Myocardial function assessed by two-dimensional speckle-tracking echocardiography in dogs

Summary of Doctor Thesis

Ryohei Suzuki

Graduate school of Veterinary and Life Science
Nippon Veterinary and Life Science University

Echocardiography plays an essential role in the assessment of cardiac disease in veterinary medicine. Two-dimensional speckle-tracking echocardiography (2D-STE) has recently been used to assess myocardial deformations in humans and dogs. This technique has enabled the assessment of myocardial variables, such as strain, strain rate, and torsional measurements, that provide better quantification of regional and global myocardial deformations and might have higher sensitivity than conventional echocardiographic parameters for detecting subtle myocardial function abnormalities. However, the effect of age and heart rate (HR) on 2D-STE variables has not previously been reported.

Myxomatous mitral valve disease (MMVD) is the most common cardiac disease of dogs, and some dogs with MMVD develop myocardial dysfunction due to enlargement and remodeling of the heart. Recently, systolic dysfunction is associated with poor outcomes in dogs with MMVD. However, assessment of systolic function using conventional echocardiographic methods is difficult in mitral regurgitation (MR) owing to altered hemodynamic loading conditions and sympathetic tone. We hypothesized that myocardial deformations assessed by 2D-STE could be useful markers of systolic dysfunction in dogs with MMVD.

This study was designed to assess 1) the effect of HR and age on 2D-STE variables in healthy dogs, 2) multidirectional myocardial deformations derived by 2D-STE in dogs with various stages of MMVD, and 3) myocardial deformations during a dobutamine stress test with 2D-STE in dogs with experimentally induced chronic MR.

1. Influence of heart rate on myocardial function using two-dimensional speckle-tracking echocardiography in healthy dogs (Chapter Ⅱ).

HR is a known important modulator of cardiac function, influencing echocardiographic variables. Therefore, it should always be considered in the evaluation of cardiac function, particularly in the event of cardiac failure. However, influence of HR on myocardial function assessed by 2D-STE has not previously been reported. In this study, thirteen healthy beagles were anesthetized and controlled HR with right atrial pacing. Myocardial function of each was assessed using 2D-STE at the pacing rates of 120, 140, 160, and 180 beats per minute (bpm). All strain and strain rate variables in the longitudinal, circumferential, and radial directions were not significantly different at the range of 120-180 bpm. The peak early diastolic torsion rate at 180 bpm was significantly increased compared with that at 120 bpm ($P = 0.003$). Torsion rate in early diastole was elevated at a HR of 180 bpm, which may reflect increased myocardial relaxation with increasing HR. Left ventricular torsion and untwisting at higher HR may play an important role in preserving stroke volume in the presence of shortened ejection and filling times.

2. Effect of age on myocardial function assessed by two-dimensional speckle-tracking echocardiography in healthy beagle dogs (Chapter Ⅲ).

Aging might affect cardiac function in dogs. Aging also seems to be related to myocardial torsion, assessed by 2D-STE in healthy humans, which is directly related to the helical orientation of myocardial fibers.

As the number and proportion of older dogs in the canine population will increase, quantitative information on age-associated changes in cardiovascular function in the absence of disease becomes more important. However, the effect of age on myocardial function assessed by 2D-STE in healthy dogs has not been previously reported. Thirty-two healthy beagles were used. Myocardial function was assessed in each dog by using 2D-STE, and the results were compared between young and old dogs. The myocardial deformations in systole, besides the apical rotation rate, were not significantly different between young and old dogs. In contrast, the early diastolic circumferential strain rate, basal rotation rate, and torsion rate were significantly lower in old dogs than in young dogs (P = 0.03, P = 0.033, and P = 0.015, respectively). Late diastolic longitudinal and radial strain rates were significantly higher in old dogs than in young dogs (P= 0.002 and P= 0.018, respectively). Young and old dogs showed similar systolic myocardial deformations, but significant differences in the values of some diastolic deformation variables were found between young and old dogs, highlighting the need for using age-matched control subjects in studies of diastolic function. Evidences about the effect of age in the heart provide important information for understanding age-related cardiovascular diseases.

3. Clinical assessment of systolic myocardial deformations in dogs with myxomatous mitral valve disease using two-dimensional speckle-tracking echocardiography (Chapter Ⅳ).

This study was designed to quantitatively measure multidirectional

myocardial deformations of dogs in various stages of MMVD. Our hypothesis for this study was that myocardial deformations assessed by 2D-STE could be useful markers of systolic dysfunction in dogs with MMVD. Eighty-seven dogs with MMVD were enrolled in the study. Dogs were placed into 1 of 3 classes, based on the International Small Animal Cardiac Health Council classification. In addition, 20 weight- and age-matched healthy dogs were enrolled as controls. The dogs were examined for myocardial deformations using 2D-STE, and the peak systolic strain and strain rate in the longitudinal, circumferential, and radial directions were evaluated. Class II and III dogs had higher circumferential strain than class I dogs ($P = 0.002$ and $P = 0.001$, respectively) and controls ($P < 0.001$ and $P < 0.001$, respectively). Class III dogs had higher radial strain than class I dogs ($P = 0.001$) and controls ($P < 0.001$). Class III dogs had higher radial strain rate than class I dogs ($P = 0.006$) and controls ($P = 0.001$). Other deformations, including longitudinal deformations, were not significantly different between classes of MMVD or between MMVD dogs and controls. In the clinical progression of MMVD in dogs, myocardial deformations, as assessed by 2D-STE, differed according to myocardial contractile direction. Thus, assessments of multidirectional myocardial deformations may be important for better assessment of clinical cardiac function in dogs with MMVD.

4. Noninvasive clinical assessment of systolic torsional motions by two-dimensional speckle-tracking echocardiography in dogs with

myxomatous mitral valve disease (Chapter Ⅴ).

This study was designed to quantitatively measure myocardial torsional deformations of dogs in various stages of MMVD. Our hypothesis for this study was that myocardial torsion, which is directly related to helically oriented myocardial fibers, could be useful markers of systolic dysfunction in dogs with MMVD. Sixty-seven client-owned dogs with MMVD classified into 3 classes based on the International Small Animal Cardiac Health Council classification and 16 weight- and age-matched healthy dogs. Dogs were examined for myocardial deformations using 2D-STE and were evaluated for peak systolic rotation and rotation rate at each basal and apical view. Dogs were also evaluated for peak systolic torsion and torsion rate. Peak systolic torsion was higher in class II than in class I ($P < 0.001$) dogs. Peak systolic torsion was lower in class III than in class II ($P = 0.001$) dogs and controls ($P = 0.003$). Torsional deformations assessed by 2D-STE differed among clinical classes of MMVD. The lower torsion in dogs with severe MMVD may contribute to latent systolic dysfunction and seems to be related to severe cardiac clinical signs. Myocardial torsional deformations using 2D-STE may provide more detailed assessment of contractile function in dogs with MMVD.

5. Dobutamine stress echocardiography for assessment of systolic function in dogs with experimentally induced mitral regurgitation (Chapter Ⅵ).

Systolic dysfunction is associated with poor outcomes in dogs with

MMVD. However, assessment of systolic variables using conventional echocardiographic methods is difficult in these dogs due to MR. We hypothesized that an inotropic challenge with dobutamine, and assessed by 2D-STE, could reveal early occult cardiac dysfunction not evident at rest. Five anesthetized dogs with experimentally induced MR were used. Dogs were examined for systolic myocardial deformations using 2D-STE during dobutamine infusion prior to and 3 and 6 months after MR induction. We evaluated peak systolic rotation and the rotation rate in each basal and apical view; peak systolic torsion and torsion rate were also calculated. Invasive peak positive first derivatives of the left ventricular pressure (dp/dt) were significantly decreased in dogs 6 months after induction of MR compared with the pre-MR values. Dogs with 3 and 6 months of MR had diminished peak systolic torsion values and torsion rates in response to dobutamine infusion compared with pre-MR data (3 months, $P < 0.001$ and $P = 0.006$; 6 months, $P = 0.003$ and $P = 0.021$). These were significantly correlated with the overall invasive dp/dt ($r = 0.644$, $P < 0.001$; $r = 0.696$, $P < 0.001$). Diminished torsion during dobutamine infusion in dogs with advanced MR may reflect latent systolic dysfunction. Contractile reserve, assessed as described, may provide a more detailed assessment of contractile function in dogs with MR.

This study confirmed that the effect of HR and age on myocardial function assessed by 2D-STE in dogs. The present study obtained normal values for 2D-STE variables in various HR and young and old dogs, and

these can be used as preliminary data for the establishment of reference intervals of 2D-STE in the dog. This study also indicated that multidirectional myocardial deformations could be assessed using 2D-STE to evaluate myocardial function of non-sedated dogs with adequate repeatability. These multidirectional myocardial deformations might improve the clinical assessment of cardiac function in dogs with MMVD. As the torsion is directly related to helically-oriented myocardial fibers, the lower torsion in dogs with severe MMVD may contribute to latent systolic dysfunction. Finally, this study suggests that contractile reserve assessed by dobutamine stress test with 2D-STE is useful tool for early detection of the systolic dysfunction in dogs with MR.