to the right atrium, allowing for normal ventricular conduction and activation. Numerous studies8–13 in humans and animals have shown the negative consequences of such nonphysiologic pacing, and the term pacemaker syndrome is used in human medicine to describe the adverse clinical and hemodynamic consequences of nonphysiologic pacing. Studies9,14–16 have shown improved hemodynamics and quality of life benefits in people with dual-chamber pacing, compared with right ventricular pacing, in which atrioventricular synchrony and the contribution of atrial contraction to ventricular filling are preserved. Additionally, pacemakers with ventricular pacing sites other than or in addition to the atrioventricular node have been shown to result in increased procedural and anesthesia times, compared with single-chamber pacemaker implantation, this did not result in a higher complication rate. (J Am Vet Med Assoc 2013;242:230–236)
right ventricular apex allow a more physiologic ventricular activation sequence and have also been shown to provide improved hemodynamics in dogs and humans and quality of life benefits in humans. It has been reported that dual-chamber pacing systems, particularly those with 2 leads, are more difficult and more time-consuming to place in dogs because of the smaller vessels and requirement for 2 leads. Additionally, dual-chamber pacemakers require more complex programming. Thus, it has been assumed that implantation of dual-chamber pacemakers would have higher complication rates both initially and in the long term, although there are no data to support this in veterinary patients. Another type of pacing, atrial synchronous pacing with VDD implantation, allows for dual-chamber pacing with only a single lead. For atrial synchronous pacing, 1 lead is implanted in the right ventricle, but unlike typical VVI pacing, this lead has a floating electrode in the right atrium that is capable of sensing inherent atrial electrical activity and stimulating ventricular contraction after an appropriate delay, therefore allowing for atrioventricular synchrony. Although an atrial synchronous pacing system has been used in veterinary medicine, the set distance between the floating atrial electrode and ventricular pacing tip often prevents its use in small dogs. Studies comparing complication rates of single-chamber versus dual-chamber pacemakers in the human literature have yielded conflicting results. In veterinary medicine, owner satisfaction with single-chamber pacemakers has been high, thereby discouraging veterinary cardiologists from changing cardiac pacing methods.

Previous studies have shown the feasibility of implanting various types of dual-chamber pacemakers in dogs. A few studies have determined complication rates, implantation times, and long-term outcomes in groups of dogs with dual-chamber pacemakers. Only dogs treated for atrioventricular block were included in these studies, and to our knowledge, no study has included direct comparisons of implantation times and complications among dogs both on the basis of pacing mode (single chamber vs dual chamber) and on the basis of number of leads, where all implantations were performed at the same institution. The purpose of the study reported here was to compare procedure times and major and minor complication rates associated with single-chamber versus dual-chamber pacemaker implantation and with 1-lead, 2-lead, and 3-lead pacemaker implantation in dogs with clinical signs of bradyarrhythmia examined at a single institution. Our hypothesis was that procedure and anesthesia times would be higher for implantation of dual-chamber pacemakers, compared with single-chamber pacemakers, and with increasing numbers of leads placed but that complication rates would not be significantly different among treatments.

Materials and Methods

Selection of cases—Medical records were reviewed for all dogs that underwent permanent pacemaker implantation because of clinical signs of bradyarrhythmia between January 2004 and December 2009 at the University of Florida Small Animal Hospital. Inclusion criteria included any dog seen by the University of Florida Small Animal Hospital in which a permanent transvenous intracardiac pacemaker (endocardial lead only) was placed by the cardiology service and for which complete anesthesia, surgical, and follow-up information was available. Cats, dogs without complete medical records, and dogs in which an epicardial lead was placed via a thoracic approach were excluded from the study.

Data were obtained regarding signalment, ECG findings, type of pacemaker implanted, person or persons performing the procedure, pacemaker-related complications, anesthesia and procedure times, follow-up examination findings, and survival time. Information was obtained by reviewing history and physical examination forms, discharge paperwork, ECG and echocardiography reports, pacemaker interrogation reports, operation reports, anesthesia reports, and any follow-up communications between the client and attending clinician.

Procedures—All implantation procedures were performed by board-certified staff cardiologists or cardiology residents under the supervision of a staff cardiologist at the veterinary medical teaching hospital. Anesthetic protocols were determined by anesthesia personnel and were not uniform for all patients. Antimicrobials were administered IV to all patients during the periprotective period. Procedural details were similar for all patients but differed slightly depending on the clinician and the type of pacemaker being implanted. Briefly, in all patients, a temporary transvenous catheter was implanted initially in the right venricular apex via percutaneous access from either the left jugular vein or a lateral saphenous vein. Dogs were placed in left lateral recumbency, and a skin incision was made over the right jugular vein, which was subsequently isolated via blunt dissection. Leads were advanced through the jugular vein under fluoroscopic guidance to the appropriate cardiac location (ie, right atrium, right ventricle, and left ventricle [via the coronary sinus]) on the basis of the type of pacemaker. Leads were then connected to a generator that was placed in a subcutaneous pocket in the neck. Bipolar leads were used exclusively. All dogs were treated with antimicrobials after surgery for 10 to 21 days; the antimicrobials most often used were cephalaxin and amoxicillin-clavulanate. Patients were scheduled for recheck examinations at the cardiology service of the veterinary medical teaching hospital if they had not been evaluated within the previous 6 months.

Dogs were grouped according to the type (single chamber vs dual chamber) of pacemaker that was implanted. Single-chamber pacemakers (ie, AAI and VVI) were capable of pacing and sensing in 1 chamber. All single-chamber pacemakers used 1 lead. Dual-chamber pacemakers (ie, VDD, DDD-RVA, or DDD-Biv) could sense or pace in > 1 cardiac chamber. In instances when there was a failed attempt at placing 1 pacemaker type, dogs were classified according to the pacemaker type that was ultimately placed. Dual-chamber pacemakers had 1 lead (VDD), 2 leads (DDDRVA), or 3 leads (DDD-Biv). Because of the unique nature of VDDS, an additional analysis was performed in which dogs with VDDS were placed in a unique category and dogs with
all other pacemaker types were classified as having single-chamber or dual-chamber pacemakers.

For the purposes of this study, complications were categorized as major or minor. Major complications were defined as those considered to be life-threatening or that required replacement or revision of the pacing system. Minor complications included those that were not life-threatening and did not require an additional procedure to replace or revise the pacing system.

Statistical analysis—Pacemaker type was defined as an independent variable on the basis of chamber type with categories (groups) defined as single or dual chamber. Lead number categories were defined as single lead or ≥ 2 leads and were subsequently collapsed into 2 lead categories for both the Cox model analyses and for determining significant differences for the means of models with continuous response variables. For the Cox models, continuous independent variables measured were body weight, procedure time, anesthesia time, and lead number. For Kaplan-Meier analysis, chamber type was analyzed as described.

For Kaplan-Meier and Cox time-to-event models, the start date was date of pacemaker implantation and end dates (dependent variable) were defined as the date of development of a minor complication, date of development of a major complication, earliest date of development of either a major or minor complication, date of death of the patient (survival time), earliest date of a major or minor complication or patient death (cumulative survival time endpoint), and date of final follow-up. Dogs that did not have an end date event for the respective analyses by the end of follow-up were censored on the final follow-up date. For determining statistical differences for mean values between chamber types, dependent variables included anesthesia time, procedure time, age in years, body weight in kilograms, and survival time determined on the basis of described endpoints (ie, minor complication, major complication, major or minor complication, survival time, or cumulative survival time endpoint).

Failed attempts at pacemaker implantation were excluded from analyses of procedure and anesthesia times, and they were not included as complications for the main Kaplan-Meier analyses. An additional Kaplan-Meier analysis was performed in which failed attempts at pacemaker implantation were classified as an immediate minor complication. The failed attempt was a complication for that pacemaker type; however, any future complication was categorized according to the pacemaker type that the patient eventually received.

Statistical differences between single-chamber and dual-chamber types for mean values for continuous variables were determined by a Student unpaired t test. Differences between lead numbers for mean values for continuous variables were determined by use of an ANOVA followed by the Fisher protected least significant difference test. Correlations between continuous variables were analyzed via Pearson correlation coefficient. Univariate event-free survival times for the independent variable chamber type were determined for all endpoints by use of Kaplan-Meier product limit estimates, whereas univariate unadjusted hazard ratios were generated from Cox semiparametric proportional hazard models. All analyses were performed with commercially available software. Statistical differences were determined to be significant at P ≤ 0.05.

Results

Fifty-four dogs met the criteria for inclusion in the study. Twenty-eight (51.9%) of the 54 patients received single-chamber pacemakers, and 26 (48.1%) received dual-chamber pacemakers. Of the 28 dogs that received single-chamber pacemakers, 4 (14.3%) received an AAI and 24 (85.7%) received a VVI. Of the 26 dogs that received dual-chamber pacemakers, 5 (19.2%) received a VDD (1 lead with a floating atrial electrode), 15 (57.7%) received a DDD-RVA (2 leads), and 6 (23.1%) received a DDD-Biv (3 leads).

Third-degree atrioventricular block was the most common indication for cardiac pacing. Forty-two of 54 (77.8%) dogs had third-degree atrioventricular block. Of these 42 dogs, 17 (40.4%) received a VVI, 13 (35.7%) received a DDD-RVA, 6 (14.3%) received a DDD-Biv, and 4 (9.5%) received a VDD. Eight of 54 (14.8%) dogs underwent pacemaker implantation for treatment of sick sinus syndrome; all of these dogs received a single-chamber pacemaker (4 dogs received an AAI and 4 dogs received a VVI). Three of 54 (5.5%) dogs had high-grade second-degree atrioventricular block, 2 of which received a VVI; the remaining dog received a VDD. One of 54 (1.8%) dogs had undergone VVI implantation for treatment of atrial standstill.

Of 54 dogs, 10 (18.5%) were mixed-breed dogs, 9 (16.7%) were Cocker Spaniels, 4 (7.4%) were Labrador Retrievers, and 3 (5.6%) were Dachshunds; there were no more than 2 of any other dog breed. Of the 28 dogs that received single-chamber pacemakers, 8 (28.6%) were Cocker Spaniels; there were no more than 2 of any other breed in this group. Of the 26 dogs that received dual-chamber pacemakers, 9 (34.6%) were mixed-breed dogs and 4 (15.4%) were Labrador Retrievers; there were no more than 2 of any other breed in this group.

Failed attempts at DDD-Biv implantation occurred in 8 dogs, which had a mean ± SD body weight of 23.5 ± 13.62 kg (31.7 ± 29.26 lb), with a median of 23.1 kg (50.8 lb) and range of 5.1 to 40.0 kg (11.2 to 88 lb). In each of these 8 dogs, a lead could not be placed successfully within the left ventricle, and all of these dogs instead received a DDD-RVA. In 2 dogs that were scheduled to undergo dual-chamber pacemaker implantation, the right atrial lead could not be appropriately placed; instead, these dogs ultimately received a VVI.

Not including dogs with failed implantations, 19 of 54 (35.2%) dogs had complications resulting from pacemaker implantation, with 11 (20.4%) dogs having major complications. The percentage of dogs that developed complications increased to 46% when failed attempts at pacemaker implantation were classified as minor complications.

There were no failed attempts at single-chamber pacemaker implantation. Twelve of 28 (43%) dogs that underwent single-chamber pacemaker implantation had 14 total complications (2 dogs had 2 complications each). Six of the 14 postsurgical complications were considered major and included the following: 2 lead migrations with perforation (1 VVI at 401 days and 1...
AAI at 79 days); 1 lead migration (VVI at 122 days) that required replacement because of loss of capture; 1 battery failure (VVI at 644 days); 1 generator infection (AAI at 122 days); and 1 death that occurred 1 day after VVI implantation in a Boxer with arrhythmogenic right ventricular cardiomyopathy that had intractable ventricular tachyarrhythmias. Eight of the 14 postsurgical complications were considered minor and included the following: 4 lead migrations (2 VVIs at 66 and 487 days and 2 AAIs at 192 and 1,016 days), 2 of which required changes in pacemaker programming by increasing the output; 1 incidence of decreased capture of unknown origin (VVI at 16 days), which required an increase in output; 1 seroma (VVI at 6 days); 1 minor erosion over the generator (VVI at 79 days) that resolved with antimicrobial treatment; and 1 lead thrombus (VVI at 94 days) that subsequently resolved and was not associated with any clinical signs.

Not including failed attempts, 7 of 26 (27%) dogs that underwent dual-chamber pacemaker implantation had 9 total complications (2 dogs had 2 complications each). Five of the 9 postsurgical complications were considered major and included the following: 2 lead failures (2 DDD-RVAs at 24 and 711 days) with 1 ventricular lead that failed owing to unknown reasons and 1 atrial lead that failed owing to inappropriate sensing because the lead was not in the optimal position, 2 generator infections (1 VDD at 10 days and 1 DDD-RVA at 67 days), and lead migration (DDD-RVA at 26 days) that required replacement of the lead. Four of the 9 postsurgical complications were considered minor and included the following: 2 instances of phrenic nerve stimulation (2 DDD-RVAs at 18 and 210 days), 1 seroma (DDD-RVA at 17 days), and 1 thrombus (DDD-RVA at 88 days) on a right ventricular lead that was seen incidentally on echocardiography and had resolved at the time of follow-up echocardiography.

Thirty-three of 54 (61.1%) dogs underwent 1-lead pacemaker implantation (ie, AAI, VVI, or VDD; 13 of these 33 (39.4%) dogs had 15 total complications (7 major and 8 minor). Fifteen of 54 (27.8%) dogs underwent 2-lead pacemaker implantation (ie, DDD-RVA); 6 of these 15 dogs had 8 total complications (4 major and 4 minor). Six of 54 (11.1%) dogs underwent 3-lead pacemaker implantation (ie, DDD-BiV); no complications were reported for these dogs.

Significantly greater mean ± SD anesthesia times (179.1 ± 57.6 minutes vs 137.9 ± 43.5 minutes, respectively; \( P = 0.02 \)), procedure times (133.5 ± 31.3 minutes vs 94.9 ± 37.0 minutes, respectively; \( P < 0.01 \)), and body weights (28.8 ± 12.9 kg [63.4 ± 28.4 lb] vs 13.2 ± 10 kg [29.0 ± 22 lb], respectively; \( P < 0.01 \)) were observed for dogs undergoing dual-chamber pacemaker implantation, compared with dogs undergoing single-chamber pacemaker implantation. Patient ages were not significantly different between dogs undergoing dual-chamber pacemaker implantation (9.9 ± 3.0 years) and dogs undergoing single-chamber pacemaker implantation (9.9 ± 3.0 years). For all endpoints (minor complication, major complication, minor or major complication combined, death, and cumulative [a combination of all complications and death]), survival times were not significantly different between dogs that underwent single-chamber pacemaker implantation and dogs that underwent dual-chamber pacemaker implantation.

Procedure time increased with placement of an increasing number of leads (1 lead, 102.3 ± 51.1 minutes; 2 leads, 114.9 ± 24.8 minutes; 3 leads, 158.2 ± 8.5 minutes). Patients with placement of 3 leads had a significantly (\( P = 0.03 \)) greater procedure time, compared with patients with placement of 1 lead. No significant differences in anesthetic times were found among dogs with placement of 1 lead (144.9 ± 58.5 minutes), 2 leads (163.6 ± 28.8 minutes), or 3 leads (201 ± 14 minutes).

In the population as a whole, no significant associations were observed between either anesthesia time or procedure time and complications (major, minor, or overall) or death. Additionally, there was no increased risk of complications or death in dogs that underwent implantation with a 2-lead (ie, DDD-RVA) pacemaker or 3-lead (ie, DDD-BiV) pacemaker, compared with those that underwent implantation with a 1-lead (ie, AAI, VVI, or VVD) pacemaker. The lack of significant associations remained whether failed attempts at pacemaker implantation were classified as complications or not.

For the endpoints of minor complication (\( P = 0.13 \)), major complication (\( P = 0.90 \)), overall complications (\( P = 0.26 \); Figure 1), death (\( P = 0.92 \); Figure 2), and cumulative failure (a combination of overall complications and death, \( P = 0.22 \)), no significant differences were seen between dogs that had single-chamber pacemakers versus dogs that had dual-chamber pacemakers for the Kaplan-Meier analysis. Further Kaplan-Meier analysis was performed in which pacemaker type (dual vs single) was classified according to type of pacemaker intended and failed attempts at pacemaker implantation were included as minor complications. In this analysis, endpoints of minor complications (\( P = 0.15 \)), overall complications (\( P = 0.72 \)), and cumulative failure (\( P = 0.38 \)) were also not significantly different between dogs that had single-chamber pacemakers versus dogs that had dual-chamber pacemakers.
Because of the unique nature of the VDD (a single-lead pacemaker that allows dual-chamber pacing), an additional analysis was performed classifying these dogs as a unique group. There was no significant difference in the mean anesthesia times or mean procedure times in dogs undergoing VDD implantation, compared with dogs undergoing dual-chamber pacemaker implantation (with >1 lead) or single-chamber pacemaker implantation. Mean ± SD anesthesia times for implantation of single-chamber pacemakers, dual-chamber pacemakers (>1 lead), and VDD were 137.9 ± 43.4 minutes, 180 ± 29.3 minutes, and 175.6 ± minutes, respectively. Procedure times for implantation of single-chamber pacemakers, dual-chamber pacemakers (>1 lead), and VDD were 94.9 ± 37.0 minutes, 132.9 ± 29.3 minutes, and 134.8 ± 90.3 minutes, respectively. Not including dogs with a VDD, differences in mean ± SD anesthesia and procedure times between dogs undergoing single-chamber pacemaker implantation versus dogs undergoing dual-chamber (>1 lead) pacemaker implantation remained significant.

Discussion

Despite the advantages seen in human medicine with dual-chamber pacing, single-chamber pacemakers (primarily VVI) have been overwhelmingly used in dogs and have drastically improved the quality of life of canine patients with clinical signs of bradyarrhythmias. A small study in dogs showed decreased left atrial size and an improved neurohormonal profile in dogs treated by atrioventricular synchronization, compared with those treated traditionally (via a VDD vs VVI). Additionally, in a study with a population of 154 dogs treated almost exclusively with single-chamber pacemakers, 9 dogs with normal systolic function initially developed myocardial failure after pacemaker implantation. Although pacemaker syndrome was suspected, it was not known whether this syndrome was the cause of myocardial failure in these dogs. These findings as well as the benefits seen with dual-chamber pacing in human cardiology suggest dual-chamber pacing may be beneficial in canine patients.

It is thought that the procedure to implant a dual-chamber pacemaker is substantially more complicated, that the size of a dog may make it difficult for multiple leads to pass through the jugular vein, and that the increased number of leads may predispose to thrombus formation. Therefore, it has been assumed that dual-chamber pacing would result in a higher complication rate.

To the authors’ knowledge, this is the first study directly comparing single and all modes of dual-chamber pacing in canine patients. The primary hypothesis of our study was that dual-chamber pacemakers would not be associated with a higher complication rate, and although we did expect the anesthesia and procedure times would be higher, we did not expect them to be drastically so. Our procedure times were slightly higher than those previously reported for both single-chamber and dual-chamber pacemaker implantation, but the difference between the 2 was lower than reported previously. Both anesthesia and procedure times were approximately 40 minutes longer for dual-chamber versus single-chamber pacemakers in our study. Although this difference was significant, it did not result in an increase in complications or decrease in survival time.

When groups were defined by number of leads (1, 2, and 3) rather than pacing mode (single-chamber vs dual-chamber), procedure and anesthesia times increased as lead number increased but the only significant difference in procedure times was between the 1-lead and 3-lead groups. Because failed attempts at pacemaker implantation were excluded from our analyses, there were only 7 dogs in the 2-lead group, reducing the statistical power of our analysis. Had more dogs been included in this analysis, differences in anesthesia and procedure times may have been significant. Our 1-lead group included dogs fitted with VDDs, which had mean procedure and anesthesia times that were higher than those for dogs fitted with the other 1-lead pacing systems (AAI and VVI) and closer to those for dogs fitted with dual-chamber pacemakers. Despite this difference being nonsignificant, inclusion of these systems in our 1-lead group increased times and may also have contributed to the lack of significant difference between the 1-lead and 2-lead groups. Nonetheless, in addition to differences between pacing mode, we wanted to uncover any associations between an increasing number of leads and both complication rates and implantation times. Our dual-chamber pacemaker implantation group’s procedure and anesthesia times were increased because of the number of dogs for which DDD-BiVs were placed. The DDD-BiVs require 3 leads, and their use in dogs is still experimental; the extra lead and lack of familiarity with implanting these pacemakers undoubtedly led to an increase in implantation times. Comparing 1-lead versus 2-lead pacemakers also removed DDD-BiVs from the analysis and arguably provided a more appropriate comparison of implantation times.

Overall complication rates in our study population (35.2%, excluding failed attempts at pacemaker implantation) were less than rates documented in ear-
recent studies. Major complication rates in our study (20.4%) were less than rates documented in the earlier studies (33% and 58%) and similar to those reported in the 2 more recent studies (14% and 13%). Inclusion of failed attempts at pacemaker implantation as minor complications increased our overall complication rate to 46%. Eight of the 10 failed attempts at pacemaker implantation in our population occurred with DDD-BiVs. All of the comparison studies used predominantly single-chamber pacemakers and presumably did not include DDD-BiVs, which makes a direct comparison impossible. Some of the pacemakers in the previous studies were not implanted transvenously, and some used unipolar leads (making muscle tremors much more likely). All procedures performed at our institution were performed by or under the direct supervision of a board-certified veterinary cardiologist and with dedicated anesthesia personnel. Previous studies in human and veterinary medicine found that an increase in operator experience results in a decrease in complication rate. It is likely that all of these factors helped to lower the complication rate seen in the present study. Our dual-chamber pacemaker implantation group’s complication rate (27%) was comparable to that reported in 1 study (28%) and much less than that reported in another study (58%) in which only dual-chamber pacemakers were used in dogs to treat atrioventricular block. Differences between studies could be explained by reporting differences, operator experience, and availability of anesthesia personnel as well as differences in the equipment and pacemakers available during the procedure.

To our knowledge, the present study is the first direct comparison of complications between single-chamber and dual-chamber pacemakers implanted in dogs at a single institution, and the findings contradict the conventional belief that dual-chamber pacemakers are inherently more difficult to implant and result in more complications. Specifically, complication rates did not differ significantly between our single-chamber and dual-chamber pacemaker implantation groups. Importantly, many, but not all, of the factors that could reasonably be expected to alter complication rates were similar for all dogs in our study. The same cardiologists and residents implanted most of the single-chamber and dual-chamber pacemakers in our study over the same period, thus eliminating the possibility that a more experienced operator was responsible for implanting the dual-chamber pacemakers and therefore artificially lowering the complication rate in that group. Additionally, all procedures were performed in the same operating room with the same equipment, and qualified anesthesia personnel supervised all procedures. These findings challenge the previously held belief that dual-chamber pacemaker implantation in dogs would be fraught with complications, and we argue against citing increased complications as a reason to avoid dual-chamber pacemakers in dogs.

Although 1 small dog (a Pomeranian weighing 5.1 kg) successfully underwent dual-chamber pacemaker implantation, no other dogs with body weight < 10 kg (4.5 lb) received a dual-chamber pacemaker in the present study. In most of the smaller dogs in our study population, no attempts were made to implant dual-chamber pacemakers. Increased body weight (and likely increased jugular vein size) likely facilitates cardiac pacemaker implantation and may allow for easier placement of more leads. The difference in body weight between groups, a large and significant difference, must be considered. If the groups had similar body weights, our results may have been different in regard to complication rates and anesthesia and procedure times.

Survival time data in this study should be interpreted with caution because the start date of this study was only 12 months after the end of the inclusion period, and accordingly, many of the dogs included in the survival time analysis were still alive. Comparisons to past studies that were performed years after the participant inclusion dates are therefore not appropriate. However, our survival time data were consistent with data for human patients, for which most studies show no survival time benefit for dual-chamber pacemakers, compared with single-chamber pacemakers, despite improvements in hemodynamic parameters and quality of life benefits. Studies have been performed in humans in which the pacing mode was alternated between dual chamber and single chamber and patients are asked for their preference; nearly all patients who had a preference prefer the dual-chamber mode. Obviously, this type of study cannot be performed in dogs, but it does at least suggest that there could be quality of life benefits in dogs treated by means of atrioventricular synchrony. Another flaw in our survival time analysis is that it did not account for differences in underlying cardiac disease. Dogs with atrial standstill have a poorer prognosis for long-term survival, compared with that for dogs with atrioventricular block or sick sinus syndrome, and cannot be treated with a dual-chamber pacemaker. Additionally, a considerable number of dogs in our study had concomitant cardiac and noncardiac diseases, which were not accounted for in our survival time analysis.

Because of the retrospective nature of our study, follow-up information and procedural protocols were not consistent for all dogs. For example, some owners brought their dogs in for all scheduled recheck examinations, although some did not. Therefore, it is possible, if not likely, that data and relevant information regarding some of our study population were incomplete or missing. Different anesthesia personnel and procedures were used, possibly affecting the anesthesia time between patients. Although preoperative, implantation, and postoperative procedures were similar for most patients, there were no standardized protocols that were consistently used. Our study population consisted of 54 dogs; although this is comparable to, if not greater than, the number used in many veterinary studies, it is a low number that may restrict the statistical power of our data.

This study challenges the validity of avoiding dual-chamber pacemakers because of an increased complication rate. Despite the theoretical benefits of maintaining atrioventricular synchrony, dual-chamber pacemakers in this study provided no improvement over single-chamber pacemakers on the basis of the outcome.
measures used. Additional studies that measure cardiac function or evaluate more sensitive measures of quality of life may reveal advantages of dual-chamber pacing as they have in humans.

References