Repair of double-chambered right ventricle using right ventricular outflow chamber ventriculotomy via left intercostal thoracotomy under beating heart in two dogs

Keichi Sato,1 Isamu Kanemoto,1 Kippei Mihara,1 Koudai Kawase,1 Takuya Mori,1 Misato Ohashi,1 Hirokazu Abe,1 Shuichi Chimura2
1Chayagasaka Animal Hospital, Nagoya, Aichi, 464-0003 Japan; 2Chimura Animal Hospital, Iwakura, Aichi, Japan

Abstract

Double-chambered right ventricle was diagnosed in two dogs, one of them a pup and the other full grown. Both dogs underwent surgery using the novel approach of right ventricular outflow chamber ventriculotomy via left intercostal thoracotomy under beating heart. No major complication occurred during and after the operation. On continuous wave Doppler echocardiography, the pressure gradient across the stenosis in the right ventricle decreased from 130 mmHg pre-operatively to 40 mmHg post-operatively at 1 year 5 months in the adult dog, and from 209 mmHg pre-operatively to 47 mmHg post-operatively at 1 year in the pup. Both dogs are active without clinical signs.

Introduction

Double-chambered right ventricle (DCRV) is a relatively uncommon congenital cardiac abnormality in dogs.1 The right ventricle (RV) is divided into two compartments by an anomalous muscular bundle and is composed of an inflow high pressure chamber and an outflow low pressure chamber.2,4 In human, DCRV usually is associated with thickening of the inflow RV wall induced by myocardial ischemia and moderate pump flow cardiopulmonary bypass under beating heart. No major complication occurred during and after the operation. On continuous wave Doppler echocardiography, the pressure gradient across the stenosis in the right ventricle decreased from 130 mmHg pre-operatively to 40 mmHg post-operatively at 1 year 5 months in the adult dog, and from 209 mmHg pre-operatively to 47 mmHg post-operatively at 1 year in the pup. Both dogs are active without clinical signs.

Case Report

Case 1 was a female miniature dachshund weighing 6.48 kg, 1 year and 10 months old, which presented with repeated syncope on excitation and a heart murmur. Case 2 was a flat-coated retriever, female, weighing 8.78 kg, 84 days old, which presented with hind limb unstable gait and a heart murmur. Auscultation revealed a 4/6 systolic ejection murmur in case 1, and a 5/6 systolic ejection murmur in case 2 at the left precordial region. Electrocardiogram and thoracic X-ray examinations suggested RV enlargement in both cases.

Echocardiography revealed a severe fixed stenosis of the RV lumen due to an abnormal bundle, which divided the RV into two chambers and mild and moderate tricuspid regurgitation (TR) was present in case 1 and 2, respectively. A persistent left anterior vena cava (PLAVC) was seen in both cases. Additionally, a right-to-left shunting flow was seen through a small membranous ventricular septal defect (VSD) in case 2. Continuous wave Doppler showed a pressure gradient of 130 mmHg across the stenosis in case 1 and a pressure gradient of 209 mmHg in case 2 (Figure 1).

Case 1 was discharged from our hospital at 46 days, and case 2 at 7 days after operation. On postoperative course: Although a grade 3/6 systolic murmur diminished, a 2/6 systolic murmur persisted in case 1, and a 5/6 systolic murmur was noticed in case 2. Continuous wave Doppler echocardiography revealed a pressure gradient of 20 mmHg across the stenosis in case 1 and 30 mmHg in case 2 post-operatively.

Correspondence: Isamu Kanemoto, Chayagasaka Animal Hospital, 1-1-5 Shinnishi, Chikusa, Nagoya, Aichi, 464-0003 Japan.
Tel. +81.527.731.866 - Fax +81.527.737.488.
E-mail: kanemoto@ta2.so-net.ne.jp

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Doppler showed that the pressure gradient across the stenosis was decreased from 130 mmHg pre-operatively to 6 mmHg at 3 months, and increased to 40 mmHg at 1 year 5 months post-operatively. In case 1, the pressure gradient decreased from 209 mmHg to 35 mmHg at 3 months and increased to 47 mmHg at 1 year post-operatively, continuing treatment with atenolol (Table 1). As shown in Table 1, continuous wave Doppler showed that the pressure gradient across the stenosis was decreased from 130 mmHg pre-operatively to 6 mmHg at 3 months, since the owner canceled the administration of a β-blocker drug (atenolol) and increased to 40 mmHg at 1 year 5 months after operation in case 1, and from 209 mmHg to 35 mmHg at 3 months and increased to 47 mmHg at 1 year after operation in case 2, continuing to administer the drug from first to the present.

**Discussion and Conclusions**

All surgical repair reports of DCRV in the dog used RVOT ventriculotomy via the right intercostal thoracotomy or the median sternotomy. They approached the stenotic lesion from the RVIC. In contrast, although we used the same RVOT ventriculotomy, we approached the stenotic lesion from the RVOT via the left 4th intercostal thoracotomy. The advantages of the RVIC approach are the ability to repair a possible tricuspid valve anomaly combined with the DCRV. The disadvantages of this technique are the difficulty in confirming and resecting the stenotic lesion of the RVOT because the RVIC is located in the dorsal position of the heart and RVIC is narrowed due to the hypertrophied RV wall, papillary muscles and chordae. As a result, there would be a greater risk of injuring the tricuspid valve apparatus or more difficulty in sufficiently removing the stenotic lesion even under cardiac arrest. In contrast, the RVIC technique makes it relatively easy to confirm the stenotic hole, to check the size and resect the stenotic lesion, because the RVOT is located under direct vision in the left 4th intercostal thoracotomy and the RVOT is relatively wide due to no hypertrophied RV wall and no interruption except for the stenotic ring. The RVIC technique described here allowed the successful repair of the DCRV under the beating heart in small sized dogs, and provides evidence for its potential usefulness for the correction of this cardiac anomaly in these patients. One disadvantage of the RVIC technique is that it does not allow correction of concurrent tricuspid valve anomaly. However, there is no report of TV anomaly repair concurrently with DCRV in dog.

From the viewpoint of myocardial preservation, Martin operated on DCRV under beating heart in two of 7 dogs; however, VF occurred during the repair in both dogs. Neither of our dogs had VF under beating heart with moderate hypothermia and moderate pump flow CPB because both techniques appropriately satisfied myocardial oxygen supply and demand for myocardial preservation.

Air embolism was avoided because the R-to-L shunt before the release of the stenotic lesion changed instantaneously to the L-to-R shunt after the release of the stenotic lesion under the beating heart in our case. When a large VSD exists and the RVIC approach is used under beating heart, there is a risk of air embolism.

On echocardiography, the pressure gradient across the stenosis was diminished from 130 mmHg pre-operatively to 40 mmHg post-operatively at 1 year 5 months in case 1, and from 209 mmHg pre-operatively to 47 mmHg post-operatively at 1 year in case 2 (Table 1). At present both dogs are active without clinical signs and the pressure gradients of <50 mmHg seems to be within the acceptable range at midterm results. However, long-term follow-up

![Figure 1](image-url1)  
**Figure 1.** Echocardiography of right outflow tract (left parasternal oblique short-axis view at basal level) and continuous Doppler in case 2. In the left figure, severe stenosis separates the RV into two chambers (RV1 and RV2) and causes mosaic blood flow in the right ventricle. In the right figure, the Doppler shows maximum blood-flow speed at stenosis of 7.2 m/sec, corresponding to the pressure gradient of 209 mmHg.

![Figure 2](image-url2)  
**Figure 2.** Surgical diagram of RV outflow ventriculotomy; surgeon stands and approaches the surgical field from dorsal side of the dog. First, the RV outflow chamber (RVOC) was incised with a scalpel (solid line 1 in the left figure A) and the stenotic hole (SH) size was measured with a sizer. Then, the stenotic ring was cut at the dorsal portion from RVOC toward the RV inflow chamber (RVIC) (dotted line 2 in the left A and vertical line in the right B figures), and the stenotic dividing wall was removed with scissors (oblique line area in the right figures B showing surgeon view). TV: tricuspid valve; PV: pulmonary valve

| Case | Pre-op | Post-op 1 month | Post-op 3 months | Post-op 8 months | Post-op 12 months | Post-op 16 months |
|------|--------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1    | 130    | 48              | 6               | 19              | -               | 40              |
| 2    | 209    | 58              | 35              | 41              | 47              | -               |

Table 1. Comparison of preoperative and postoperative pressure gradient across the stenosis in both cases.
should be considered because of restenosis. Also, the dog operated for DCRV should be administered the β-blocker drug to prevent the restenosis or be combined with the RVOC technique and patch technique in large sized dogs, especially in young dogs during periods of growth.11 Our novel surgical technique for DCRV may be useful in a low-body weight small dog.

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