Combined cutting balloon and conventional balloon angioplasty in a dog with supravalvular pulmonary stenosis

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ABSTRACT. A 7-year-old Miniature Schnauzer presented with exercise intolerance and easy fatigability. Echocardiography revealed the presence of supravalvular pulmonary stenosis. The peak velocity through the stenosis was 6.4 m/sec, and the interventricular septum was flattened. Cutting balloon angioplasty was designed for the treatment of coronary artery stenosis, which was resistant to conventional balloon angioplasty. Accordingly, the dog underwent cutting balloon angioplasty and conventional balloon dilation. One month after treatment, it showed neither exercise intolerance nor easy fatigability. The ventricular septum flattening disappeared. Five months later, the dog showed an increase in activity. Two years later, the peak velocity through the stenosis decreased to 4.4 m/sec. Neither clinical symptoms nor restenosis was observed. Thus, supravalvular pulmonary stenosis was successfully treated using this combination method. The present case showed that combined cutting balloon and conventional balloon angioplasty is a useful and minimally invasive treatment for supravalvular pulmonary stenosis.

KEY WORDS: cardiovascular, congenital heart disease, dog, heart failure
Atropine sulfate (Atropine sulfate; Tanabe Seiyaku Co., Ltd., Saitama, Japan, 50 µg/kg subcutaneously [SC]), meloxicam (Metacam 0.5%; Boehringer Ingelheim Vetmedica, Tokyo, Japan, 0.2 mg/kg SC), ampicillin sodium (ampicillin Na injection; Kyoritsu Seiyaku, Tokyo, Japan, 30 mg/kg, intravenously [IV]), buprenorphine hydrochloride (Lepetan 0.2 mg; Otsuka Pharmaceutical, Tokyo, Japan, 10 µg/kg IV), and midazolam hydrochloride (Dormicum; Astellas Pharma Inc., Tokyo, Japan, 0.2 mg/kg IV) were administered prior to induction. The dog was intubated after induction with propofol (Propofol Mylan; Mylan Seiyaku, Tokyo, Japan, 4 mg/kg IV). General anesthesia was maintained by the inhalation of isoflurane (Isoflurane for Animal Use; Intervet, Osaka, Japan, 1.5–1.7%). The dog was restrained in the right lateral recumbent position.

Catheterization was performed under fluoroscopic and transesophageal echocardiographic (TEE) guidance. A surgical area on the left jugular vein was prepared using aseptic technique, and the jugular vein was surgically exposed. A 7-Fr introducer (Radifocus; Terumo, Tokyo, Japan) was inserted into the jugular vein. Then, a super stiff guidewire measuring 0.025” × 260 cm was inserted through the introducer into the right ventricle and passed through the stenosis under TEE guidance. Immediately before CBA, TEE showed that the velocity through the stenotic lesion was decreased from 6.4 m/sec before anesthesia to 3.8 m/sec. This could be attributed to attenuation of the right ventricular peak pressure by anesthesia. An Over-the-Wire peripheral cutting balloon catheter (Cutting Balloon Peripheral Microsurgical Dilation Device 8.0 mm × 2.0 cm × 135 cm; Boston Scientific, Natick, MA, U.S.A.) was advanced over the guidewire and passed just below the center of the stenotic lesion (Figs. 2 and 3). The cutting balloon catheter was rapidly inflated and deflated seven times after confirmation of its position under TEE guidance. The cutting balloon was completely deflated before removal to avoid vascular injury from the blades. TEE revealed a decrease in the velocity through the stenotic lesion from 3.8 m/sec before CBA to 3.2 m/sec after CBA. After removal of the cutting balloon, a conventional balloon catheter measuring 12 mm × 3.0 cm × 90 cm (Tyshak II; NuMed Canada, Cornwall, ON, Canada) was inserted via the guidewire into the stenotic lesion. After withdrawing the guidewire, the conventional balloon catheter was rapidly inflated and deflated eight times. Decrease in the velocity through the stenotic lesion from 3.2 to 3.0 m/sec was confirmed by TEE. After removing the...
The jugular vein was continuously sutured using a 5-0 synthetic non-absorbable monofilament suture (Prolene; Ethicon, Tokyo, Japan), and an intradermal suture was performed using 3-0 Maxon (Maxon; Covidien, Mansfield, MA, U.S.A.). Recovery from anesthesia was uneventful, and the dog was discharged on the following day. The dog received antibiotics (Cefalexin, 15 mg/kg, q12h) for seven days.

One month after CBA, the dog showed neither exercise intolerance nor easy fatigability. The tricuspid valve regurgitation and ventricular septum flattening also disappeared (Fig. 4). The peak velocity through the stenotic lesion was decreased to 5.5 m/sec (Table 1). Five months later, the owner reported that the dog showed markedly increased activity. The peak velocity through the stenotic lesion decreased to 5.2 m/sec. Two years later, the peak velocity through the stenotic lesion further decreased to 4.4 m/sec, and neither clinical symptoms nor restenosis was observed.

CBA has been used for refractory stenosis in major aortic-to-pulmonary collateral arteries, \[14\] and for dogs with subaortic stenosis \[13\]. Compared with conventional balloon dilation, CBA seems to be more efficient in dilating the firm stenosis with a fibrous ring. A previous study has reported on successful conventional balloon dilation in a dog with supravalvular PS \[18\]. Although decades have passed since balloon dilation was available in small animal clinics, this was one case with supravalvular PS that could have been treated by conventional balloon dilation. However, this treatment shows a poor response. Additionally, the stenotic lesion in the previous report was shaped like an “hourglass deformity” \[18\]. In the present case, the stenotic lesion, as observed by TEE, was thick and motionless, with a diaphragm-like form (i.e. a firm stenosis with fibrous ring). Differences in stenotic lesions may lead to outcomes different from those observed in previous reports. Thus, conventional balloon angioplasty alone might have been ineffective for this dog. The maximum diameter of the currently available cutting balloon is 8 mm. If the balloon diameter was larger than that of the pulmonary valve annulus, the blades of the cutting balloon would likely injure the artery wall. The diameter of the pulmonary valve annulus in the present case was 9.4 mm; therefore, damage to the pulmonary artery was avoided using a CBA balloon measuring 8 mm in diameter. This balloon was also effective for cutting the tissue of the stenotic lesion measuring 2.6 mm in diameter. In the present case, conventional balloon dilation was performed after CBA. For conventional balloon dilation, the size of the balloon ranging 1.2 to 1.5 times of the diameter of the pulmonary valve annulus in dogs with PS has been recommended \[7\]. After cutting the stenotic lesion with a CBA balloon measuring 8 mm, inflation with conventional balloon was more effective for the induction of significant dilation. This combined method has been reported in dogs with subaortic stenosis \[13\]. In the present case, the right ventricular pressure was not directly measured after CBA and balloon valvuloplasty to avoid the risk of arrhythmia by catheter stimulation to the right ventricle. However, the peak velocity through the stenotic lesion measured by TEE was helpful to detect the effect of CBA and conventional balloon valvuloplasty. The peak velocity through the stenotic lesion after CBA decreased greatly from 3.8 to 3.2 m/sec. The estimated pressure gradient decreased by approximately 30%. In contrast, conventional balloon dilation resulted in only approximately 10% decrease in the estimated pressure gradient. This result showed that CBA contributed primarily to stenosis release, while the therapeutic effect of conventional balloon dilation was additive. In the present case, the order of CBA and conventional balloon dilation may have

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**Table 1.** Changes in the echocardiographic findings before and after treatment

|                              | Before | 1 month after | 5 months after | 2 years after |
|------------------------------|--------|---------------|----------------|--------------|
| Peak velocity through the stenotic lesion (m/sec) | 6.4    | 5.5           | 5.2            | 4.4          |
| Tricuspid valve regurgitation | +      | -             | -              | -            |
| Ventricular septum flattening | +      | -             | -              | -            |
influenced the good outcome, because conventional balloon dilation was not performed before CBA. Bergersen et al. reported the effectiveness of high-pressure balloon angioplasty after CBA in children with tetralogy of Fallot and pulmonary atresia resistant to high-pressure balloon angioplasty [4]. This report suggested that the effective order of the combined method is “CBA followed by conventional balloon dilation” rather than “conventional balloon followed by CBA”. Thus, conventional balloon dilation after CBA was also considered to be effective in the present case. Therefore, our study shows that combined CBA and conventional balloon angioplasty is effective for dogs with supravalvular PS.

This procedure also improved the clinical symptoms and echocardiographic findings of the dog. Exercise intolerance and easy fatigability were resolved within one month after treatment, and the activity of the dog increased markedly five months later. Restenosis was not noticed, even after two years, and the peak velocity through the stenotic lesion decreased gradually from 6.4 m/ sec before treatment to 4.4 m/sec.

The severity of PS is generally evaluated based on the peak velocity through the stenotic lesion. The peak velocity through the stenosis gradually decreased within two years after treatment. Increased right ventricular afterload secondary to PS results in right ventricular infundibular hypertrophy, which narrows the right ventricular outflow tract. The narrowing worsens when the right ventricular end-systolic pressure decreases after balloon angioplasty, and contractility increases. It fully resolves as contractility returns to normal and hypertrophy regresses [8]. As right ventricular infundibular hypertrophy progressively diminishes over several months, intermediate-term to long-term follow-up is required to assess the full effect of the procedure and the duration of relief [17]. As the peak velocity through the stenosis gradually decreased in the current case, regular measurement of the peak velocity through the stenosis is important in the long term to assess the therapeutic effect of the procedure on PS.

In conclusion, supravalvular PS that does not respond to balloon dilation procedures can be successfully treated using a cutting balloon together with a conventional balloon. Combined CBA and conventional balloon angioplasty alleviated the stenotic lesion and improved clinical signs of the dog in the current case. The present case shows that this combined method is a useful and minimally invasive treatment for supravalvular PS.

REFERENCES

1. Ajani, A. E., Kim, H. S., Castagna, M., Satler, L. F., Kent, K. M., Pichard, A. D. and Waksman, R. 2001. Clinical utility of the cutting balloon. J. Invasive Cardiol. 13: 554–557. [Medline]
2. Barath, P., Fishbein, M. C., Vari, S. and Forrester, J. S. 1991. Cutting balloon: a novel approach to percutaneous angioplasty. Am. J. Cardiol. 68: 1249–1252. [Medline] [CrossRef]
3. Baumgartner, C. and Glaus, T. M. 2003. Congenital cardiac diseases in dogs: a retrospective analysis. Schweiz. Arch. Tierheilkd. 145: 527–533, 535–536 (in German). [Medline] [CrossRef]
4. Bergersen, L. J., Perry, S. B. and Lock, J. E. 2003. Effect of cutting balloon angioplasty on resistant pulmonary artery stenosis. Am. J. Cardiol. 91: 185–189. [Medline] [CrossRef]
5. Buchanan, J. W., Anderson, J. H. and White, R. I. 2002. The 1st balloon valvuloplasty: an historical note. Am. J. Roentgenol. 179: 619–623. [Medline] [CrossRef]
6. Engelke, C., Sandhu, C., Morgan, R. A. and Belli, A. M. 2002. Using 6-mm Cutting Balloon angioplasty in patients with resistant peripheral artery stenosis: preliminary results. AJR Am. J. Roentgenol. 179: 554–557. [Medline]
7. Estrada, A., Moise, N. S., Erb, H. N., McDonough, S. P. and Renaud-Farrell, S. 2006. Prospective evaluation of the balloon-to-annulus ratio for balloon valvuloplasty in the treatment of pulmonic stenosis in the dog. J. Vet. Intern. Med. 20: 862–872. [Medline] [CrossRef]
8. Fawzy, M. E., Galal, O., Dunn, B., Shaikh, A., Siriam, R. and Duran, C. M. 1990. Regression of infundibular pulmonary stenosis after successful balloon pulmonary valvuloplasty in adults. Cathet. Cardiov. Diagn. 21: 77–81. [Medline] [CrossRef]
9. Feltes, T. F., Bacha, E., Beckman, R. H. 3rd., Cheatham, J. P., Feinstein, I. A., Gomes, A. S., Hijazi, Z. M., Ing, F. F., de Moor, M., Morrow, W. R., Mullins, C. E., Taubert, K. A., Zahn E. M., American Heart Association Congenital Cardiac Defects Committee of the Council on Cardiovascular Disease in the Young Council on Clinical Cardiology Council on Cardiovascular Radiology and Intervention American Heart Association. 2011. Indications for cardiac catheterization and intervention in pediatric cardiac disease: a scientific statement from the American Heart Association. Circulation 123: 2507–2625. [Medline] [CrossRef]
10. Fox, P. R., Sisson, D. and Moise, N. S. 1999. Textbook of Canine and Feline Cardiology: Principles and Clinical Practice, 2nd ed., W. B. Saunders, London.
11. Johnson, M. S. and Martin, M. 2004. Results of balloon valvuloplasty in 40 dogs with pulmonic stenosis. J. Small Anim. Pract. 45: 148–153. [Medline] [CrossRef]
12. Kan, J. S., White, R. I. Jr., Mitchell, S. E. and Gardner, T. J. 1982. Percutaneous balloon valvuloplasty: a new method for treating congenital pulmonary-valve stenosis. N. Engl. J. Med. 307: 540–542. [Medline] [CrossRef]
13. Kleman, M. E., Estrada, A. H., Maisenbacher, H. W. 3rd., Prošek, R., Pogue, B., Shih, A. and Paolillo, J. A. 2012. How to perform combined cutting balloon and high pressure balloon valvuloplasty for dogs with subaortic stenosis. J. Vet. Cardiol. 14: 351–361. [CrossRef]
14. Mertens, L., Denis, J. and Gewillig, M. 2001. Use of a cutting balloon catheter to dilate resistant stenoses in major aortic-to-pulmonary collateral arteries. Cardiol. Young 11: 574–577. [Medline] [CrossRef]
15. Peregrin, J. H. and Roczek, M. 2007. Results of a peripheral cutting balloon prospective multicenter European registry in hemodialysis vascular access. Cardiovasc. Intervent. Radiol. 30: 212–215. [Medline] [CrossRef]
16. Saida, Y., Yanane, Y. and Yamane, Y. 2009. Successful surgical correction of supravalvular pulmonary stenosis under beating heart using a cardiopulmonary bypass system in a dog. J. Vet. Med. Sci. 71: 203–206. [Medline] [CrossRef]
17. Stanger, P., Cassidy, S. C., Girod, D. A., Kan, J. S., Lababidi, Z. and Shapiro, S. R. 1991. Balloon pulmonary valvuloplasty: results of the Valvoplasty and Angioplasty of Congenital Anomalies Registry. Am. J. Cardiol. 65: 775–783. [Medline] [CrossRef]
18. Treseder, J. R. and Jung, S. 2017. Balloon dilation of congenital supravalvular pulmonic stenosis in a dog. J. Vet. Sci. 18: 111–114. [Medline] [CrossRef]