










Case Report Surgery



Successful mitral repair in dogs by mitral annuloplasty using Hegar dilator: two case reports

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ABSTRACT



Mitral regurgitation (MR) is the most common heart disease in small-breed dogs. Mitral repair, which comprise artificial chorda tendineae implantation and mitral annuloplasty, has become the mainstay of treatment in the veterinary field. We report on two small dogs who underwent mitral repair surgery for MR. A Hegar dilator was used during mitral annuloplasty for accurate and reproducible surgery. In both cases, mitral regurgitant flow almost disappeared after surgery, and clinical signs improved. The treatment regimen was terminated 3 months after the surgery. We concluded that using a Hegar dilator may facilitate mitral valve repair surgery.

Keywords: Case reports; dog; cardiac surgery; mitral valve; mitral annuloplasty

INTRODUCTION

Mitral regurgitation (MR) associated with myxomatous valvular degeneration is one of the most commonly acquired heart problems in small dogs [1]. Surgical treatment, such as mitral repair or artificial valve replacement, is routinely performed for human patients [2,3]. However, only few veterinary centers can perform open heart surgeries to treat MR due to technical difficulties [4].

The major surgical methods for mitral repair are mitral annuloplasty and artificial chordae implantation [5,6]. In humans, commercially available prosthetic annuloplasty rings are used for mitral repair [7,8]. However, these are not applicable for small veterinary patients because of their anatomical differences and the small heart size [8]. Alternatively, mitral annuloplasty techniques have been introduced, including annuloplasty with hand-made expanded polytetrafluoroethylene (ePTFE) strip and suture annuloplasty with prolene or ePTFE suture [5,8]. Recently, ePTFE suture annuloplasty has been preferred to reduce the risk of thrombosis formation [9].

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution

Conceptualization: Kim DH; Data curation: Kim J, Eom T, Son D, Lee S; Formal analysis: Lee WJ, Kim J, Kim DH; Funding acquisition: Kim DH; Investigation: Lee WJ, Moon CH; Supervision: Kim DH; Writing - original draft: Lee WJ, Kim J; Writing - review & editing: Lee H, Jeong SM, Kim DH.



Fig. 1. Image of a commercially available Hegar dilator.

To the best of our knowledge, this is the first case report of successful mitral repair in a veterinary patient in South Korea. Herein, we present the surgical technique of mitral valve repair in a small animal and usefulness of the Hegar dilator (**Fig. 1**) for mitral annuloplasty.

CASE PRESENTATION

Case 1

A 10-year-old, castrated male Maltese dog weighing 2.58 kg was referred for mitral valve repair surgery. The patient had been coughing four to five times per day since the previous 3 months accompanied with frequent panting. Heart murmur and mild cardiomegaly were diagnosed by radiography at a local veterinary hospital. Thereafter, the dog received pimobendan 0.25 mg/kg twice daily.

On physical examination, a grade 4/6 holosystolic murmur was heard at the apex of the heart with normal lung auscultation. Thoracic radiography revealed mild left cardiomegaly (**Table 1**). Echocardiography revealed severe MR with a moderate anterior mitral leaflet prolapse. Both the left atrium and mitral annulus were mildly dilated (**Table 1**). Based on

Table 1. Pre- and postoperative thoracic radiographic and echocardiographic findings

Index	Case No.	Pre-operative	Post-operative	1 month	3 months
VHS	1	11.2	9.5	10.0	10.2
	2	10.4	9.6	9.5	9.0
MR (m/s)	1	6.56	N	N	N
	2	4.71	N	N	N
MV annulus (mm)	1	15.38	10.88	9.77	10.77
	2	13.33	9.5	9.49	8.55
LA/Ao	1	1.83	1.13	1.33	1.30
	2	1.70	1.27	1.40	1.20
LVIDd (mm)	1	24.8	17.0	16.8	15.6
	2	23.5	15.8	16.8	16.9
LVIDs (mm)	1	10.6	10.6	10.4	9.0
	2	8.01	10.7	12.3	9.79
FS (%)	1	57.3	37.6	38.1	42.1
	2	65.9	32.3	37.9	42.1

VHS, vertebral heart score; MR, mitral regurgitation; MV, mitral valve; LA, left atrium; Ao, aorta; LVIDd, left ventricular end diastolic diameter; LVIDs, left ventricular end systolic diameter; FS, fractional shortening.

these examinations, the patient was diagnosed with mitral valve insufficiency (American College of Veterinary Internal Medicine [ACVIM] stage B2). We recommended follow-up with medication because the dog had relatively mild clinical signs and heart remodeling. However, the owner desired that the dog be treated by surgical mitral repair.

Case 2

An 8-year-old, castrated male Maltese dog weighing 2.36 kg was referred for mitral valve repair surgery. The dog had a history of mild cough since the age of 7 years and had sudden dyspnea with hemoptysis and cyanosis 3 weeks before surgery. A radiograph taken at a local hospital confirmed pulmonary edema, and 0.75 mg/kg/h of furosemide was administered. Thereafter, the treatment regimen was shifted to oral intake. However, pulmonary edema developed again, requiring hospitalization and intravenous treatment. After the pulmonary edema improved, 0.5 mg/kg pimobendan twice daily, 0.5 mg/kg enalapril twice daily, 1 mg/kg spironolactone once daily, and 2 mg/kg furosemide thrice daily were prescribed for oral intake before surgery.

On physical examination, a grade 5/6 holosystolic murmur was heard at the apex of the heart with normal lung auscultations. Thoracic radiography revealed mild left cardiomegaly and confirmed pulmonary edema (**Table 1**). On echocardiography, severe MR was observed with flail movement of the mitral valve and suspected rupture of the chorda tendineae. Both the left atrium and mitral annulus were mildly dilated (**Table 1**). Therefore, the patient was diagnosed with congestive heart failure with acute mitral valve prolapse due to the ruptured chordae tendineae (ACVIM stage C). Considering the request of the owner, the patient underwent surgery as soon as possible.

Anesthesia and cardiopulmonary bypass

Before surgery, the animals were premedicated intravenously with 0.025 mg/kg atropine sulfate, 0.3 mg/kg midazolam, and 5 µm/kg fentanyl as a pre-anesthetic adjuvant and 22 mg/kg of cefazolin as a precaution. Anesthesia was induced intravenously with 6 mg/kg of propofol and maintained with 2.0% isoflurane inhalation until cardiopulmonary bypass (CPB) was established.

The CPB was prepared during patient anesthesia. An oxygenator (Terumo Baby FX-05; Terumo Co, Japan) was installed on the roller type CPB machine (Terumo Advanced Perfusion System 1; Terumo Co). The size of the main pump tubing was 1/4 and that of the other tubing (suction line, artery filter line, and cannulation line) was 3/16. Before priming the CPB circuit, we made a target hematocrit (Hct) percentage of 25%–30% and decided the minimum level of the reservoir tank to be approximately 350 mL. The CPB circuit was filled with 20% albumin, 100 mL; 20% mannitol, 5 mL/kg; 8.4% bicarbonate, 1 mL/kg; heparin, 500 units; antibiotic (22 mg/kg of cefazolin); packed red blood cells; and volume expander (Plasmalyte).

After inducing anesthesia, the patient was placed in a right lateral recumbent position. The right femoral artery was exposed and catheterized with a 22 G over-the-needle catheter for monitoring the arterial pressure. At this time, 200 U/kg heparin was administered initially, and additional administration was performed when the activated clotting time (ACT) was below 300 sec, according to the previous reports [5]. Then, a 6 Fr arterial cannula was inserted into the left carotid, and a 10 Fr venous cannula was inserted into the left jugular vein. The aorta and left auricle were exposed by left fifth intercostal thoracotomy. After confirming that the ACT was over 300 sec, CPB was initiated and inhalation anesthesia

with isoflurane was terminated and switched to continuous intravenous infusion of 0.4 µg/kg/min fentanyl and 0.2 mg/kg/min propofol. Cardioplegia (cardioplegic solution 1; JW Pharmaceutical Co., Korea) mixed with 10 mL 8.4% sodium bicarbonate was induced with 20 mL/kg of cold blood cardioplegia solution comprising one-part cardioplegia to four parts blood from the patient and repeated every 20 min; the body temperature was maintained at 28°C during the intracardiac procedure.

Surgical procedure

The mitral valve was exposed via a left auricular incision; it was carefully examined, including both valve leaflets and the chorda tendineae. The nomenclature of the mitral valve segment, septal 1–3 (S1–S3) and mural 1–3 (M1–M3), was referred to by Uechi et al. (2012) [5]. In case 1, mildly thickened septal and mural leaflets and elongated chorda tendineae were confirmed. In case 2, the mitral valve was moderately thickened, and three of the chorda tendineae (S2, S3, and M1) were ruptured. The septal mitral leaflet prolapse was confirmed through a saline test for both patients. Four artificial chordae tendineae (GORE-TEX, CV-6; WL Gore & Associates, Inc., USA) were implanted at the S1–S2, S2–S3, M–M2, and M2–M3 segment areas. A semi-circular annuloplasty was performed as purse-string suture by continuous suture of 5-0 ePTFE (GORE-TEX, CV-5; WL Gore & Associates, Inc.) through the mural leaflet with 2 pledgets placed both ended from the septal commissure to the mural commissure of the basal portion of the septal leaflet, and the suture was tightly tied using an 11-mm Hegar dilator [5,10,11] (**Fig. 2A and B**). The size of the requisite Hegar dilator was previously measured on ultrasonography. After mitral repair, a saline test was performed to examine the remaining regurgitation. The left auricle was closed with a double simple continuous pattern using a 6-0 polypropylene suture (Prolene 6-0; Ethicon, Johnson & Johnson Company, USA). Then, the maximum volume of air in the left atrium and ventricle was removed through the aortic root cannula by aspiration, and the aortic cross-clamp was released. Concurrent ventricular fibrillation was initiated, although the heart rhythm normalized immediately after applying the defibrillator once. The bypass flow was slowly reduced to allow the cardiac function to return to normal. Rewarming was initiated simultaneously at the CPB weaning stage, and both cases took approximately 1 h to increase the patient temperature from 28°C to 38°C. Dobutamine 5–10 mcg/kg/min, if needed norepinephrine 0.05–0.3 mcg/kg/min, was administered (intravenous [IV] injection, constant rate infusion [CRI]) to support heart contraction during CPB weaning. When the bypass pump was completely terminated,

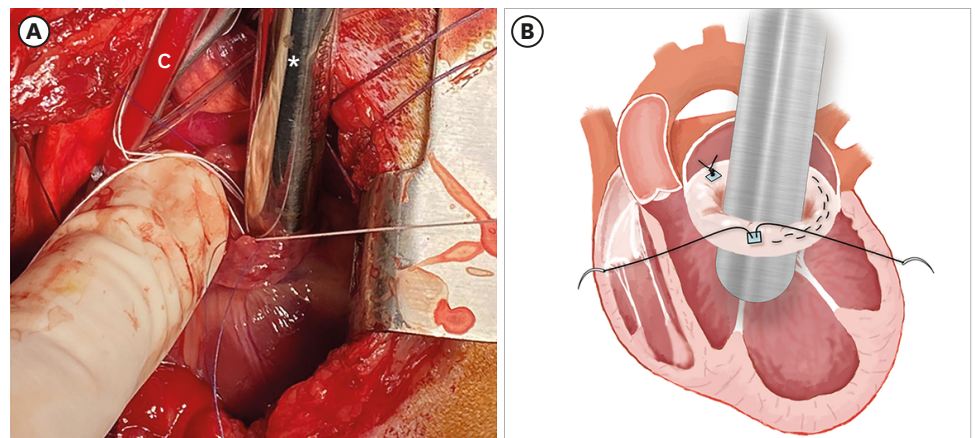


Fig. 2. Mitral annuloplasty. (A) Intraoperative photograph of mitral annuloplasty (asterisk: Hegar dilator; C: aortic root cannula for cardioplegia infusion). (B) Illustration of mitral annuloplasty procedure.

protamine administration was initiated. The duration of protamine administration was 30 min to prevent side effects. No adverse effects were observed after administration.

Both arterial and venous cannulas were removed from the carotid artery and jugular vein, and the vessels were closed by suturing in a simple continuous pattern using a 7-0 polypropylene suture (Prolene 7-0; Ethicon, Johnson & Johnson Company). Subsequently, a chest tube was placed, and the chest was closed routinely.

During the surgery, the heart rate, respiratory rate, rectal temperature, esophageal temperature, arterial oxygen saturation, end-tidal carbon dioxide (CO₂), and arterial blood pressure were continuously monitored. Arterial blood gas analysis and the ACT were measured every 30 min or after an event, such as a rapid drop of arterial blood pressure. Arterial blood gas analysis was conducted to monitor pH, partial pressure of CO₂, partial pressure of oxygen, Hct, and electrolyte balance. Whole blood was added to the CPB reservoir when the Hct was below 25%. However, if the Hct was above 25% and the reservoir level was under the minimum value, a volume expander was added. Arterial blood pressure was measured by invasive arterial blood pressure through the right femoral artery. Other than low blood pressure (systolic blood pressure < 60 mmHg) during CPB, there were no other problems. Drug administration (IV injection, CRI) details and isoflurane concentration were documented. The lowest bypass flow was 63 mL/kg/min, and the highest flow was 121 mL/kg/min. Bicarbonate was injected when the patient's lactate level was higher than 3 mmol/L. Heparin was added when the ACT was lower than 300 sec. Phenylephrine 20 mcg/kg was added to the bypass reservoir when the mean arterial pressure was lower than 60 mmHg.

Postoperative course

Both the dogs recovered from anesthesia smoothly and had uneventful postoperative courses. No cardiac murmur was heard immediately after surgery. Three hours after surgery, the owner was able to visit, and 24 h after surgery, spontaneous eating and standing were possible.

Postoperative medications, including an antibiotic (22 mg/kg of cefazolin, IV), an anticoagulant (dalteparin sodium, subcutaneous), and an analgesic (fentanyl, CRI), were administered to both the patients. Additionally, inotropic drugs, plasma/blood volume expanders, and vasodilators were added depending on the patient's condition. In both cases, blood transfusion was indicated right after the surgery when the Hct was below 20% and administered until the Hct reached 30%.

Three days after surgery, a fentanyl patch was applied and maintained for 1 week. The diuretic was removed immediately after surgery in both cases; 0.5 mg/kg of rivaroxaban once daily and 0.2 mg/kg of pimobendan twice daily were maintained after discharge. Eventually, at 3 months after surgery, the treatments were terminated. During the recovery stage, no specific problems, such as neurologic or respiratory issues, electrolyte disorder, acidosis, or blood panel issues, were observed.

On thoracic radiography, the vertebral heart score (VHS) in case 1 decreased from 11.2v (preoperative) to 9.5v (postoperative) and was 10.2v 3 months after surgery (**Fig. 3** and **Table 1**). VHS in case 2 decreased from 10.4v (preoperative) to 9.6v (postoperative) and was 9.0v at 3 months after surgery (**Table 1**). Echocardiography 3 months after the surgery showed no regurgitation after surgery in both cases (**Fig. 4**). The left atrium to aorta ratio in case 1 decreased from 1.83 (preoperative) to 1.13 (postoperative) and was 1.30 after 3 months

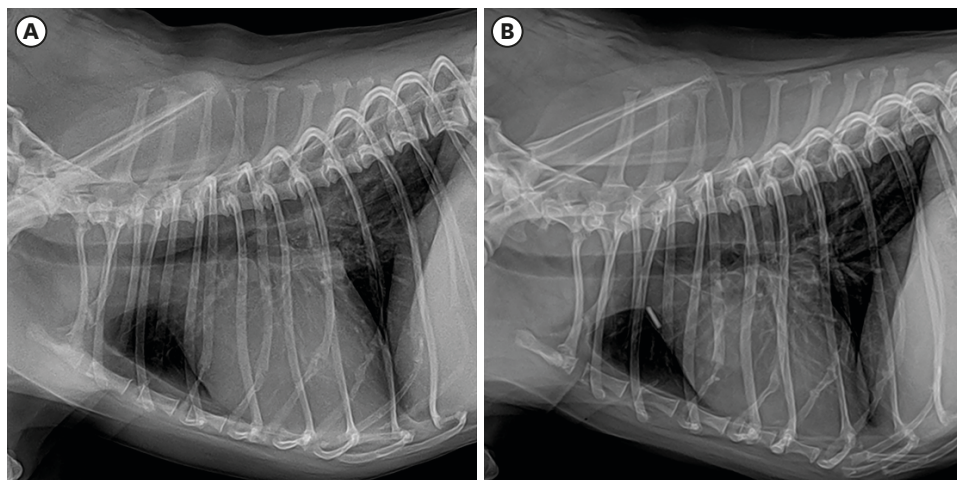


Fig. 3. Radiography examples in case 1. (A) Pre-operative and (B) 3 months post-operative radiographs.

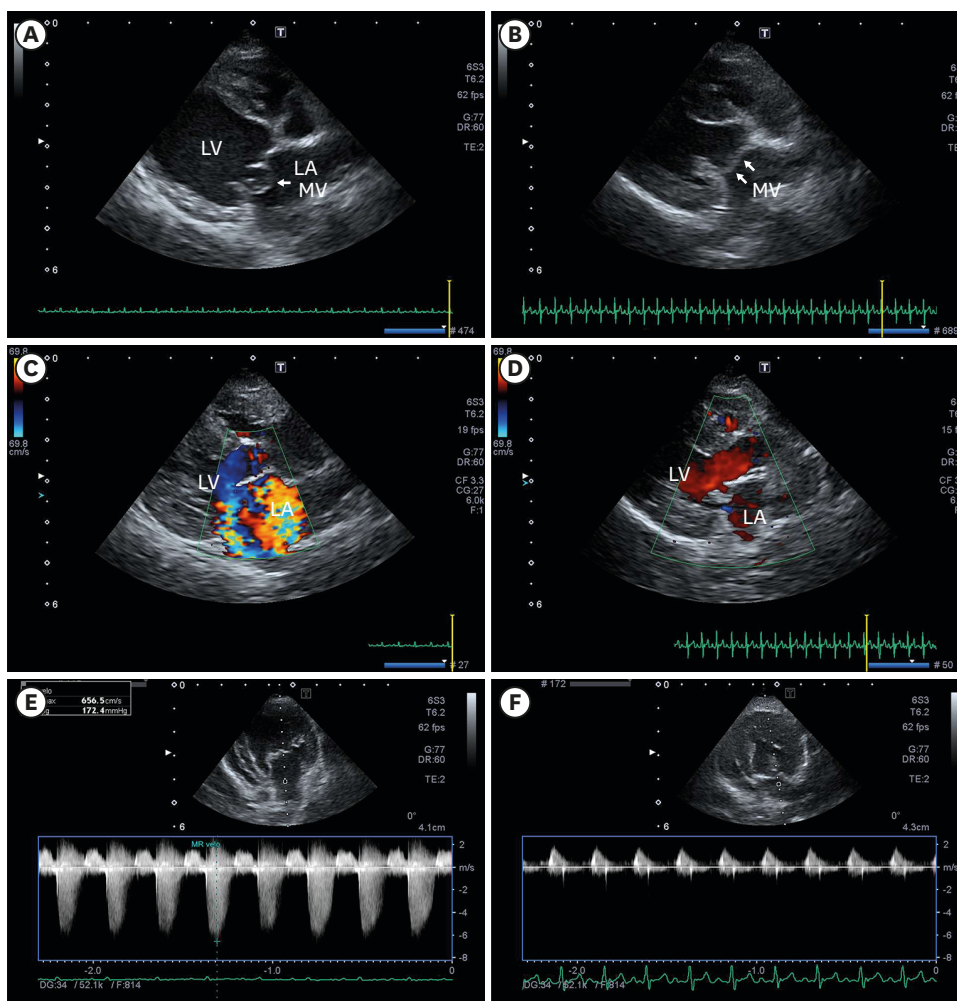


Fig. 4. Echocardiography examples in case 1. Moderate mitral leaflet prolapse are confirmed in right-parasternal four-chamber view (A). There is no valve prolapse on postoperative echocardiography (B). Severe mitral valve regurgitation is detected on color Doppler mapping (C). After mitral valve repair, a mosaic-pattern has almost disappeared (D). On continuous wave Doppler imaging, late systole regurgitation flow is confirmed (E), although this could not be observed after surgery (F). (A, C, and E) taken before the surgery and (B, D, and F) taken 3 months after the surgery.

(**Table 1**). Case 2 had decreased ratio from 1.70 (preoperative) to 1.27 (postoperative) and was 1.20 after 3 months (**Table 1**). The left ventricular end diastolic diameter (LVIDD) in case 1 decreased from 24.8 mm before surgery to 17.0 mm after surgery and was 15.6 mm at 3 months after surgery; in case 2, it decreased from 23.5 mm (preoperative) to 15.8 mm (postoperative) and was 16.9 mm at 3 months after surgery (**Table 1**). The LVIDs in case 1 decreased from 10.6 mm (before surgery) to 9.0 mm (3 months after surgery); in case 2, it increased from 8.01 mm (before surgery) to 9.79 mm (3 months after surgery).

Case 1 did not show any heart-induced clinical signs. No specific changes on radiography and echocardiogram were revealed. However, intermittent hematuria was observed induced by urinary cystolith. Cystotomy with scaling to remove urinary cystolith was conducted 188 days after the mitral valve repair. Urinary cystolith treatment was completed, and the patient was discharged 198 days after the mitral valve repair. The patient weighed 2.65 kg on discharge.

The second patient's owner refused regular checkups 3 months after the mitral valve repair due to the patient's stress. Since the patient's owner refused checkups, we followed up with phone calls and patient videos. The last follow-up was 225 days after the surgery, and the owner reported that the patient showed no clinical signs and that the quality of life increased. The patient's recently measured weight was 2.50 kg.

DISCUSSION

This report presents a successful mitral repair performed on veterinary subjects using a Hegar dilator. Mitral regurgitant flow almost disappeared after surgery, and patients were able to terminate all cardiovascular drug use at 3 months after surgery.

Open heart surgery in small animals is performed by only a few veterinary centers because of its relative complexity and requirement for specialized equipment and skills [4]. To achieve good surgical outcomes, well-trained surgeons, anesthesiologists, perfusionists, radiologists, and cardiologists are needed, and communications between the team is very important [5]. To the best of our knowledge, this is the first report of successful mitral repair with cardiopulmonary bypass in South Korea.

Annuloplasty rings are widely used for mitral annuloplasty in humans [7]. The flexible band (Cosgrove) and rigid band (Carpentier) are conventional products [12,13]. Recently, a biodegradable ring (Kalangos) was introduced for mitral valve annuloplasty [14]. However, the anatomical differences between animals and humans, as well as the small size of the animal's heart, present challenges in the application of the ring method to mitral annuloplasty in veterinary medicine [8]. Therefore, suture annuloplasty is preferred for dogs [8]. As prosthetic valves are available with different diameters, reducing the mitral annulus to the desired diameter is highly feasible [15,16]. However, suture annuloplasty is limited by the disability to regulate the mitral valve annulus with an accurate diameter.

The Hegar dilator is widely used for cervical dilation in obstetrics and gynecology [17]. Other applications have been expanded to urology surgery, laparoscopy, and heart valve surgery [17-19]. In cardiovascular surgery, the Hegar dilator accurately measures the inner diameter of the valve annulus during the annuloplasty, especially in cases of congenital heart defects (e.g., atrial and ventricular septal defects), and prostheses, such as stentless aortic

valves [20,21]. In addition, Schneider et al. introduced the suture annuloplasty technique for aortic valve repair using ePTFE suture and the Hegar dilator [22]. The advantages of the Hegar dilator for measurements during cardiothoracic surgery include the feasibility offered by its conical tip to advance into the annulus or defect and that the main body of the Hegar dilator is perfectly circular such that its cross section reveals the exact diameter of the annulus or defect [20]. The dilator's diameter is calibrated by 1 mm, and the range is sufficient to perform mitral annuloplasty regardless of the animal's body weight (< 20 kg); the mean normal mitral valve annulus diameter in systole of dogs under 20 kg is 11.41–23.59 mm (minimum 6.80 mm, maximum 27.91 mm) [1,23]. The Hegar dilator size was chosen as the same diameter as that of the aortic sinus of Valsalva by measuring the diameter of the aortic sinus of Valsalva via echocardiography at the short-axis aortic level before the annuloplasty [5]. The use of a Hegar dilator in open heart surgery on dogs was reported in 1983 only; pulmonary valvectomy to correct the Tetralogy of Fallot [24]. When we applied the Hegar dilator in mitral valve annuloplasty, the dilated mitral annulus could be reduced to the diameter desired. Postoperative echocardiography confirmed that the mitral annulus width was effectively decreased. Therefore, applying the Hegar dilator is appreciable for veterinary mitral valve annuloplasty.

Mitral annuloplasty in humans has different criteria for correcting the mitral valve [25-27]. However, in dogs, mitral valve annuloplasty is applied based on the surgeon's experience due to the absence of criteria. In these two cases, the annuloplasty criteria were referred to previous report [5]. Annuloplasty was performed as same as the diameter of the aortic sinus of Valsalva measured by echocardiography. These cases have the limitation of body weight, which was approximately 3 kg. Therefore, more cases of mitral valve repair with varying bodyweight are needed.

The optimal timing of mitral valve repair has often been discussed [1,5,28]. Uechi et al. [5] reported that early MVR may be more beneficial. However, recent reports show that the optimal timing of mitral valve repair for dogs does not depend on the stage [28]. Our study also suggested that ACVIM stage B2 patients are potential candidates [1]. The ACVIM consensus guidelines (2019) state that surgical treatment is more beneficial than risk in stage B2 patients [1]. Tribouilloy et. al. [29] reported that for humans, New York Heart Association classes 3–4 had a higher mortality and morbidity than stages 1–2 when surgical treatment was applied [5]. In particular, mitral valve surgery in advanced heart failure enhances the morbidity and mortality and prolongs medical treatment duration following left ventricular function [30]. Nonetheless, more case studies from our institution would be able to demonstrate important advantages for stage B2 and C.

In conclusion, the Hegar dilator can reproducibly reduce the planned diameters of the mitral annulus during annuloplasty. Further studies should examine this technique with a large sample size.

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REFERENCES

1. Keene BW, Atkins CE, Bonagura JD, Fox PR, Häggström J, Fuentes VL, et al. ACVIM consensus guidelines for the diagnosis and treatment of myxomatous mitral valve disease in dogs. *J Vet Intern Med.* 2019;33(3):1127-1140.
[PUBMED](#) | [CROSSREF](#)
2. Di Salvo TG, Acker MA, Dec GW, Byrne JG. Mitral valve surgery in advanced heart failure. *J Am Coll Cardiol.* 2010;55(4):271-282.
[PUBMED](#) | [CROSSREF](#)
3. Bonow RO, Carabello BA, Chatterjee K, de Leon AC Jr, Faxon DP, Freed MD, et al. 2008 focused update incorporated into the ACC/AHA 2006 guidelines for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the 1998 guidelines for the management of patients with valvular heart disease). Endorsed by the Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. *J Am Coll Cardiol.* 2008;52(13):e1-e142.
[PUBMED](#) | [CROSSREF](#)
4. Thornton KC. Repair surgery among latest treatments for mitral valve disease. *Am Vet.* 2017;2(4):22-24.
5. Uechi M, Mizukoshi T, Mizuno T, Mizuno M, Harada K, Ebisawa T, et al. Mitral valve repair under cardiopulmonary bypass in small-breed dogs: 48 cases (2006-2009). *J Am Vet Med Assoc.* 2012;240(10):1194-1201.
[PUBMED](#) | [CROSSREF](#)
6. Miura T, Eishi K, Yamachika S, Hashizume K, Yamane K, Taniguchi S, et al. Mitral valve repair for degenerative disease with leaflet prolapse: to improve long-term outcomes. *Gen Thorac Cardiovasc Surg.* 2009;57(1):10-21.
[PUBMED](#) | [CROSSREF](#)
7. McGee EC Jr, Gillinov AM, Blackstone EH, Rajeswaran J, Cohen G, Najam F, et al. Recurrent mitral regurgitation after annuloplasty for functional ischemic mitral regurgitation. *J Thorac Cardiovasc Surg.* 2004;128(6):916-924.
[PUBMED](#) | [CROSSREF](#)
8. Nishida M, Kagawa Y, Mizukoshi T, Mizuno M, Mizuno T, Harada K, et al. Post-mortem evaluation of expanded polytetrafluoroethylene (ePTFE) used in mitral valve repair in dogs. *J Vet Cardiol.* 2012;14(1):307-312.
[PUBMED](#) | [CROSSREF](#)
9. Revuelta JM, Garcia-Rinaldi R, Gaité L, Val F, Garijo F. Generation of chordae tendineae with polytetrafluoroethylene stents. Results of mitral valve chordal replacement in sheep. *J Thorac Cardiovasc Surg.* 1989;97(1):98-103.
[PUBMED](#) | [CROSSREF](#)
10. Kanemoto I, Mihara K, Sato K. Open-heart techniques and mitral valve plasty for mitral regurgitation in toy- and small-breed dogs: a review. *Open Vet J.* 2021;11(1):14-26.
[PUBMED](#) | [CROSSREF](#)
11. Mizuno T, Mizukoshi T, Uechi M. Long-term outcome in dogs undergoing mitral valve repair with suture annuloplasty and chordae tendinae replacement. *J Small Anim Pract.* 2013;54(2):104-107.
[PUBMED](#) | [CROSSREF](#)
12. Deloche A, Jebara VA, Relland JY, Chauvaud S, Fabiani JN, Perier P, et al. Valve repair with Carpentier techniques. The second decade. *J Thorac Cardiovasc Surg.* 1990;99(6):990-1001.
[PUBMED](#) | [CROSSREF](#)
13. Gillinov AM, Cosgrove DM 3rd, Shiota T, Qin J, Tsujino H, Stewart WJ, et al. Cosgrove-Edwards Annuloplasty System: midterm results. *Ann Thorac Surg.* 2000;69(3):717-721.
[PUBMED](#) | [CROSSREF](#)
14. Cherian S, Cikiricioglu M, Can Depboylu B, Jolou J, Kalangos A. Mitral annuloplasty using a biodegradable annuloplasty ring. *Oper Tech Thorac Cardiovasc Surg.* 2015;20(2):124-134.
[CROSSREF](#)
15. Braun J, van de Veire NR, Klautz RJ, Versteegh MI, Holman ER, Westenberg JJ, et al. Restrictive mitral annuloplasty cures ischemic mitral regurgitation and heart failure. *Ann Thorac Surg.* 2008;85(2):430-436.
[PUBMED](#) | [CROSSREF](#)
16. Carpentier A, Deloche A, Dauptain J, Soyer R, Blondeau P, Pivnicka A, et al. A new reconstructive operation for correction of mitral and tricuspid insufficiency. *J Thorac Cardiovasc Surg.* 1971;61(1):1-13.
[PUBMED](#) | [CROSSREF](#)

17. Gaur D. The use of Hegar's dilator in laparoscopy. *Minim Invas Ther.* 1993;2(6):333-334.
[CROSSREF](#)
18. Gnanaraj J. The use of Hegar's dilator for finding correct planes around the uterus. *Trop Doct.* 2011;41(4):222-223.
[PUBMED](#) | [CROSSREF](#)
19. Kaplan F, Alvarez J, Dwyer P. Nonsurgical separation of complete labial fusion using a Hegar dilator in postmenopausal women. *Int Urogynecol J Pelvic Floor Dysfunct.* 2015;26(2):297-298.
[PUBMED](#) | [CROSSREF](#)
20. Bapat VN, Attia R, Thomas M. Effect of valve design on the stent internal diameter of a bioprosthetic valve: a concept of true internal diameter and its implications for the valve-in-valve procedure. *JACC Cardiovasc Interv.* 2014;7(2):115-127.
[PUBMED](#) | [CROSSREF](#)
21. Dashkevich A, Blanke P, Siepe M, Pache G, Langer M, Schlensak C, et al. Preoperative assessment of aortic annulus dimensions: comparison of noninvasive and intraoperative measurement. *Ann Thorac Surg.* 2011;91(3):709-714.
[PUBMED](#) | [CROSSREF](#)
22. Schneider U, Aicher D, Miura Y, Schäfers HJ. Suture annuloplasty in aortic valve repair. *Ann Thorac Surg.* 2016;101(2):783-785.
[PUBMED](#) | [CROSSREF](#)
23. Wesselowski S, Borgarelli M, Mencioti G, Abbott J. Echocardiographic anatomy of the mitral valve in healthy dogs and dogs with myxomatous mitral valve disease. *J Vet Cardiol.* 2015;17(2):97-106.
[PUBMED](#) | [CROSSREF](#)
24. Herrtage ME, Hall LW, English T A H. Surgical correction of the tetralogy of Fallot in a dog. *J Small Anim Pract.* 1983;24(2):51-62.
[CROSSREF](#)
25. Brown ML, Schaff HV, Li Z, Suri RM, Daly RC, Orszulak TA. Results of mitral valve annuloplasty with a standard-sized posterior band: is measuring important? *J Thorac Cardiovasc Surg.* 2009;138(4):886-891.
[PUBMED](#) | [CROSSREF](#)
26. Rausch MK, Bothe W, Kvitting JP, Swanson JC, Miller DC, Kuhl E. Mitral valve annuloplasty: a quantitative clinical and mechanical comparison of different annuloplasty devices. *Ann Biomed Eng.* 2012;40(3):750-761.
[PUBMED](#) | [CROSSREF](#)
27. Choo SJ, Olomon J, Bowles C, Luo HH, Pang D, Oury JH, et al. An *in vitro* study of the correlation between aortic valve diameter and mitral intertrigonal distance: a simple method to select the correct mitral annuloplasty ring size. *J Heart Valve Dis.* 1998;7(5):593-597.
[PUBMED](#)
28. Mizuno M, Uechi M. Mitral valve annuloplasty and chordal replacement in dogs. *J Vet Cardiovasc Med.* 2020;4(1):1-7.
29. Tribouilloy CM, Enriquez-Sarano M, Schaff HV, Orszulak TA, Bailey KR, Tajik AJ, et al. Impact of preoperative symptoms on survival after surgical correction of organic mitral regurgitation: rationale for optimizing surgical indications. *Circulation.* 1999;99(3):400-405.
[PUBMED](#) | [CROSSREF](#)
30. Stone GW, Lindenfeld J, Abraham WT, Kar S, Lim DS, Mishell JM, et al. Transcatheter mitral-valve repair in patients with heart failure. *N Engl J Med.* 2018;379(24):2307-2318.
[PUBMED](#) | [CROSSREF](#)