Published in final edited form as:

J Vet Cardiol. 2012 September ; 14(3): 409–414. doi:10.1016/j.jvc.2012.05.003.

Efficacy of two commercially available cardiac pacing catheters for transesophageal atrial pacing in dogs

Emily H. Chapel, BS^a and Robert A. Sanders, DVM, MS^{a,*}

^aMichigan State University College of Veterinary Medicine, East Lansing, MI 48823, USA

Abstract

Objective—Compare the efficacy of two cardiac pacing catheters for transesophageal atrial pacing (TAP).

Animals—Ten healthy dogs.

Methods—Transesophageal atrial pacing was attempted in left lateral recumbency under general anesthesia. In series, a curved electrophysiologic (EP) catheter and a straight transesophageal pacing (TP) catheter were passed transorally into the distal esophagus, caudal to the heart. Each catheter was slowly withdrawn until pacing was initiated. The catheter continued to be withdrawn in 5 mm increments until capture was no longer achieved at maximal pacing setting creating a total zone of capture (tZOC). Minimum pacing threshold (Th_{min}) and degree of extraneous muscle stimulation (EMS) were determined at each site.

Results—The EP catheter achieved TAP in 10/10 dogs with a Th_{min} of 8.8 ± 4.8 mA and tZOC of 4.0 ± 1.7 cm. The TP catheter achieved TAP in 7/10 dogs with a Th_{min} of 22.5 ± 5.6 mA and tZOC of 1.2 ± 1.6 cm. No EMS was noted during TAP at Th_{min} using the EP catheter. Of the 7 dogs in which TAP was successful, 3/7 experienced considerable EMS at Th_{min} . There was no significant relationship between patient body weight and Th_{min} with either catheter (EP catheter $P = 0.09$; TP catheter $P = 0.81$)

Conclusions—The electrophysiology catheter captured the atria of more dogs over a larger area without EMS as compared to the TP catheter. The electrophysiology catheter is recommended for transesophageal atrial pacing in dogs.

Keywords

Transesophageal; atrial; cardiac; temporary; pacing

Introduction

Transesophageal atrial pacing (TAP) has been shown to be a safe and effective technique that can achieve accurate heart rate control in dogs and people experiencing hemodynamically compromising bradycardia in the absence of significant atrioventricular

© 2012 Elsevier B.V. All rights reserved.

*Corresponding author: ras@cvm.msu.edu (R.A. Sanders).

Conflict of interest

The authors report no conflict of interest.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

(AV) nodal conduction disturbances.^{1–5} In people, the ability to successfully perform TAP has been demonstrated to depend on pulse amplitude, pulse width and polar separation.^{5,7–9} Studies in humans have demonstrated that an optimal polar separation range of 15 to 28 mm results in the lowest pacing threshold values.^{5,7–9} While there are no data about the effect of polar shape or surface area in TAP, endocardial pacing experiments have shown that poles with smaller surface areas create stronger current densities which allow for lower pacing thresholds compared to poles with larger surface areas.¹⁰

Currently there are no studies investigating the optimal catheter characteristics in the dog. However, two studies have investigated the potential of TAP in dogs using markedly different catheters and with different outcomes. One study reported considerable extraneous muscle stimulation (EMS) when consistent atrial pacing was achieved using a pulse stimulus of 30 mA with 2 ms pulse width.³ In the other study no EMS was reported when consistent atrial pacing was achieved with lower thresholds (10.5 ± 3.9 mA at a pulse width of 2 ms) in nine dogs.⁴ There may be multiple reasons for the different observations including patient and catheter characteristics. Studies in humans have shown that patient's age and weight have no significant effect on ability to pace and pacing thresholds.⁶ As such it is unlikely that the small difference in weight between dogs resulted in the differences noted.

In humans, higher minimum pacing thresholds are associated with discomfort or pain and may be more likely to cause EMS.^{7,11–14} In the clinical case described by Schmidt et al., the dog showed signs of pain and required progressively higher levels of anesthesia.⁴ Excessive muscular stimulation may also interfere with the concurrent procedure being performed and thus limit the clinical practicality of TAP. Thus, it is important to identify a pacing catheter that will provide highly successful atrial pacing without significant EMS. Currently there are no pacing catheters that are specifically designed to perform TAP in the dog. Based on previous studies on TAP in people and in dogs, we believe that a curved catheter with smaller poles would provide consistent TAP in dogs with a lower pacing threshold and less concurrent EMS than would a straight pacing catheter with larger poles. To test this hypothesis, TAP was attempted in dogs using two commercially available cardiac pacing catheters with different catheter shapes and polar surface areas.

Animals, materials and methods

This study was approved by the institutional animal care and use committee of Michigan State University and informed owner consent was obtained for all dogs.

Ten shelter-owned mixed breed dogs (18.3 ± 5.0 kg, mean $\pm$ SD) undergoing routine surgery (ovariohysterectomy or orchiectomy) were used for this study. Dogs were excluded if their intrinsic heart rate was above 120 bpm or any AV nodal conduction disturbances were noted. All dogs were premedicated using one of two protocols: acepromazine (0.03–0.04 mg/kg) combined with either hydromorphone (0.08–0.10 mg/kg) or morphine (0.5–0.8 mg/kg) administered intramuscularly. Anesthesia was induced with either propofol (13 mg/kg) or a ketamine/diazepam mixture (11.0/0.55 mg/kg respectively) administered through an indwelling IV catheter. Dogs were maintained under anesthesia with isoflurane gas anesthetic in oxygen and continually monitored with a surface ECG.

Bipolar atrial pacing was attempted using a 10 Fr transesophageal pacing (TP) catheter^b and a 6 Fr quadripolar electrophysiology (EP) catheter^c with the distal pole as the cathode and the most proximal pole as the anode in each dog (Fig. 1 and 2). The EP catheter was curved

^bTAPcath 205, CardioCommand, Tampa, FL USA

^c6 Fr Josephson curved quadripolar electrophysiologic catheter, St. Jude Medical, St. Paul, MN USA

with 2mm poles (12.6 mm² surface area) whereas the TP catheter was straight with 10 mm poles (103.7 mm² surface area) with a similar polar spacing of 19 mm and 20 mm, respectively.

All pacing catheters were placed and TAP was attempted without the use of fluoroscopic guidance. The dogs were placed in left lateral recumbency. Using an esophageal stethoscope^d cut at both ends as a semi-rigid plastic guide, each catheter was passed transorally into the esophagus to a distance aboral to the base of the heart. The esophageal stethoscope was then withdrawn, leaving the catheter in place within the esophagus. The same pulse generator^e was used in all dogs with each catheter. A stimulus was initiated using a pulse amplitude (PA) of 30 mA and a pulse width of 10 ms at a pacing rate of approximately 20 bpm above the intrinsic heart rate. The catheter was then slowly withdrawn until atrial capture was achieved as noted on the surface ECG. Atrial capture was defined as consistent atrial pacing without loss of atrial capture. Minimum pacing threshold, defined as the minimum PA required to pace the atria throughout the respiratory cycle, was determined and recorded at all sites of capture. The degree of EMS was subjectively described and recorded as none, mild, moderate or severe (Table 1). After the initial site of capture was determined, the catheter was withdrawn in 5-mm increments and minimum pacing threshold (Th_{min}) was determined at each site until atrial capture could not be achieved using a PA of 30 mA. A distance of 5-mm increments was chosen as this is the smallest distance at which accurate placement was achievable in our lab. The distance over which atrial capture was achieved was termed total zone of capture (tZOC). The distance over which atrial capture was achieved without moderate or severe EMS was termed clinical zone of capture (cZOC). Success of capture with each catheter was analyzed using a Fischer's exact test. Differences in minimum pacing thresholds and zone of capture between each catheter were analyzed using Student's paired t-tests. Linear regression analysis between the lowest Th_{min} and patient body weight was performed. A *P*-value of 0.05 was considered statistically significant.

Results

The body weight, Th_{min} , tZOC, cZOC and EMS data for each patient using the EP and TP catheter are presented in Table 2. Data is reported as mean $\pm$ standard deviation (SD).

Transesophageal atrial pacing was achieved in 10 of 10 (100%) dogs using the EP catheter and 7 of 10 (70%) dogs using the TP catheter (*P* = 0.21). Using the EP catheter, no EMS was noted in dogs at Th_{min} and EMS was never noted using PA of 12.5 mA. Of the 7 dogs in which TAP pacing was achieved using the TP catheter, only 4 dogs could be paced without EMS at Th_{min} and EMS was never noted using PA of 10 mA. The average lowest Th_{min} using the EP catheter (8.8 ± 4.8 mA) was significantly lower (*P* < 0.01) than the mean lowest Th_{min} using the TP catheter (22.5 ± 5.6 mA). The tZOC was significantly longer (*P* = 0.03) using the EP catheter (4.0 ± 1.7 cm) than the tZOC using the TP catheter (1.2 ± 1.6 cm). The cZOC was significantly longer using the EP catheter (3.4 ± 1.8 cm) than TP catheter (0.4 ± 0.7 cm) (*P* < 0.01). There was no significant relationship between patient body weight and Th_{min} with either catheter (EP catheter, *P* = 0.09; TP catheter *P* = 0.81).

Discussion

The optimal transesophageal atrial pacing catheter would pace all attempted patients without EMS, which would limit concurrent procedures. Several variables affect the success of

^d18 Fr Disposable Esophageal Stethoscope and Temperature Probe, 400 series, Mindray, Duluth, Georgia, USA

^eTransesophageal cardiac stimulator, Model 7A, CardioCommand, Tampa, FL USA

transesophageal atrial pacing. These may include patient characteristics, the width and amplitude of the applied pulse stimulus and catheter characteristics (interpolar spacing, pole size, pole and catheter shape).^{7,9,11} Studies in humans have demonstrated that use of wide pulse widths (5–10ms) and polar spacing included between 15 and 28 mm results in the lowest atrial pacing thresholds.^{7,9,11} Studies in people using endocardial pacing have demonstrated that as pole surface area decreases, current density increases and therefore lower thresholds can be obtained.¹⁰ However, to the authors' knowledge, there have been no studies evaluating the effect of catheter shape or pole size or shape on the efficacy of transesophageal atrial pacing. In this study, we evaluated two readily available pacing catheters with different pole sizes and catheter shapes and found significant differences in the ability to achieve TAP and in the length of the total and clinical zones of atrial capture.

Transesophageal atrial pacing was achieved in all dogs using the EP catheter whereas use of the TP catheter failed to pace the atria in 30% of the dogs. While this failure to pace the atria was not statistically significant it is a major clinical limitation to the utility of the TP catheter. When pacing was successful using the TP catheter a significantly higher Th_{min} was required and EMS was frequently noted. In some cases, EMS was severe and may have resulted in the inability to perform a concurrent procedure without neuromuscular blockade. The TP catheter caused moderate or severe muscular stimulation resulting in whole body movement in 3 of the 7 dogs who were successfully paced using the TP catheter. Extraneous muscular stimulation was not noted using currents less than or equal to 12.5 mA when using the EP catheter and 10 mA using the TP catheter. A PA of 10 mA is well below the average Th_{min} for the TP catheter and would not likely achieve atrial capture in many dogs. Frequent EMS noted during atrial pacing using the TP catheter would likely limit the clinical utility of this catheter. Both the tZOC and the cZOC were significantly longer for the EP catheter as compared to the TP catheter. A larger cZOC would allow for ease of placement of the catheter without other placement aids such as fluoroscopy. In this study, there was no statistically significant relationship between body weight and Th_{min} using either catheter. While this is a small study of 10 dogs with relatively similar weights, this finding is consistent with the studies of humans demonstrating that patient characteristics such as age and weight do not significantly affect the ability to pace the heart using TAP.⁶ In humans this is thought to be due to a relatively constant distance between the esophagus and heart throughout all life stages.⁶ In dogs, differences in breed conformations may alter the distance between the esophagus and the left atria and therefore change the requirements for successful pacing. This hypothesis is supported by the fact that pacing requirements change significantly within the same person when positioned in different recumbencies.¹⁵ Further evaluation of the relationship between body weight and breed conformation is needed.

There may be multiple possible reasons for the lower Th_{min} , longer cZOC and the significant reduction of EMS noted when using the EP catheter. The key differences between the EP catheter and the TP catheter are the catheter shape and polar surface area. The curved distal end of the EP catheter may result in better apposition between the catheter and ventral esophageal mucosa. This may have decreased the distance between the pacing catheter and the electrically conductive cells within the atria. By doing so, the current density at the level of the atria would increase, causing atrial capture at lower thresholds¹⁶. Smaller endocardial pacing poles have been shown to create a smaller but more intense electrical field and this property is likely to apply to esophageal pacing poles as well.^{10,17} The results of this study cannot be used to effectively discriminate between the individual importance of polar surface area and catheter shape. As such, further investigation is necessary in order to fully understand what effects polar surface and catheter shape may have on the efficacy of TAP.

Conclusion

Transesophageal atrial pacing without significant EMS was successfully achieved in 100% of dogs using the EP catheter whereas TAP without significant EMS was achieved in only 40% of dogs using the TP catheter. The EP catheter is therefore recommended for use in transesophageal atrial pacing for the treatment of bradycardia in dogs without significant AV nodal conduction disturbances.

Acknowledgments

Funding in part by NIH grant 5T35RR017491-09 to Michigan State University.

Table of abbreviations

TAP	Transesophageal atrial pacing
AV	Atrioventricular
EMS	Extraneous muscle stimulation
TP	Transesophageal pacing
EP	Electrophysiology
PA	Pulse amplitude
tZOC	Total zone of capture
Th_{min}	Minimum pacing threshold
cZOC3	Clinical zone of capture

References

1. Green HG III, Sanders RA, Ramos-Vara J, Hogan DF, Barta AJ. Safety of transesophageal pacing for 24 h in a canine model. *Pacing Clin Electrophysiol*. 2009 Jul; 32(7):888–889.
2. Sanders RA, Green HW III, Hogan DF, Sederquist K. Use of transesophageal atrial pacing to provide temporary chronotropic support in a dog undergoing permanent pacemaker implantation. *J Vet Cardiol*. 2011 Sep; 13(3):227–30. Epub 2011 Aug 2. [PubMed: 21813344]
3. Sanders RA, Green HW III, Hogan DF, Trafney D, Barta AS. Efficacy of transesophageal and transgastric cardiac pacing in the dog. *J Vet Cardiol*. 2010; 12:49–52. [PubMed: 20303843]
4. Schmidt M, Estrada A, VanGilder J, Masenbacher H, Prosek R. Safety and feasibility of transesophageal pacing in a dog. *J Am Anim Hosp Assoc*. 2008; 44:19–24. [PubMed: 18175795]
5. Gallagher JJ, Smith WM, Kerr R, Cook L, Reiter M, Sterba R, Harte M. Esophageal pacing: a diagnostic and therapeutic tool. *Circulation*. 1982; 65:336–341. [PubMed: 7053892]
6. Crawford T, Dick M II, Bank E, Jenkins J. Transesophageal atrial pacing: importance of the atrio-esophageal relationship. *Medical Instrumentation*. 1986; 20:40–44.
7. Roth J, Brody J, Denham EJ. Positioning the pacing esophageal stethoscope for transesophageal atrial pacing without p-wave recording: implications for transesophageal ventricular pacing. *Anesth Analg*. 1996; 83:48–54. [PubMed: 8659764]
8. Dick M II, Campbell R, Jenkins J. Thresholds for transesophageal atrial pacing. *Catheterization and Cardiovascular Diagnosis*. 1984; 10:507–513. [PubMed: 6518515]
9. Benson DW, Sanford M, Dunnigan A, Benditt DG. Transesophageal atrial pacing threshold: role of interelectrode pacing, pulse width and catheter insertion depth. *Am J Cardiol*. 1984; 53:63–67. [PubMed: 6691280]
10. Furman S, Parker B, Escher DJ. Decreasing electrode size and increasing efficiency of cardiac stimulation. *J Surg Res*. 1971; 11:105–10. [PubMed: 5092548]

11. Kerr R, Gallagher JJ, Smith WM, Sterba R, German LD, Cook L, Kassel JH. The introduction of atrial flutter and fibrillation and the termination of atrial flutter by esophageal pacing. *PACE*. 1983; 6:60–72. [PubMed: 6188126]
12. Benson DW Jr, Dunnigan A, Sterba R, Benditt DG. Atrial pacing from the esophagus in the diagnosis and management of tachycardia and palpitations. *J Pediatr*. 1983; 102:40–46. [PubMed: 6848726]
13. Critelli G, Grassi G, Perticone F, Coltorti F, Monda V, Condorelli M. Transesophageal pacing for prognostic evaluation of preexcitation syndrome and assessment of protective therapy. *AM J Cardiol*. 1983; 102:40–46.
14. Touborg P, Anderson HR, Pless P. Low current bedside emergency atrial and ventricular cardiac pacing from the esophagus. *Lancet*. 1982; 1:166. [PubMed: 6119539]
15. Schwann N, Maguire D, Roth J, McNulty S, Saouaf A. Evaluation of transesophageal atrial pacing in the prone and lateral positions. *J Cardiothoracic and Vascular Anesthesia*. 2001; 15:192–196.
16. Arzbaecher R, Jenkins J. A review of the theoretical and experimental bases of transesophageal atrial pacing. *J Electrocardiology*. 2002; 35:137–141.
17. Barold SS, Ong LS, Heinle RA. Stimulation and sensing thresholds for cardiac pacing: electrophysiologic and technical aspects. *Prog Cardiovasc Dis*. 1981; 24:1–24. [PubMed: 7019961]

Figure 1. Catheters evaluated in this study: Transesophageal pacing catheter (top) and electrophysiology catheter (bottom). Note the curved distal end and smaller poles of the electrophysiology catheter.

Figure 2.

Fluoroscopic images of the transesophageal pacing catheter (left) and electrophysiology catheter (right). These images were taken to demonstrate the location and relationship of the pacing catheters to the heart. Fluoroscopy was not used in this study to position the catheters.

Table 1

Description of extraneous muscular stimulation classification scheme.

None	No appreciable extraneous muscular stimulation
Mild	Cutaneous twitches. Concurrent procedure could continue unaffected.
Moderate	Stimulation of the diaphragm (respiration rate matched pacing rate) or front limbs causing body movement.
Severe	Whole body movement

Table 2

Patient weight, pacing thresholds, zones of capture, clinical zones of capture and degree of extraneous muscular stimulation using each catheter. (NC = No capture)

Electrophysiologic catheter					Transesophageal pacing catheter				
Patient	Weight (kg)	Th _{min} (mA)	ZOC (cm)	cZOC (cm)	EMS at Th _{min}	Th _{min} (mA)	ZOC (cm)	cZOC (cm)	EMS at Th _{min}
1	11.5	2.5	8	7.0	None	27.5	1.5	0	Severe
2	19.1	5	3.5	3.0	None	NC	0	0	N/A
3	10.5	5	4.5	2.0	None	22.5	1.0	0	Severe
4	20.0	15	3	1.0	None	NC	0	0	N/A
5	16.0	7.5	2.5	2.5	None	15	1.5	0.5	None
6	26.0	10	3	3.0	None	22.5	1.5	1.0	None
7	15.9	5	4.5	4.5	None	15	5.0	2.0	None
8	22.3	15	2	2.0	None	27.5	0.5	0	Moderate
9	23.6	7.5	4	4.0	None	NC	0	0	N/A
10	18.1	15	5	5.0	None	27.5	<0.5	<0.5	None