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NOTE

Surgery

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

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Pulmonary valve stenosis (PS), classified as valvular, subvalvular, or supravalvular, is a common congenital heart disease in dogs [3, 10]. Percutaneous balloon valvuloplasty in human medicine was first reported by Kan *et al*. [12]. Although balloon valvuloplasty is used as a first-line treatment for moderate and severe PS [9], it is limited to valvular pulmonary artery stenosis caused by commissural fusion or valve cusp dysplasia. This criterion has also been applied in veterinary medicine; hence, pulmonary artery balloon valvuloplasty is not applicable for supravalvular PS [5, 11]. In previous cases, we have performed valvuloplasty using cardiopulmonary bypass [16]; however, this cardiac surgery is highly invasive and could lead to postoperative complications.

Cutting balloon angioplasty (CBA) is an angioplasty technique that uses a balloon catheter with four microsurgical blades mounted in the longitudinal direction. CBA was initially designed for the treatment of coronary artery stenosis that is resistant to conventional balloon angioplasty [1, 2]. This technique has been reported to effectively treat peripheral arterial stenosis resistant to conventional angioplasty in humans [6, 15]. Recently, CBA has been used for the treatment of major aortic-to-pulmonary collateral arteries in humans [14] and subaortic stenosis in dogs [13]. This study reports on the combined treatment of CBA and conventional balloon valvuloplasty in a dog with supravalvular PS.

A 7-year-old male Miniature Schnauzer weighing 7.8 kg was referred to the Animal Medical Center at Tokyo University of Agriculture and Technology with exercise intolerance and easy fatigability. Thoracic auscultation revealed a grade IV/VI systolic left basilar murmur. Complete blood count and serum biochemical test results were within the reference ranges. Thoracic radiography showed moderate cardiomegaly, with a vertebral heart score of 11.2. Two-dimensional echocardiography revealed right ventricular hypertrophy and right atrial enlargement. Stenosis was observed in the upper portion of the pulmonic valve, with a minimum diameter of 2.6 mm (Fig. 1). The stenotic lesion was 8.2 mm distal to the pulmonic valve. Echocardiography showed a normal structure and motion of the pulmonic valve but also a marked post-stenotic dilatation of the main pulmonary artery. Color flow Doppler showed tricuspid valve regurgitation and a turbulent flow at the level of the stenotic lesion. The location of the increased flow velocity was confirmed by pulsed wave Doppler (not observed at the level of the valve but in the area above the pulmonary valve). The peak velocity through the stenosis was confirmed as 6.4 m/sec using continuous wave Doppler (estimated pressure gradient was 164 mmHg). The diameter of the pulmonary artery valve was 9.7 mm. The severely flattened interventricular septum suggested severe right ventricular pressure overload.

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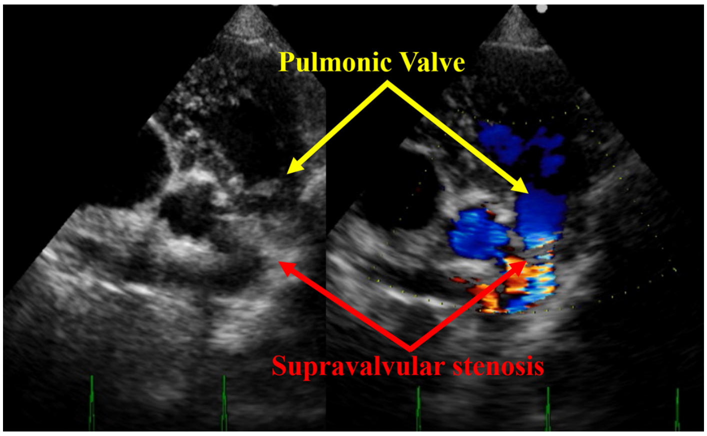

Fig. 1. Right parasternal short axis view at the pulmonic valve level. A stenosis was found in the main pulmonary artery. The pulmonary valve was normal. Pulse wave Doppler proved that the increased velocity of flow was associated with the stenosis, which was not apparent at the level of the pulmonic valve.

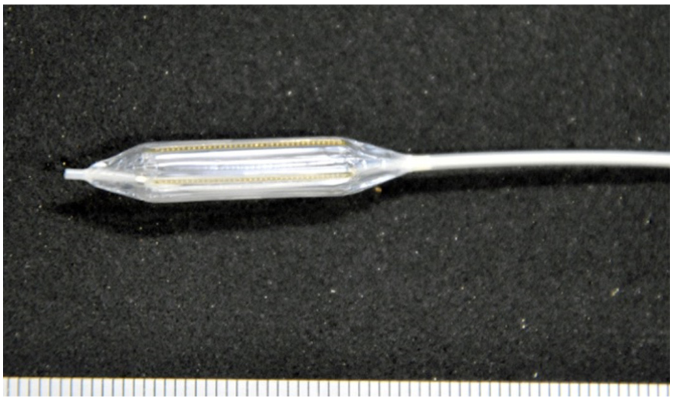

Fig. 2. Peripheral cutting balloon catheters. The four blades are attached longitudinally to the outer surface of the balloon. These blades are used to make a longitudinal incision in the lesion.

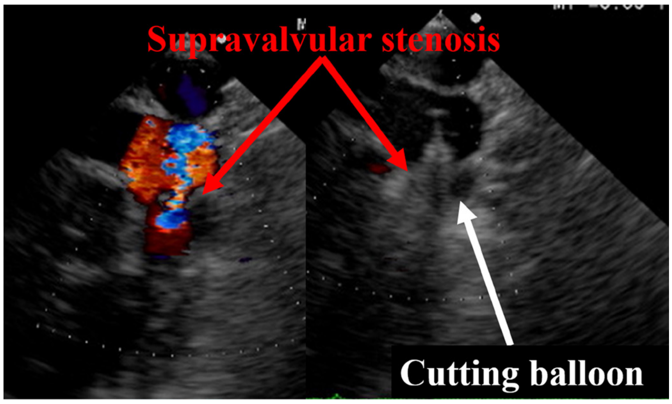

Fig. 3. Longitudinal cranial–esophageal pulmonary artery long-axis-view by intraoperative TEE. TEE provided accurate information about the site of inflation of the cutting balloon.

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

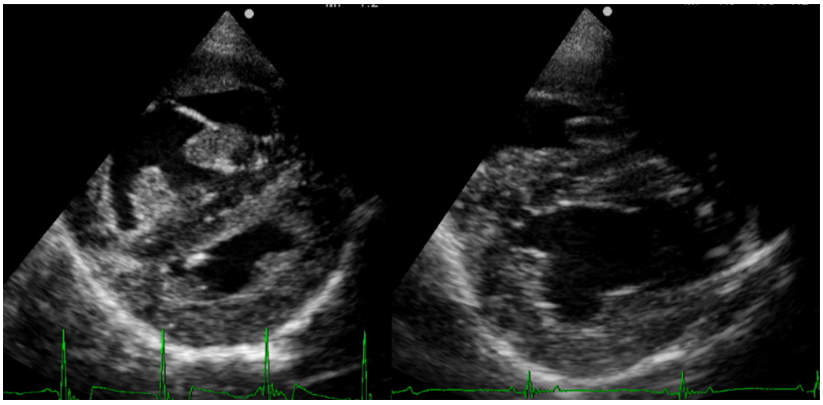

Fig. 4. Right parasternal short axis view at papillary muscle level at the end-diastole. Left: before CBA; Right: 1 month after CBA. After CBA, the ventricular septum flattening disappeared and the area within the left ventricular enlarged markedly.

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	+	-	-	-

balloon catheter and the introducer, 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 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.

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