A Modified Kay–Reed Method for Mitral Annuloplasty in Dogs

Takuma Aoki

Hiroshi Sunahara

Keisuke Sugimoto

Yoko Fujii

Laboratory of Veterinary Surgery I, Azabu University,
1-17-71 Fuchinobe, Chuo-ku, Sagamihara-shi, Kanagawa 252-5201, Japan

KEY WORDS: mitral annuloplasty, mitral regurgitation, extracorporeal circulation system, dogs

ABSTRACT

The aim of this study was to apply a modified Kay–Reed (MKR) method, in which modified horizontal mattress sutures are placed in the mitral annulus without involvement of the middle scallops of the septal and mural leaflets in dogs, and to estimate its effect on left atrial pressure. Four normal laboratory beagles underwent the MKR procedure. The peak velocity and pressure half-time (PHT) of the E-wave and mean pulmonary capillary wedge pressure (PCWP) were measured to estimate left atrial pressure before and 1 month after surgery. The peak velocity of the E-wave significantly increased ($p < 0.01$), but the PHT of the E-wave was not prolonged 1 month after surgery ($p = 0.110$). The mean PCWP did not change ($p = 0.200$), and was within the reference range 1 month after surgery. Our MKR method is an alternative approach to mitral annuloplasty; it is easier to perform compared with traditional circumferential mitral annuloplasty and does not affect the PCWP, although the echocardiographic parameters are changed. However, further studies are needed in order to apply the MKR method to clinical cases such as those assessing the usefulness of the MKR method in small-sized dogs and its long-term durability.

INTRODUCTION

Mitral regurgitation (MR) caused by myxomatous mitral valve disease (MMVD) is the most commonly acquired heart disease among elderly dogs.[1,2] In MMVD, the valve cusps thicken and the chordae tendineae extend and/or rupture, with the mitral annulus dilating due to eccentric hypertrophy following volume overload.[2] Left-sided heart failure is commonly managed by medical treatments; however, progression of the disorder renders these treatments palliative.

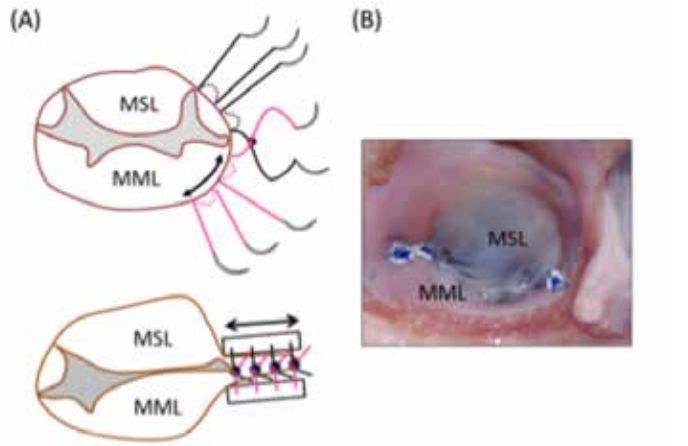
Recently, surgical treatments were reported in dogs with refractory MR.[3-8] Surgical treatments for MR include mitral valve repair and mitral valve replacement, although the latter requires a costly artificial valve and lifelong anticoagulant administration, which appears to be difficult in dogs. Thus, mitral valve repair is currently the most appropriate surgical treatment for dogs with MR, despite the technical difficulties and lack of subjective procedural information for mitral valve repair in veterinary medicine. Therefore, a well-skilled technical operator with extensive experience is required for successful mitral valve repair.

Mitral valve repair involves chordal re-

construction with expanded polytetrafluoroethylene (ePTFE) sutures and mitral annuloplasty. In humans, commercialized artificial rings are applied to the mitral annulus without septal leaflets for circumferential mitral annuloplasty.[9] However, these are expensive and too large for dogs.

In veterinary medicine, strips of expanded ePTFE material are used as substitutes for commercialized rings. This alternative technique is effective when performed by a skilled surgeon, since it is a complex and subjective procedure.[4,10] Simple and durable mitral annuloplasty, such as that conducted using the Kay–Reed method, has been reported in humans.[11] This technique is a smaller mitral annuloplasty in which both commissures of the mitral annulus are closed with only a horizontal mattress suture. Therefore, it appears suitable for canine mitral annuloplasty owing to its easy and objective procedural nature.

Figure 1. *The methodology of the modified Kay–Reed (MKR) procedure. Two opposing double-armed ligatures are combined to form 1 mattress suture. A strip of ePTFE material, whose length is similar to the distance between the point from where the first suture was started to the point where the last suture was ended on each side (double-headed arrow), was used. Distal sutures were tied in the air and the proximal opposite suture was then tied to the stick opposite the mitral annulus (A). An image showing a completed MKR procedure is shown (B). MSL: middle scallop of septal leaflet; MML: middle scallop of mural leaflet.*



However, the function of the mitral annulus may markedly change because its shape may deform more after this technique than after traditional circumferential mitral annuloplasty. In addition, left atrial pressure may markedly increase because the mitral orifice seems to be greatly decreased. Thus, the objective of the present study was to assess the effect of the Kay–Reed method on left atrial pressure in dogs.

MATERIALS AND METHODS

Animals

This study was approved by the ethical committee of Azabu University and conducted in accordance with the guidelines established by the United States Animal Welfare Act and National Institutes of Health's Guide for the Care and Use of Laboratory Animals.

We used 4 normal laboratory beagles. The mean (±SD) age and body weight were 2.5 (±1.6) years and 11.6 (±0.9) kg, respectively. Three beagles were male and one was female.

Modified Kay–Reed method (MKR)

In the Kay–Reed method, horizontal mattress sutures are placed in the commissure of the mitral annulus. In our approach, two opposing double-armed ligatures were combined to make one mattress suture because each suture was towed using a suture holder for visualizing the mitral valve apparatus during chordal reconstruction.

In addition, the tensile force for the mitral annulus was more uniform compared with that for normal horizontal mattress sutures. Polypropylene sutures (5-0) were placed in the mitral annulus, devoid of two large valve cusps (ie, middle scallops of

the septal and mural leaflets), with double-armed sutures (Fig. 1A and 1B).

Each suture bite was approximately 2–3 mm in length. The sutures were passed through a strip of ePTFE material, whose length was similar to the distance from the point from where the first suture was started to the point where the last suture ended on each side (Fig. 1A). Distal sutures were tied in the air and then the proximal opposite suture was tied to the stick opposite to the mitral annulus (Fig. 1A, bottom).

Cardiac Surgery with a Cardiac Pulmonary Machine

Open heart surgery was performed with cardiopulmonary bypass (CPB) using an extracorporeal circulation system (MERA Heart Lung Machine HAS type; Senko Medical Instrument Manufacturing Co. Ltd, Tokyo, Japan) under moderate hypothermia (28°C), as based on common procedures.4,5,8,10

Left thoracotomy was performed through the left fifth intercostal space. After performing left atriotomy, the MKR method was performed as described above. After the procedure was completed, the left atrium was closed with a 5-0 polypropylene suture, and the aorta was declamped. The animals were then weaned from the CPB according to commonly used procedures.[5,8,10]

The thoracic musculature, subcutaneous tissue, and skin were closed in a routine manner. For antibiotic therapy, cefazolin (22 mg/kg intravenously [IV] or orally every 12 h) was administered for 7 days after surgery. For anticoagulant therapy, dalteparin sodium (100 IU/kg subcutaneously every 12 h) was administered for 1 month after surgery once intrathoracic hemorrhage had decreased.

Estimation of Left Atrial Pressure

All dogs were examined using the Vivid 7 Dimension cardiovascular ultrasound system (GE Healthcare Japan Corporation, Tokyo, Japan), with mechanical phased array transducer frequencies of 2–5 and 3.1–8 MHz. An echocardiographic view was obtained according to the guidelines of the American Society of Echocardiography.12 A left parasternal long-axis view was obtained, and pulsed wave Doppler echocardiography was used to estimate the peak velocity (reference range, 0.5–1.0 m/s13) and pressure half-time (PHT; reference range, 10–52 ms13) of flow during early ventricular diastole (E-wave) before and 1 month after surgery. The mean value of three cardiac cycles was calculated. Doppler inflow across the mitral valve was measured with the sample volume positioned at the tip of the mitral valve leaflets.

Pulmonary capillary wedge pressure (PCWP) was estimated with cardiac catheterization before and 1 month after surgery. General anesthesia was induced using propofol (6–8 mg/kg IV) and maintained with inhalation of 1.5–2.0% isoflurane in 100% oxygen. After aseptic preparation, the right jugular vein was punctured percutaneously using the Seldinger technique, and a 5-French (Fr) hemostatic valve sheath was introduced and fixed with suturing. Approximately 3 h after recovery from anesthesia, the animals were gently left in left-lateral recumbency, and then a 5-Fr Swan-Ganz catheter was inserted through the sheath. With the balloon inflated, the catheter was advanced until it was wedged in a pulmonary capillary and then connected to a manometer for mean PCWP measurements (reference range, 5–10 mmHg14).

Statistical Analysis

Results are expressed as mean (±SD). Statistical difference was determined using a two-sided paired t-test. Differences with $p < 0.05$ were considered significant. The statistical processes described previously were performed using the statistical software Ekuseru-Toukei 2010 (Social Survey Research Information Co., Ltd., Tokyo, Japan).

RESULTS

Comparison of Pulsed Wave Doppler Echocardiographic Data

The peak velocity of the E-wave before and 1 month after surgery was 0.74 (±0.09) m/s and 1.59 (±0.16) m/s, respectively. The peak velocity of the E-wave significantly increased ($p < 0.01$) and was above the

reference range in all dogs 1 month after surgery. The PHT before and after surgery was 33.5 (±4.8) ms and 56.3 (±16.4) ms, respectively. The PHT of the E-wave was not significantly prolonged ($p = 0.110$) but was above the reference range in 1 beagle (80.8 ms). However, no dogs had clinical signs associated with pulmonary edema despite these echocardiographic changes.

Comparison of the Mean PCWP

The mean PCWP before and 1 month after surgery was 5.2 (±2.6) mmHg and 7.6 (±1.2) mmHg, respectively. The mean PCWP did not increase after surgery ($p = 0.200$), and was within the reference range in all dogs before and 1 month after surgery.

DISCUSSION

In humans[3] and dogs,[5] circumferential mitral annuloplasty in which 75% of the mitral annulus without septal leaflets is reefed is commonly employed. On the other hand, hemi-circumferential mitral annuloplasty, which is employed in the mitral annulus of cranial and caudal commissures, has been reported in dogs.[10] This smaller annuloplasty is not theoretically enough for mitral annuloplasty because MR resulting in commissure-commissure annular dilatation has been reported.[15] However, hemi-circumferential mitral annuloplasty might reduce the risk of thromboembolism and cross-clamp time because the number of ligations and amount of artificial materials is lesser than in circumferential mitral annuloplasty.

However, the degree of reefing is determined by the surgeon's level of experience. On the other hand, the MKR method is not only a smaller annuloplasty, but also simpler and a more objective technique because it only requires modified mattress sutures and the site of ligations is decided (the mitral annulus without the middle scallops of the septal and mural leaflets). In addition, the modified mattress sutures appear to be more useful than the normal horizontal mattress sutures because the mitral valve apparatus is able to be visualized well during choral reconstruction when each suture is towed using a suture holder and the tensile force for the mitral annulus is more uniform compared with that for normal horizontal mattress sutures. Therefore, the MKR method appears to be easier and more objective than hemi-circumferential mitral annuloplasty and original Kay-Reed method.

Despite its advantages, the MKR method provides less natural results in the shape of mitral annulus compared with common circumferential and hemi-circumferential mitral annuloplasty[5,9,10] and might cause mitral stenosis due to its excessive mitral annulus reefing. The shape of the mitral annulus resembles the shape of a saddle[15] and dynamically changes during the cardiac cycle.[16] Indeed, the saddle-shaped annuloplasty decreases leaflet stress and potentially increases the durability of mitral valve repair in humans with ischemic mitral regurgitation.[17]

In addition, excessive mitral annuloplasty in the septal–lateral dimension may be caused by a left ventricular outflow tract due to systolic anterior motion of the elongated septal or mural leaflets.[18] Therefore, the shape and dynamic motion of the mitral annulus may need to be preserved in the natural state as much as possible. In fact, echocardiographic data indicated a high left atrial pressure, similar to that seen in mitral stenosis, in dogs who underwent the MKR procedure, because peak velocity of the E-wave was significantly increased and PHT mildly prolonged.

However, pulmonary capillary wedge pressure, the gold standard for left atrial pressure estimation, did not change and was within the reference range 1 month after surgery in all four beagles. In addition, none of the animals had clinical signs associated with pulmonary edema despite these echocardiographic changes. Thus, the MKR method appears not to affect left atrial pressure, despite echocardiographic data changes. However, long-term durability of the method should be investigated since the shape of the mitral annulus was less natural than that seen with traditional circumferential and hemi-circumferential mitral annulo-

plasty.

There are several limitations in the present study. Firstly, only beagles were used for assessment of the MKR method, even though MMVD is commonly observed in small-sized breeds.[2] Secondly, the long-term durability of the MKR method was not investigated. Finally, the influence of the method was only examined for left atrial pressure. The influence of the method on the function of the mitral annulus should be further investigated because the echocardiographic data markedly changed after surgery.

CONCLUSION

In conclusion, the MKR method is a simple, easy, and objective mitral annuloplasty technique that does not have short-term effects on left atrial pressure. However, further studies involving assessment of the long-term durability and usefulness of the method in small-sized dogs are needed in order to apply the technique in clinical cases.

CONFLICT OF INTEREST

This study was performed at the Laboratory of Surgery 1, Azabu University and Azabu University Veterinary Teaching Hospital. We have no conflicts of interest

REFERENCES

1. Atkins C, et al. Guidelines for the diagnosis and treatment of canine chronic valvular heart disease. *J Vet Intern Med* 2009;23:1142-50.
2. Haggstrom J, Duelund Pedersen H, and Kvart C. New insights into degenerative mitral valve disease in dogs. *Vet Clin North Am Small Anim Pract* 2004;34:1209-26.
3. Boggs LS, Dewan SJ, and Ballard SE. Mitral valve reconstruction in a toy-breed dog. *J Am Vet Med Assoc* 1996;209:1872-6.
4. Griffiths LG, Orton EC, and Boon JA. Evaluation of techniques and outcomes of mitral valve repair in dogs. *J Am Vet Med Assoc* 2004;224:1941-5.
5. Orton EC, et al. Technique and outcome of mitral valve replacement in dogs. *J Am Vet Med Assoc* 2005;226:1508-11.
6. Kanemoto I, et al. Successful mitral valvuloplasty for mitral regurgitation in a dog. *Nippon Juigaku Zasshi* 1990;52:411-4.
7. Terzo E, et al. Echocardiographic assessment of 537 dogs with mitral valve prolapse and leaflet involvement. *Vet Radiol Ultrasound* 2009;50:416-22.
8. Kanemoto I, et al. Open heart surgery with deep hypothermia and cardiopulmonary bypass in small and toy dogs. *Vet Surg* 2010;39:674-9.
9. Enriquez-Sarano M, Akins CW and Vahanian A. Mitral regurgitation. *Lancet* 2009;373:1382-94.
10. Uechi, M. Mitral valve repair in dogs. *J Vet Cardiol* 2012;14:185-92.
11. Reed GE, Pooley RW, and Moggio RA. Durability of measured mitral annuloplasty: seventeen-year study. *J Thorac Cardiovasc Surg* 1980;79:321-5.
12. Gottdiener JS, et al. American Society of Echocardiography recommendations for use of echocardiography in clinical trials. *J Am Soc Echocardiogr* 2004;17:1086-119.
13. Lehmkuhl LB, Ware WA, and Bonagura JD. Mitral stenosis in 15 dogs. *J Vet Intern Med* 1994;8:2-17.
14. Richard D Kienle. 1998 Caridiac Catheterization. In: Mark D Kittleson and Richard D Kienle (ed). *Small animal cardiovascular medicine*. Mosby, St Louis, pp 118-132.
15. Nguyen TC, et al. The effect of pure mitral regurgitation on mitral annular geometry and three-dimensional saddle shape. *J Thorac Cardiovasc Surg* 2008;136:557-65.
16. Komeda M., et al. Three-dimensional dynamic geometry of the normal canine mitral annulus and papillary muscles. *Circulation* 1996;94:159-63.
17. Vergnat M, et al. The influence of saddle-shaped annuloplasty on leaflet curvature in patients with ischaemic mitral regurgitation. *Eur J Cardiothorac Surg* 2012;42:493-9
18. Schiavone WA, et al. Long-term follow-up of patients with left ventricular outflow tract obstruction after Carpentier ring mitral valvuloplasty. *Circulation* 1988;78:60-5.