Note
Surgery

Modified loop technique in three dogs with mitral regurgitation

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Running head:
MODIFIED LOOP TECHNIQUE IN DOGS
Mitral valvuloplasty (MVP) is used in dogs with refractory mitral regurgitation (MR); however, it is difficult to tie the artificial chord, i.e., the expanded polytetrafluoroethylene suture, at the planned height of the mitral valve because of the slippery nature of the knot. The loop technique has resolved these difficulties in humans. Premanufactured loops (length, 8.0–15.0 mm with 1.0-mm increments) were used in the new modified loop technique. In the current study, cardiac murmurs disappeared, and the MR markedly improved or completely disappeared approximately 3 months after surgery in 3 dogs. Therefore, this new technique might be effective in dogs.

KEY WORDS: extracorporeal circulation system, canine, loop technique, mitral regurgitation, mitral valvuloplasty
Surgical treatments for dogs with mitral regurgitation (MR) have recently been reported [2, 7, 9, 10, 16, 21]. Surgical options include mitral valvuloplasty (MVP), in which the patient’s valve is preserved, and mitral valve replacement, in which an artificial valve is used. However, artificial valves are extremely expensive, and immense efforts are required to avoid thrombosis with anticoagulant administration [16]. Therefore, MVP is the most appropriate surgical treatment for dogs with MR.

Expanded polytetrafluoroethylene (ePTFE) is used as an artificial chord for chordal reconstruction because of its strong, biocompatible, and flexible nature; however, due to its slippery nature, tying a knot becomes difficult [5, 12, 15]. Therefore, Mohr developed the loop technique in which 4–5 loops are fixed on a pledget using a single suture thread and double needles during surgery [22]. This technique does not have the above-mentioned drawbacks of the ePTFE sutures, and is used for minimally invasive surgery. This technique can be easily performed even in a narrow surgical area, as it requires only double-armed sutures and simple interrupted sutures [19, 22]. The surgical area in dogs is very narrow, even in cases with cardiomegaly due to MR, because almost all the subjects are small- to medium-breed dogs [1, 8]. Thus, use of the loop technique may be effective in dogs with MR.

In the current modified loop technique, the loops were fashioned using CV-6 ePTFE sutures (Gore-Tex CV-6 ePTFE suture; Japan Gore-Tex Co. Ltd., Tokyo, Japan) and sterilized by ethylene oxide gas prior to surgery. Each loop was tied using 1 surgical knot and 5 square knots on the apparatus that was fixed at a length of 8.0–15.0 mm at 1.0-mm increments (Fig. 1).

Open-heart surgery was performed by cardiopulmonary bypass using an extracorporeal circulation system (MERA Heart Lung Machine, HAS type; Senko Medical Instrument Manufacturing Co. Ltd., Tokyo, Japan) under moderate hypothermia (28°C) using common procedures [7, 10, 21]. After a left atriotomy was performed,
the length of the strut chordae adjacent to the elongated chordae was measured using the scale (Fig. 2A); the value obtained was multiplied by 0.8 and then rounded off (Fig. 2A). The loops that were closest in size to the calculated value mentioned above were selected for chordal reconstruction. The loops were fixed to the papillary muscle using a CV-6 double-armed ePTFE suture with a double needle attached with a pledget and then connected to the prolapsed valve cusp using another CV-6 simple interrupted ePTFE sutures (Fig. 2B). Other MVP procedures, such as annuloplasty, were not performed during cardiac repair. Anticoagulant, dalteparin sodium (100 IU kg\(^{-1}\), SC; q 12 h) was administered for 1 month after surgery, after intrathoracic hemorrhage decreased.

This study was approved by the Ethics Committee of Azabu University and conducted in accordance with the guidelines established by the Animal Welfare Act and the National Institutes of Health Guide for the Care and Use of Laboratory Animals.

The first dog used in the study was an intact 8-year-old male laboratory Beagle, weighing 9.0 kg. A systolic murmur with maximal intensity over the left apex (grade 4/6) was auscultated. Echocardiography showed a septal leaflet prolapse without cardiomegaly (left ventricular diameter index during diastole [LVDd-index] = 1.55, normal range [3] = 1.27–1.85; left atrium aorta ratio [LA/Ao] = 1.09, normal range [17] <1.6). Two marginal chordae derived from the cranial and caudal papillary muscles (CrPM and CaPM, respectively) were elongated. One artificial 9.0-mm loop was applied for CrPM, while 3 artificial 10-mm loops were applied for CaPM. The cardiac murmur and the turbulent flow caused by the MR disappeared completely at 122 and 1,111 days after surgery, respectively.

The second dog used in the study was an intact 6-year-old female laboratory Beagle, weighing 11.45 kg. A systolic murmur with maximal intensity over the left apex (grade 4/6) was auscultated. Echocardiography showed septal leaflet prolapse without
cardiomegaly (LVDd-index = 1.46, normal range [3] = 1.27–1.85; LA/Ao = 0.92, normal range [17] < 1.6). Two marginal chordae derived from each papillary muscle were elongated. Two artificial 7.0-mm loops were applied for CrPM, while 3 artificial 9.0-mm loops were applied for CaPM. The cardiac murmur and the turbulent flow caused by the MR disappeared completely at 113 and 1,058 days after surgery, respectively.

The third dog used in the study was an intact 17-year-old female mongrel dog weighing 10.75 kg. A systolic murmur with maximal intensity over the left apex (grade 4/6) was auscultated. Echocardiography showed bileaflet prolapse without cardiomegaly (LVDd-index = 1.63, normal range [3] = 1.27–1.85; LA/Ao = 1.06, normal range [17] < 1.6) [20]. Two marginal chordae derived from each papillary muscle were elongated. Two artificial 12.0-mm loops were applied for CrPM and CaPM. Only the septal leaflet was reconstructed. The cardiac murmur disappeared completely; however, the turbulent flow caused by the MR was faintly detectable at 82 days after surgery. Moreover, the grade 4/6 systolic regurgitation murmur, like a musical murmur, with maximal intensity over the left apex was auscultated 1,027 days after surgery, and moderate turbulent flow caused by the MR streamed toward the atrial septum similarly to a mural leaflet prolapse [6]. The dog did not have cardiomegaly at any time, i.e., the LVDd-indices at 82 and 1,027 days after surgery were 1.41 and 1.47, respectively (normal range [3] = 1.27–1.85). In addition, LA/Ao at 82 and 1,027 days after surgery was 1.39 and 1.05, respectively (normal range [17] < 1.6).

Fig. 3 shows the echocardiogram results of each dog before and after surgery using the color Doppler method.

In humans, the loop technique is performed for chordal reconstruction using minimally invasive cardiac surgery because of its ease and simplicity, i.e., tying the knot without the knot slipping and choosing the precise length of the artificial chord [12,
In this study, the modified loop technique was easily performed in a narrow surgical area, because it required only easy ligations (i.e., double-armed suture and simple interrupted suture), and the length of artificial chord did not shorten when the knots were tied. In our modified loop technique, loops of various sizes were premanufactured prior to surgery and then selected during surgery for use in the chordae that required repair. The original loop technique, in which the loops were fabricated using a single ePTFE suture during surgery [22], is not preferable in veterinary medicine, because a shorter cardiac arrest time is required in animals due to the small blood volume and the later surgical timing, which results in a more injured myocardium. In addition, our modified method, in which loops of various sizes can be selected during surgery, might be effective for chordal reconstruction even when the valve cusp is not uniformly affected, although loops of the same length were used in the original method [22].

In humans, the artificial chord length of the septal leaflet was commonly determined using the height of the mural leaflet [22], although various methods have been used to determine the correct artificial chord length [13, 14]. However, in our study, an accurate mural leaflet height could not be easily measured in dogs without cardiomegaly due to our inexperience. Conversely, the strut chordae could be easily identified in the small surgical area, because the septal leaflet was larger than the mural leaflet and the strut chordae was the thickest of the chordae [11, 18]. Thus, the size of the artificial loops in the present study was determined on the basis of the length of the strut chordae that was adjacent to the elongated chordae since the strut chordae was wider than the marginal chordae [18], and therefore, seemed to be less elongated and more resistant to prolapse due to its wide width. The loop size was calculated by multiplying the strut chordae length by 0.8 and then rounding the value off, although much shorter artificial chords of the septal leaflet may fail to match the mural leaflet height. However, the tip
of the affected leaflet appeared to be ineffective for valvular function due to its nodal and rigid pathological changes [11], and an artificial chord shorter than the strut chordae was selected in the present study.

In case of the third dog, the MR caused by mural leaflet prolapse was identified after the surgery, although it occurred before the surgery and had been overlooked. In cases with bileaflet prolapse, annuloplasty is required in combination with chordal reconstruction for the septal leaflet [4] or bileaflets. Our method would be able to match the opposed leaflet height when loops of the same size were applied to them.

This study has several limitations. First, obtaining the loop size index might not be as simple as that mentioned above, since the affected area varies in practical cases, particularly when the strut chordae are elongated. Second, estimation of left atrial pressure was not included in the present study, although none of the dogs showed pulmonary vein enlargement on thoracic radiography. Finally, the combined use of chordal reconstruction technique and annuloplasty should be evaluated in practical cases, although the evaluation of chordal reconstruction alone has not been reported in dogs with spontaneous MR.

This new technique might be effective in dogs with MR, but its concomitant use with annuloplasty should be examined since those techniques are concurrently performed in practical cases [7]. In addition, further studies are required to develop a method to determine the correct length of artificial loops.
**Figure legend**

Fig. 1. Loops ranging in length from 8.0–15.0 mm with 1.0-mm length increments, expanded-polytetrafluoroethylene suture, and the apparatus used to manufacture the loops.

Fig. 2. (A) Anatomical image shown as a right parasternal 4-chamber view in echocardiography. The chordae tendinae attached to the tip of the septal leaflet, i.e., the marginal chordae, secured the mitral valve in the left ventricle. The length of the chordae tendinae adjacent to the elongated chordae, i.e., the strut chordae, was measured using the scale bent at the tip for deciding loop size (yellow double-headed arrow). (B) The modified loop technique. The loops are fixed using another CV-6 double-needle expanded polytetrafluoroethylene suture with a pledget in the papillary muscle and the rough zone of the prolapsed valve cusp using another CV-6 suture. RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle; CaPM, caudal papillary muscle; PM, papillary muscle; SC, strut chordae; MC, marginal chordae; SL, septal leaflet.

Fig. 3. The color Doppler echocardiographic findings of all dogs. Panels A, B, and C show the results for Dogs 1, 2, and 3, respectively. The images (from the left) represent those obtained before surgery, 2–3 months after surgery, and approximately 3 years after surgery in each dog. The third dog had mild to moderate mitral regurgitation approximately 3 years after surgery that appeared to be a result of mural leaflet prolapse. LA, left atrium; LV, left ventricle.
REFERENCES


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