Pulsed Doppler Echocardiography in Normal Dogs and Calves and Three Cases of Valvular Regurgitation

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ABSTRACT. Pulsed Doppler examinations combined with M-mode and/or two-dimensional echocardiography (pulsed Doppler echocardiography) were performed on 10 dogs and 9 calves which were clinically normal, and 3 cases of valvular regurgitation. The Doppler technique is described. The blood flow patterns obtained at all four valve areas in normal animals and the abnormal pulsed Doppler echocardiographic findings in clinical cases are reported. The findings suggested that pulsed Doppler echocardiography can be useful not only for diagnosis, but also for assessing the degree of severity of any type of valvular regurgitation in dogs and calves.—**KEY WORDS:** calf, dog, Doppler echocardiography, valvular regurgitation.

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There have been new developments in echocardiography. In human medicine, clinical values of echocardiographic techniques such as M-mode or two-dimensional (2-D) echocardiography, the pulsed or continuous Doppler method combined with M-mode or 2-D echocardiography, and newly-developed color flow Doppler mapping (a system providing a Doppler color image of blood flow on a real-time 2-D echocardiogram) are well established [2, 8]. In veterinary medicine, however, the clinical application of these techniques has been so far limited to M-mode, and 2-D echocardiography has only been recently used in several animal species. Little information has been available in the clinical use of Doppler echocardiography in the veterinary medicine, although these modalities are employed on preliminarily studies [5, 18].

Echocardiographic techniques, either contrast echocardiography or Doppler echocardiography can be used to monitor blood flow within the heart and great vessels. Contrast echocardiography by injecting contrast medium into peripheral vein can usual-

ly show blood flow only in the right side of the heart, and cardiac catheterization is usually necessary to inject contrast medium into the left side of the heart. In contrast, pulsed Doppler echocardiography, which is entirely noninvasive, can detect the flow in a given sample volume at any location in the heart and vessels, and its usefulness has been well recognized in the diagnosis of abnormal forms of intracardiac flow such as regurgitation, shunt, and stenosis in man [2, 8]. The present paper describes the technique for pulsed Doppler combined with M-mode and/or 2-D echocardiography and its use to study the normal blood flow patterns in the region of the four cardiac valves in the healthy dog and calf, and in three clinical cases of valvular regurgitation.

MATERIALS AND METHODS

Animals: Doppler examination was performed in 10 clinically healthy adult mongrel dogs weighing 10–12 kg and 9 healthy calves (5 Holstein-Friesian and 4 Japanese Black) aged 6 to 10 days and weighing 25–45

Fig. 1. Schematic illustration of the pulsed Doppler system used. AWAY=flow away from the transducer; ECG=electrocardiogram; LA=left atrium; LV=left ventricle; PCG=phonocardiogram; RA=right atrium; RV=right ventricle; SV=sample volume; TOWARD=flow toward the transducer; 2-DE=two-dimensional echocardiography.

kg. A dog with mitral regurgitation (case 1), a dog with tricuspid and pulmonary regurgitation (case 2), and a calf with aortic regurgitation (case 3) were also examined.

Apparatus: A duplex Doppler echocardiograph (Hitachi pulsed Doppler unit Model EAU-PD2 incorporated in a main unit Model EUB-40) was used for both 2-D and Doppler echocardiographic examinations. The basic physical principles of Doppler have been described in detail elsewhere [2, 8]. Figure 1 shows a schematic illustration of the pulsed Doppler system used. 2-D imaging, M-mode tracing, and Doppler recording were made with a single mechanical sector scanner with a frequency of 3.5 MHz or an electronic convex array scanner with a frequency of 5.0 MHz. When the mechanical scanner is used, the Doppler image and M-mode image are displayed while the 2-D image is frozen. With the electronic scanner, simultaneous display of the Doppler recording, 2-D image, and

M-mode image can be obtained while re-writing the 2-D image every 0.5 sec. A cursor line was interrogated for pulsed Doppler sampling and M-mode tracing, and the ultrasound beam direction and the sample volume were respectively monitored as a white dotted line and a white dot on the line within the 2-D image. On the M-mode tracing, the position of the sample volume was indicated by a horizontal line. The cursor line could also be moved to the right or left within the image. The sample volume in the present system can be adjusted in length (ranging from 2 to 20 mm) but was set at 2 mm in this study. The pulse repetition frequency (PRF) ranged from 4 kHz to 6.8 kHz, but the highest PRF was chosen as far as possible in order to avoid the so-called aliasing artifact. Doppler frequency analysis was performed by Chirp-Z transform. The Doppler signal of the blood flow away from the transducer was displayed below the baseline, and that toward the

transducer was displayed above the baseline on the display of the Doppler frequency shift spectrum. In addition, it was possible to hear various audible signals corresponding to the spectrum of Doppler frequency shifts arising from the blood flow. The Doppler audiosignal was used for orientation with the flow. All graphic images were recorded on a line scan recorder (Hitachi Model EZU-RL5) or a 3/4-inch videocassette recorder (Sony Model VO-5800) for retrospective analysis.

Ultrasound examination: All the normal dogs were studied under general anesthesia (pentobarbital), all the normal calves under light sedation (xylazine), and the 3 patients without anesthesia or sedatives. Ultrasound examinations were performed with the animals positioned in right or left lateral recumbency, except for case 3, being examined while standing. After the thoracic hair had been clipped and an ultrasonic gel applied to the skin, the transducer was placed at the third to fifth intercostal space on either the left or right side of the thoracic wall to visualize the appropriate 2-D images for Doppler examinations. To obtain a more optimal Doppler flow signal, the 2-D imaging plane was adjusted in each view until the direction of the Doppler beam was oriented as parallel as possible to the estimated approximate direction of blood flow. Basic systematic imaging techniques for 2-D echocardiography in dogs and calves have been described in our previous studies [4, 6] and by others [21]. The terminology of the 2-D imaging planes utilized in this study generally followed the format previously described for dogs [4, 21].

RESULTS

Normal animals

In some dogs and calves, it was difficult to obtain satisfactory Doppler flow patterns of right ventricular inflow and/or outflow be-

cause of poor 2-D imaging ability and consequently inadequate setting of the sample volume in an appropriate location. In contrast, there were few limitations of Doppler examinations for the left ventricular inflow and outflow. The Doppler flow patterns of the dogs and calves obtained at the same sampling points within the heart and proximal great artery were much the same. Representative flow patterns from each animal at each of the four cardiac valve areas are shown in Figures 2 and 3. The favorable 2-D imaging planes for each Doppler examination and the flow patterns gained are outlined as follows.

Left ventricular inflow (Figs. 2A, 3A): A left intercostal apical four-chamber view was a more preferable 2-D echocardiographic plane for Doppler recording than a left intercostal long-axis view of the left ventricular outflow tract, since this provided more parallel orientation of the Doppler beam to the left ventricular inflow. When the sample volume was placed at the level of the mitral valve orifice, Doppler signals with two peaks of flow were recorded above the baseline in diastole. The first peak occurred during the rapid filling phase of the ventricle in early diastole, while the second peak occurred in late diastole due to atrial contraction. This biphasic flow signal was composed of a relatively narrow-ranged frequency spectrum, as shown by the narrow gray scale band on the Doppler display, suggesting that the flow was laminar. No significant Doppler signal was recorded in systole.

Right ventricular inflow (Figs. 2B, 3B): A good view of the right ventricular inflow for Doppler examination was provided in a left intercostal long-axis view of the right atrium and caudal vena cava or a left intercostal apical four-chamber view. The flow patterns, recorded at the level of the tricuspid orifice, resembled those of transmitral flow. However, some differences in flow pattern

Fig. 2. Pulsed Doppler echocardiograms from the left ventricular inflow (A), right ventricular inflow (B), left ventricular outflow (C), proximal aorta (D), right ventricular outflow (E), and proximal pulmonary artery (F) in a healthy dog. The upper left of each panel is the 2-D echocardiogram, showing the position of the sample volume. The upper right is the M-mode tracing and the lower half is Doppler recording derived from that sample site. AO=aorta; kHz=kilohertz; PA=pulmonary artery; RVO=right ventricular outflow; Other abbreviations as in Fig. 1.

through the two atrioventricular valves were noted. Tricuspid inflow usually had a lower velocity than mitral inflow and occasionally also had a slow-velocity flow toward the

right ventricle in systole.

Left ventricular outflow (Fig. 2C) and proximal ascending aorta (Figs. 2D, 3C): Doppler examination was approached in a

Fig. 3. Pulsed Doppler echocardiograms from the left ventricular inflow (A), right ventricular inflow (B), proximal aorta (C), and proximal pulmonary artery (D) in a healthy calf. In each panel, the 2-D echocardiogram at the upper left shows the position of the sample volume. The derived M-mode tracing and Doppler recording are at the upper right and in the lower half, respectively. Abbreviations same as in previous figures.

left or right intercostal long-axis view of the left ventricular outflow tract. In either view, it was considerably difficult to orient the Doppler beam nearly parallel to the blood flow. A slightly modified apical four-chamber view, in which the left ventricular outflow tract and a small portion of the ascending aorta could be visualized, was an alternative. With the sample volume placed in the left ventricular outflow tract just below the aortic valve, a single peaked flow with a narrow-ranged frequency spectrum was recorded below the baseline in systole, followed by a slow-velocity flow signal in diastole in the same direction as the systolic flow. When the sample volume was moved to the ascending aorta just above the aortic

valve, only the systolic flow was observed.

Right ventricular outflow (Fig. 2E) and proximal main pulmonary artery (Figs. 2F, 3D): The best Doppler signals were obtained from a left intercostal long-axis view of the right ventricular outflow tract and pulmonary artery that allowed near-parallel orientation of the Doppler beam to the pulmonary artery flow. The blood flow patterns recorded in the areas just below and above the pulmonary valve were essentially the same as those in the areas just below and above the aortic valve. The difference in waveform between the pulmonary artery and aortic flows was that the velocity curve in the aorta had a more rapid increase with a peak velocity which was

Fig. 4. 2-D and Doppler echocardiograms of a dog with mitral regurgitation. The 2-D echocardiogram on the left demonstrates prolapse of the anterior mitral leaflet (arrow) into the left atrium in systole. The pulsed Doppler echocardiogram at the lower right with the sample volume in the atrial side of the mitral valve shows the abnormal Doppler signals produced with high and multiple (wide-ranged) velocities on both sides of the baseline in systole. These signal anomalies indicate mitral regurgitant flow. The diastolic flow is normal. MV=mitral valve; Other abbreviations as in previous figures.

earlier in systole than that in the pulmonary artery.

Clinical cases

Case 1: An 8-year-old female maltese dog was referred for evaluation of chronic cough. A holosystolic murmur could be auscultated over the mitral area. 2-D echocardiography demonstrated mitral valvular thickening with the anterior mitral leaflet prolapsing into the dilated left atrium during systole. Contrast 2-D echocardiography, during the period of cardiac catheterization, showed that injection of contrast medium (0.5 ml of 0.25% H_2O_2 solution preactivated with a drop of autologous blood) [3] into the left ventricle via a catheter opacified not only the left ventricle and aorta but also the left atrium, indicating mitral regurgitation. Pulsed Doppler echocardiography obtained with the sample volume located in the left atrium above the mitral orifice showed a

normal diastolic flow pattern, plus abnormal systolic signals characterized by high-pitched and harsh sounds from the speakers (Fig. 4). Such abnormal signals are indicative of mitral regurgitant flow, as has been proven in man [2, 8, 14]. A search for these abnormal Doppler signals was made by continuously moving the sample volume over a wide area in the left atrial cavity while carefully listening to the harsh audio signal. The abnormal systolic signals were detected in the area from the mitral orifice to a location near the back wall of the left atrium (Fig. 5). The intensity of the abnormal Doppler signals, estimated by the Doppler audio signal and by the quality of the Doppler spectral display, was maximum near the mitral valve and decreased as the sampling site was moved further into the left atrium.

Case 2: A 6-year-old male mixed-breed dog

Fig. 5. Doppler scan for assessing the severity of mitral regurgitation in the same case as in Fig. 4. At the far left of the M-mode record, the sample volume is located close to the mitral valve. In the corresponding Doppler record, the mitral regurgitant flow pattern is seen. Toward the right of the M-mode record, the sample volume is progressively moved further into the atrium. The abnormal systolic signals are still recorded at the posterior wall of the left atrium, indicating the extension of regurgitant flow deeply into the left atrium. Abbreviations same as in previous figures.

was admitted with a 1-week history of progressive ascites and anorexia. Heart sounds were muffled, but a systolic murmur over the right cardiac apex was faintly auscultated. Thoracic radiography showed pleural effusion and right-sided cardiomegaly. A test for heartworm microfilaria in peripheral blood was positive. 2-D echocardiography revealed an echo-free area of pleural effusion and severe right-sided cardiac enlargement. In addition, small amounts of heartworm echoes were seen moving back and forth between the pulmonary artery and right ventricle and between the right ventricle and right atrium. Timing of the heartworm movement across the two valves was assessed by simultaneous M-mode and 2-D echocardiography. Heartworm echoes in the pulmonary artery started to flow retrogradely into the right ventricle in late systole, while those in the right ventricle started to flow retrogradely

into the right atrium in late diastole. Cardiac catheterization, performed under general anesthesia, revealed a high peak right ventricular pressure (94 mmHg). Pulsed Doppler study with the sample volume placed just to the atrial side of the tricuspid valve showed a normal flow in diastole, followed by abnormal flow signals throughout systole (Fig. 6), which was similar to that of the mitral regurgitant flow in case 1. These abnormal signals were present continuously until the sampling site extended farther to the back wall of the right atrium. Moving the sample volume toward the right ventricular outflow tract just below the pulmonary valve, abnormal holodiastolic Doppler signals other than those of the normal systolic flow were obtained (Fig. 7A). Pulsed Doppler findings of the pulmonary artery flow when the sample volume was placed above the pulmonary valve also showed abnormal flow signals characterized

Fig. 6. Pulsed Doppler echocardiogram of a dog with tricuspid regurgitation and pulmonary regurgitation. The 2-D echocardiogram on the left indicates a long-axis view of the right atrium and caudal vena cava with the sample volume (large arrow) about midway from the tricuspid valve. A heartworm echo can be seen as a spotlike structure (small arrows) within the right atrium on the 2-D image and as a linear structure (black arrows) within the right ventricle on the M-mode record at the upper right. The Doppler record at the lower right shows a normal diastolic flow pattern, plus holosystolic abnormal signals with high and multiple velocities above and below the baseline, suggesting the presence of tricuspid regurgitation. Note the aliased waveform (outlined interrupted line, black curved arrow), which documents the abnormal systolic flow being directed toward the right atrium. TV=tricuspid valve; Other abbreviations as in previous figures.

by a marked reversal flow toward the pulmonic valve in late systole and early diastole (Fig. 7B).

Case 3: A 5-month-old female Holstein calf was admitted for a cardiac murmur detected on routine physical examination. The calf had no signs of disease, except for a slightly smaller in size compared with other same age calves. On auscultation and phonocardiography a diastolic murmur was detected over the left side of the heart base. 2-D echocardiographic findings included a markedly dilated left ventricle and prolapsing of aortic cusp tissue into the left ventricular outflow tract in diastole. M-mode echocardiography demonstrated diastolic fluttering of the mitral valves and interventricular septum. The calf was subsequently donated to the veterinary teaching hospital of Miyazaki University. Contrast 2-D echo-

cardiography was performed at the time of cardiac catheterization in order to confirm aortic regurgitation. Contrast medium (2 ml of activated blood- H_2O_2 mixture), injected into the ascending aorta through a catheter, was seen retrogradely entering the left ventricle, filling it densely, and then a few contrast echoes were further seen entering the left atrium. This confirmed the presence of not only aortic regurgitation but also mitral regurgitation. A pulsed Doppler echocardiogram recorded in the area just below the aortic valve showed a normal systolic flow associated with mild aliasing, followed by abnormal flow signals throughout diastole (Fig. 8). This diastolic flow disturbance could even be detected for a considerable distance below the aortic valve. Doppler machine was unable to confirm the existence of mitral regurgitant

Fig. 7. Pulsed Doppler echocardiogram of the same case as in Fig. 6. In A, the sample volume is placed in the right ventricular outflow tract below the pulmonic valve imaged in a long-axis view of the right ventricular outflow tract and pulmonary artery. In the derived Doppler record at the lower left, the normal systolic ejection flow with a relatively narrow-ranged velocity is shown, followed by abnormal holodiastolic signals characterized by high and wide-ranged velocities on both sides of the baseline. However, the components above the baseline are dominant, suggesting that the abnormal diastolic flow moves toward the right ventricle. This diastolic reverse flow indicates pulmonary regurgitation. In B, the sample volume is placed in the main pulmonary artery above the pulmonic valve. The derived pulsed Doppler record at the lower right shows the reverse flow through late systole to early diastole. PV=pulmonary valve; Other abbreviations as in previous figures.

Fig. 8. Pulsed Doppler echocardiogram of a calf with aortic regurgitation and mitral regurgitation. On the left, the sample volume is positioned in the left ventricular outflow tract below the aortic valve in a long-axis view of the left ventricular outflow tract. The derived Doppler record on the right shows abnormal Doppler signals with a wide-ranged frequency spectrum on both sides of the baseline in diastole. This abnormal diastolic flow is considered to be aortic regurgitant flow. The systolic flow pattern is normal but has mild aliasing. AV=aortic valve; Other abbreviations as in previous figures.

flow, because the sampling site at the mitral valve orifice or in the left atrium was far beyond the maximum measurable depth (17 cm) of the Doppler frequency shift. At

necropsy seven months later, there was marked dilatation of the left side of the heart where the aortic valve had two cusps of unequal size, which were thickened and

separated from each other, resulting in incomplete closure of the aortic ostium. The larger cusp of the aortic valve was somewhat prolapsed into the left ventricle. Jet lesions were observed in the left ventricular and atrial endocardium.

DISCUSSION

Cardiac Doppler instruments are available with a great variety of capabilities [2, 8]. The instrument used was a pulsed Doppler system combined with M-mode and/or 2-D echocardiography, allowing the operator to set the Doppler sample volume at any desired location within the heart. It was possible to use the M-mode scan in the absence of 2-D imaging in localizing the sample volume at the location of interest during the examination. However, 2-D imaging gave better and much easier guidance for Doppler work than the M-mode method, even though there was a disadvantage in that when the mechanical scanner was used, it had to be checked whether the sampling location had remained unchanged during the Doppler examination by switching the instrument quickly from the Doppler mode to the real-time 2-D imaging mode, or *vice versa*. Other pulsed Doppler methods allow for simultaneous real-time 2-D imaging and Doppler recording using phased-array devices. This type of instrument can make Doppler examination much easier by allowing more rapid localization of the sample volume, particularly when mapping techniques, discussed later, are performed.

If the flow velocity exceeds the maximal limit of the Doppler display, the excess fraction is displayed on the opposite side, as was observed in case 2. This phenomenon is known as frequency aliasing [2, 8]. Multiple aliasing, in which equal portions of velocity are displayed on both sides of the baseline, causes ambiguity in determining the true peak velocity, the direction of flow, and

whether the existing flow is laminar (with blood cells moving at relatively similar velocities and in a similar direction) or disturbed (with blood cells moving at various velocities and in various directions simultaneously). There are several ways of overcoming this aliasing including selecting the lowest frequency transducer or highest PRF available, moving the baseline to the top or bottom of the display to reduce the aliasing, and by creating large Doppler beam-flow intercept angles in order to reduce the existing velocity within a measurable range. With our own instrument, a frequency of less than 3.5 MHz was not available and baseline movement could not be done. However, we feel that the aliasing artifact in itself causes little diagnostic inaccuracy in the examination of valvular regurgitation.

Examinations using pulsed Doppler in animals have brought similar results to those obtained in man [7, 19]. In addition, in the present study, there was no significant difference between dogs and calves in the flow profile recorded at the same sampling location within the heart and vessels. Measurement of the maximal velocity of each flow was not investigated in this study, because the velocity of a given blood flow was appreciably influenced by the angle between the Doppler beam and flow direction [11] and the condition of anesthesia of each animal. Technical difficulties were occasionally encountered in obtaining reliable Doppler flow signals in the right side of the heart in some normal dogs and calves.

In clinical cases, contrast 2-D echocardiography was valuable for definitive diagnosis of mitral regurgitation (case 1) and aortic regurgitation (case 2), but this technique is invasive and requires catheterization. The results also showed that the pulsed Doppler method was equally valuable in the diagnosis of either form of valvular regurgitation, while its noninvasive nature was

advantageous. Doppler examination for any type of valvular regurgitation involves screening for regurgitant flow signals that arise in the chamber just below the affected valve [2, 8]. A careful search for the maximal intensity of the regurgitant flow signals based upon both the Doppler audio signal and the graphic display may provide an important means of differentiating it from other similar abnormal flows, since the intensity and velocity of the regurgitation are usually maximal at the affected valve and decrease gradually with increased distance from the valve, as observed in our study. There are several methods available for visualizing regurgitant flows in tricuspid and pulmonary regurgitation, including contrast echocardiography, angiocardiology, and Doppler echocardiography. By contrast echocardiography, injecting contrast medium into a peripheral vein allows to visualize the contrast echoes flowing retrogradely into the right atrium or posterior vena cava during systole (tricuspid regurgitation) [12] or by observing the retrograde flow into the right ventricle during diastole (pulmonary regurgitation) [13]. This is best achieved by simultaneous 2-D and M-mode echocardiography. Although not performed in this study, our past experience with contrast echocardiography suggests that regurgitant flow may be missed even when it is existed, due to sampling error, where the width of the M-mode beam against the valvular orifice is too narrow to detect the actual site of the leakage at any given time. Furthermore, the contrast method is even less sensitive when regurgitation is mild. Also, the invasive angiographic diagnosis of tricuspid or pulmonary regurgitation is not totally reliable, since imperfect closure of the tricuspid or pulmonic valve caused by the catheter may produce a false-positive diagnosis [20]. In addition, this technique cannot be performed in critically ill patients, especially patients with pulmonary hyper-

tension. Accordingly, the pulsed Doppler method seems to be useful for right-sided valvular regurgitation [1, 15, 17]. It is believed at present that pulsed Doppler shows high sensitivity in the diagnosis of any type of regurgitation, as compared with the other methods [1, 16, 23]. However, several limitations and pitfalls related to this form of methodology should be emphasized. First, sampling error where the presence of regurgitant flow can be missed occurs in a similar way to that in contrast M-mode echocardiography. We therefore consider that a full exploration for regurgitant flow should be performed using a variety of approaches before the results of a Doppler study can be considered negative. Secondly, it is not always possible technically to secure the correct position of the sample volume in a given area within a small chamber or vessel of a rapidly beating heart, and respiration or the movement of animals also hinders stable holding of the sample volume placement. Thirdly, the high sensitivity of this technique detects even physiological valvular regurgitation in normal human subjects [10]. In the present cases, however, no such regurgitant flow signals were seen at least in the limited numbers of normal subjects examined. Finally, Doppler instruments are much more expensive than M-mode or 2-D types.

In case 2, the abnormal Doppler signals detected in the right atrium and pulmonary artery were interpreted respectively as tricuspid and pulmonary regurgitant flow based on their position of detection (chamber preceding the affected valve), time of appearance, and flow direction (opposite to the direction of flow). The late systolic reverse-flow pattern in the pulmonary artery seen in case 2 is a well-known sign of pulmonary hypertension in man [9]. The pulmonary regurgitation in this case may have been secondary to pulmonary hypertension.

According to the criteria for severity of regurgitation by the pulse Doppler method in human cardiology [16, 22], the so-called "mapping technique", each of the mitral (case 1), tricuspid (case 2), and aortic (case 3) regurgitations with regurgitant flows extending far into the chamber preceding each of the affected valves, was considered to be at least more than moderate. We have also experienced dogs suspected to have mild mitral or tricuspid regurgitation on the basis of clinical and radiographic findings. In these dogs, pulsed Doppler recordings showed abnormal systolic Doppler signals similar to those of regurgitant flow that were localized within a small area of the atrium below the atrioventricular valve, their velocities being insufficient to produce aliasing. When quantitative assessment of regurgitation is carried out using pulsed Doppler, it must be borne in mind that the presence of regurgitant flow signals with high velocity extending far into the atrium or ventricle, but showing no broad regurgitant flow or any sign of chamber dilatation associated with regurgitant volume overloading, suggests a less pronounced degree of regurgitation.

From the results of this study and the author's clinical experience with pulsed Doppler echocardiography during the past two and a half years, it was concluded that pulsed Doppler echocardiography is a very useful technique for the detection (qualitative) and perhaps even the estimation of severity (semiquantitative) of valvular regurgitation in domestic animals. In veterinary cardiology, however, research in this field has just begun and further study on the usefulness and limitations of this modality will be needed for its clinical use.

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REFERENCES

1. Curtius, J. M., Thyssen, M., Breuer, H. W., and Loogen, F. 1985. Doppler versus contrast echocardiography. *Am. J. Cardiol.* 56: 333-336.
2. Feigenbaum, H. 1986. Echocardiography, 4th ed., Lea & Febiger, Philadelphia.
3. Gaffney, F. A., Lin, J. C., Peshock, R. M., Bush, L., and Buja, M. 1983. Hydrogen peroxide contrast echocardiography. *Am. J. Cardiol.* 52: 607-609.
4. Hagio, M. 1985. Two-dimensional echocardiography in the dog: technique and clinical utility. *Adv. Anim. Cardiol.* 18: 7-21 (in Japanese).
5. Hagio, M., and Otsuka, H. 1985. Combined pulsed Doppler and two-dimensional echocardiography in canine and bovine heart diseases. In: 7th International Vet. Radiol. Confer. Dublin Ireland).
6. Hagio, M., Murakami, T., and Otsuka, H. 1986. Two-dimensional echocardiographic diagnosis of bovine congenital heart disease: a systematic approach. *Adv. Anim. Cardiol.* 19: 1-10 (in Japanese).
7. Hatle, L., and Angelsen, B. 1985. Pulsed Doppler recording of intracardiac blood flow velocities: orientation and normal velocity patterns. pp. 74-96. In: Doppler Ultrasound in Cardiology: Principles and Clinical Applications, 2nd ed., Lea & Febiger, Philadelphia.
8. Kitabatake, A., and Inoue, M. 1986 (translated title) Doppler echocardiography. Maruzen, Tokyo (in Japanese).
9. Koizumi, K., Tohda, E., Kashida, M., Isobe, M., Kuwano, K., Umeda, T., and Machii, K. 1984. Hemodynamic determinants of late systolic reversed flow in the main pulmonary artery in pulmonary hypertension: a pulsed Doppler echocardiographic study. *J. Cardiology.* 14: 359-374 (in Japanese with English summary).
10. Kostucki, W., Vandenbossche, J. L., Friart, A., and Englert, M. 1986. Pulsed Doppler regurgitant flow patterns of normal valves. *Am. J. Cardiol.* 58: 309-313.
11. Lighty, G. W., Gargiulo, A., Kronzon, I., and Politzer, F. 1986. Comparison of multiple views for the evaluation of pulmonary arterial blood flow by Doppler echocardiography. *Circulation* 74: 1002-1006.
12. Meltzer, R. S., Vered, Z., Hegesh, T., Benjamin, P., Visser, C. A., and Neufeld, H. N. 1983. Diagnosing tricuspid regurgitation by direct imaging of the regurgitant flow in the right atrium using contrast echocardiography. *Am. J. Cardiol.* 52: 1050-1053.
13. Metltzer, R. S., Vered, Z., Hegesh, T., Benjamin, P., Visser, C. A., Shem-Tou, A. A., and

- Neufeld, H. N. 1984. Diagnosis of pulmonic regurgitation by contrast echocardiography. *Am. Heart J.* 107: 102-107.
14. Miyatake, K., Kinoshita, N., Nagata, S., Beppu, S., Park, Y. D., Sakakibara, H., and Nimura, Y. 1980. Intracardiac flow pattern in mitral regurgitation studied with combined use of the ultrasonic pulsed Doppler technique and cross-sectional echocardiography. *Am. J. Cardiol.* 45: 155-162.
 15. Miyatake, K., Okamoto, M., Kinoshita, N., Matsushita, M., Nagata, S., Beppu, S., Park, Y. D., Sakakibara, H., and Nimura, Y. 1982. Pulmonary regurgitation studied with the ultrasonic pulsed Doppler technique. *Circulation* 65: 969-976.
 16. Miyatake, K., Okamoto, M., Kinoshita, N., Ohta, M., Kozuka, T., Sakakibara, H., and Nimura, Y. 1982. Evaluation of tricuspid regurgitation by pulsed Doppler and two-dimensional echocardiography. *Circulation* 66: 777-784.
 17. Patel, A. K., Rowe, G. G., Dhanani, S. P., Kosolcharoen, P., Lyle, L. W., and Thomsen, J. H. 1982. Pulsed Doppler echocardiography in diagnosis of pulmonary regurgitation: its value and limitations. *Am. J. Cardiol.* 49: 1801-1805.
 18. Pipers, F. S., Reef, V., and Wilson, J. 1985. Echocardiographic detection of ventricular septal defects in large animals. *J. Am. Vet. Med. Assoc.* 187: 810-816.
 19. Schuster, A. H., and Nanda, N. C. 1985. Doppler examination of the heart, great vessels, and coronary arteries. pp. 77-129. *In: Doppler Echocardiography* (Nanda, N. C. ed), Igaku-Shoin, Tokyo.
 20. Sobol, B. J., Bottex, G., Emirgil, C., and Gissen, H. 1964. Valvular insufficiency occurring during cardiac catheterization. *Am. J. Cardiol.* 14: 533-536.
 21. Thomas, W. P. 1984. Two-dimensional, real-time echocardiography in the dog: technique and anatomic validation. *Vet. Radiol.* 25: 50-64.
 22. Veyrat, C., Abitbol, G., Bas, S., Manin, J. D., and Kalmasons, D. 1984. Quantitative assessment of valvular regurgitations using the pulsed Doppler technique. Approach to the regurgitant lesion. *Ultrasound in Med. & Biol.* 10: 201-213.
 23. Waggoner, A. D., Quinones, M. A., Young, J. B., Brandon, T. A., Shah, A. A., Verani, M. S., and Miller, R. R. 1981. Pulsed Doppler echocardiographic detection of right-sided valve regurgitation. Experimental results and clinical significance. *Am. J. Cardiol.* 47: 279-286.

要 約

正常犬、正常子牛および弁閉鎖不全3例の超音波パルスドプラー所見：萩尾光美・大塚宏光（宮崎大学農学部，家畜外科学教室）——断層心エコー図とパルスドプラー法を組み合わせた超音波パルスドプラー法の家畜への臨床応用を検討する目的で、犬および子牛健常例および弁閉鎖不全症例について各心室流入・流出路および大血管近位の超音波パルス血流測定を行った。健常動物では、各部位での血流測定は概ね良好であり、得られた血流パターンは犬および子牛ともにヒト健常者のそれらときわめて類似していた。犬および子牛の弁閉鎖不全3症例についての所見から、本法により、閉鎖不全の重症度をある程度推定することが可能と思われた。