Doppler-derived Velocity of Blood Flow across the Cardiac Valves in the Normal Dog

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ABSTRACT

Doppler echocardiography is a relatively new procedure used to assess certain cardiovascular disorders in the dog. The objectives of this study were to determine the range of values for the maximal peak velocity of blood flow across each of the four cardiac valves in a sample population of normal adult dogs, using duplex continuous wave Doppler echocardiography, and to determine the optimal tomographic planes to use for an adequate continuous wave Doppler evaluation of the canine heart. Twenty normal dogs were examined to obtain values for peak transvalvular velocity for each of the four cardiac valves. The mean values ± 1 SD, in cm/s were: 98.1 ± 9.4 for the pulmonary valve imaged from the left side of the chest, 95.5 ± 10.3 for the pulmonary valve imaged from the right side of the chest (n = 19), 118.1 ± 10.8 for the aortic valve, 86.2 ± 9.5 for the mitral valve and 68.9 ± 8.4 for the tricuspid valve. Regurgitation was detected across the pulmonic valve in 14 of the 20 dogs, and across the tricuspid valve in ten dogs. The analysis of the tomographic images confirmed that for a complete assessment of a given intracardiac valve, the valve must be examined from all possible directions to obtain maximum values for peak velocity.

RÉSUMÉ

La technologie de l'échocardiographie-Doppler trouve depuis peu une application clinique chez des chiens présentant certains troubles cardiovasculaires. Cette étude avait pour but de déterminer à l'aide de cette technique les variations normales de la vitesse sanguine maximale au niveau de chacune des valvules cardiaques. De plus, elle visait à décrire le plan tomographique idéal pour une évaluation cardiaque adéquate chez le chien. Les observations ont été faites à l'aide d'un échocardiographe-Doppler à ondes « duplex » continues. Vingt chiens adultes et en bonne santé, ont été utilisés. Les vitesses sanguines transvalvulaires ($\bar{X}$ cm/s ± 1 S.D.) observées furent de : 98,1 ± 9,4 pour la valvule pulmonaire, sondée du côté gauche du thorax, 95,5 ± 10,3 pour la valvule pulmonaire sondée du côté droit du thorax (n = 19), 118,1 ± 10,8 pour la valvule aortique, 86,2 ± 9,5 pour la valvule mitrale et 68,9 ± 8,4 pour la valvule tricuspide. Un reflux sanguin a été décelé au niveau de la valvule pulmonaire chez 14 des 20 sujets, et au niveau de la tricuspide chez la moitié des chiens utilisés. L'analyse des images tomographiques a confirmé que pour une évaluation complète d'une valvule cardiaque donnée, celle-ci doit être examinée sous tous les angles possibles afin d'obtenir la valeur maximum de la vélocité sanguine. (*Traduit par Dr André Dallaire*)

INTRODUCTION

Echocardiography has become the primary imaging technique used for the investigation of a wide range of cardiac abnormalities in humans (1). With its noninvasive and relatively nonstressful nature, it is ideally suited to monitor the progression of disease or the efficacy of therapeutic interventions. Echocardiography may involve the use of any of three modalities: time motion mode (M-Mode); two-dimensional (2D); or Doppler echocardiography. The first two of these provide a functional analysis of cardiac structure (2), while the third gives a physiological assessment of blood flow within the cardiac chambers, across valve orifices, and in the great vessels (2,3). By combining modalities, clinicians can obtain a more complete evaluation of cardiac function (4).

Doppler instruments have variable capabilities, with the differences determined primarily by the transducer. Doppler transducers may operate in pulsed wave (PW) or continuous wave (CW) modes. Pulsed wave Doppler can detect flow patterns in a very discrete region of the simultaneously-imaged 2D echocardiographic plane (3,5), but is limited to the measurement of velocities less than 2 m/s. Continuous wave Doppler can detect extremely high flow velocities (2–4), but since the velocity is measured along the entire length of the Doppler beam, its specific origin is ambiguous. A CW examination may be performed with either a duplex or a dedicated transducer (4). Duplex transducers are capable of generating a two-dimensional image and simultaneously displaying the location of the Doppler beam within this image. With dedicated transducers, the Doppler examination occurs independently of the imaging study, and thus is a blind procedure.

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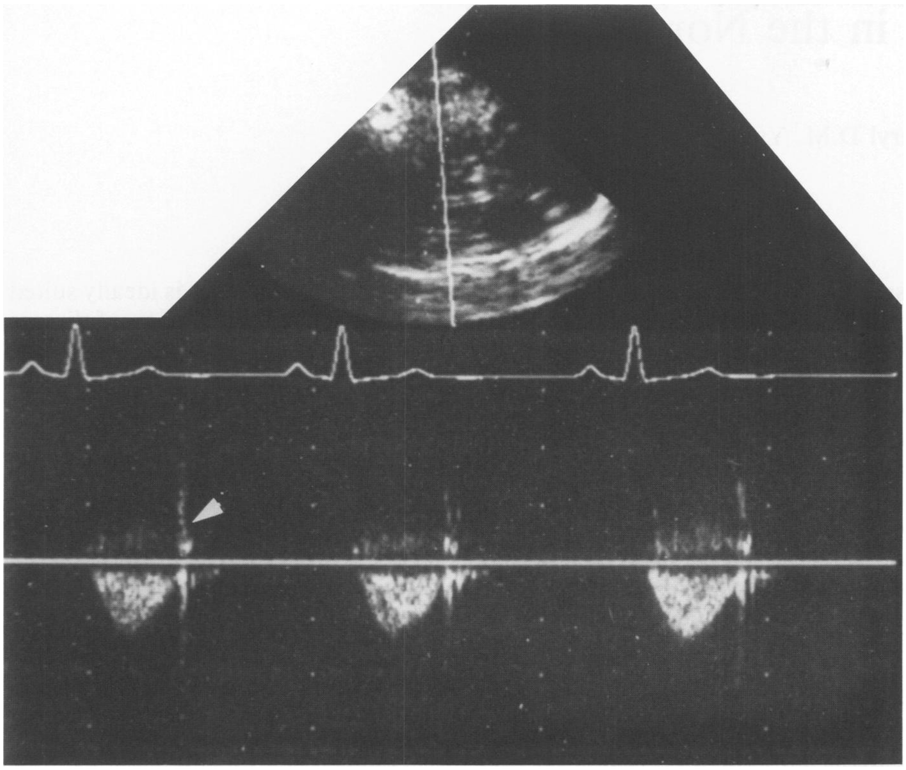

Fig. 1. Spectral display of a semilunar valve velocity profile. Blood is flowing away from the transducer during systole. Thus, a velocity profile (analogous to a histogram of peak velocities) is displayed below the zero baseline during systole. The sharp vertical deflection (arrowhead) at the end of the flow profile represents the closing of the valve cusps.

Doppler echocardiography is ideal for the detection and quantitation of stenotic valvular disorders. In these disorders, the velocity of blood flow across the stenotic orifice is greatly accelerated. In order to assess the severity of these increased velocity states it is essential to know the maximum velocity of blood flow across normal cardiac valvular orifices. The mean values and ranges for intracardiac blood flow velocities in normal dogs and horses, as detected by PW Doppler echocardiography, have recently been reported (6,7). No similar data are currently available for CW Doppler techniques.

The objectives of this study were to determine the normal blood flow velocity across the four cardiac valves in a sample population of normal adult dogs, using duplex CW Doppler echocardiography, and to determine the optimal views to use for an adequate CW Doppler evaluation of the canine heart.

MATERIALS AND METHODS

EXAMINATION PROCEDURE

All examinations were performed using a Toshiba SSH-40A Echocardiographic Unit with an SDS-21B Doppler Unit and a PSD 24D phased array probe with nonsteerable duplex continuous wave (CW) Doppler capabilities and a carrier frequency of 2.4 MHz (Toshiba Medical Systems; 151 Nashdene Rd., Units 36 & 37; Scarborough, Ontario). Examinations were recorded on VHS tape and subsequently digitized and measured using a commercially available software program (Danmark Video Image Analyser, Version Mod. 2.0; Dan Schnurr Computer Applications; 29 Elora Street; Guelph, Ontario).

Twenty adult dogs, judged to have no abnormalities of the cardiovascular system, based on history, physical examination and electrocardiography were studied. Mean age of the subjects was 3.9 yr (range 1.5 to 8) and mean weight was 23.2 kg (range 3 to 41). Six of eleven males were castrated and six of nine females were spayed. Echocardiographic examinations were performed from both left and right parasternal locations, as previously described (8,9), using manual restraint only.

DESCRIPTION OF TOMOGRAPHIC PLANES IMAGED

For each two-dimensional image, there were two directions for examination of the valve of interest with the CW Doppler cursor beam. The beam could either be directed across the video screen from upper left to lower right or from upper right to lower left. The former position will henceforth be known as the left view, while the latter will be known as the right view. In each view, after the Doppler cursor beam was directed across the valve of interest, fine adjustments in the beam orientation were necessary to maximize the spectral display of peak velocity of blood flow (see Figs. 1 and 2).

Pulmonic valve right parasternal long axis views (Fig. 3a) — From this position, the two views examined were the pulmonic valve right parasternal long axis left view (PV1) and the pulmonic valve right parasternal long axis right view (PV2). The transducer was initially positioned in the right parasternal long axis view optimized for the aortic valve, as described by Thomas (9). The beam was then tilted slightly towards the dog's head and was rotated approximately 15° clockwise. Fine repositioning of the ultrasonic beam generated an image which showed the right ventricular outflow tract on the right hand side of the display screen, with the pulmonic valve found at about the 3 to 4 o'clock position. On the left of the screen, a view of the left ventricular outflow tract, cut on an oblique plane, was seen.

Pulmonic valve right parasternal short axis views (Fig. 3b) — The two views examined in this orientation were the pulmonic valve right parasternal short axis left (PV3) and right (PV4). For these views, the transducer was rotated 90° clockwise from the right parasternal long axis position. The transducer was angled craniad to display a longitudinal view of the right ventricular

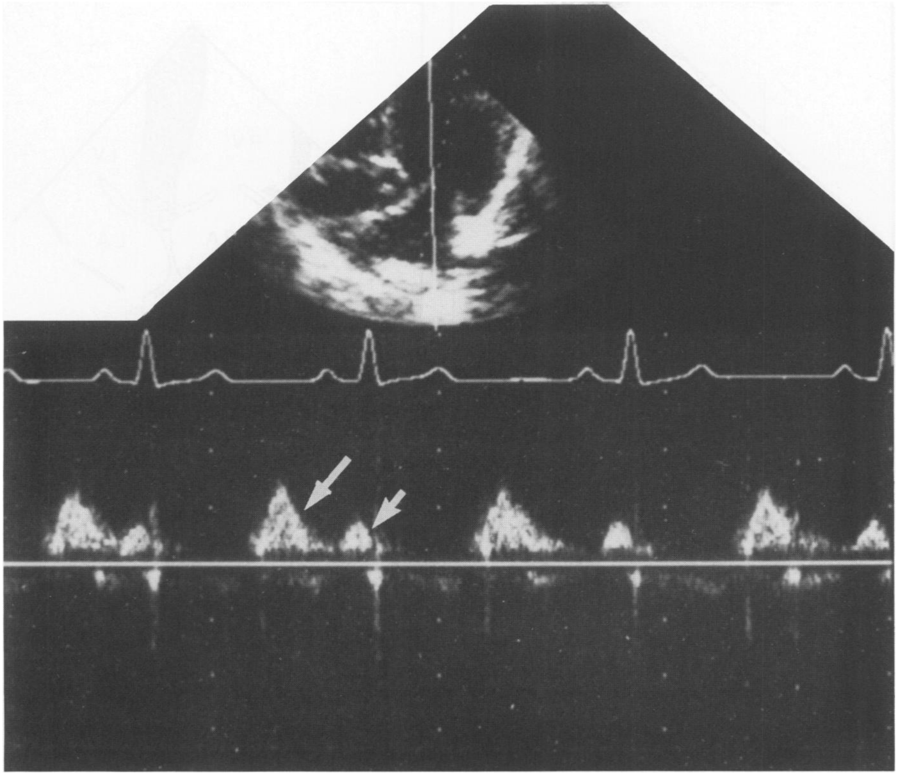

Fig. 2. Spectral display of an atrioventricular valve velocity profile. Blood flow is towards the transducer in diastole and is biphasic. Thus, a velocity profile (analogous to a histogram of the peak velocities) is displayed above the zero baseline during diastole. The first peak, known as the "E-wave" (large arrow), represents the rapid diastolic filling phase. The second peak, known as the "A-wave" (small arrow), represents atrial contraction, and is usually a lower velocity than the E-wave.

outflow tract wrapping around the centrally placed aorta from left to right, with the pulmonic valve located between the 3 and 5 o'clock positions.

Pulmonic valve left cranial parasternal long axis views (Fig. 3c) — The two views examined from this orientation were designated the pulmonic valve left cranial parasternal left (PV5) and right (PV6). The transducer was positioned high in the left axillary region, as previously described (9), and a long axis view of the left ventricular outflow tract and ascending aorta was displayed. The transducer was then titled steeply in a dorsal direction to show a long axis view of the right ventricular outflow tract, pulmonic valve and main pulmonary artery; the pulmonic valve was imaged between the 9 and 10 o'clock positions.

Aortic valve left apical five chamber views (Fig. 4a) — The two views examined from this orientation were the aortic valve left apical five chamber left (AV1) and right (AV2). The transducer was directed through the fifth or sixth left intercostal space, with the apical five chamber image displayed as described by O'Grady *et al* (8), with the left atrium and left ventricle on the right side of the display monitor.

Aortic valve left apical long axis views (Fig. 4b) — The aortic valve left apical long axis left (AV3) and right (AV4) views were obtained from this position. The transducer was rotated 45° to 60° from the apical five chamber view to image the left ventricular inflow and outflow tracts (9). The image was displayed with the mitral valve on the right and the aortic valve more central, so that blood flowed across the mitral valve from left to right, and across the aortic valve from right to left.

Mitral valve left apical four chamber views (Fig. 5a) — The mitral valve left apical four chamber left (MV1) and right (MV2) views were obtained from the previously described (8) four chamber tomographic plane, with the left atrium and left ventricle displayed on the right side of the screen.

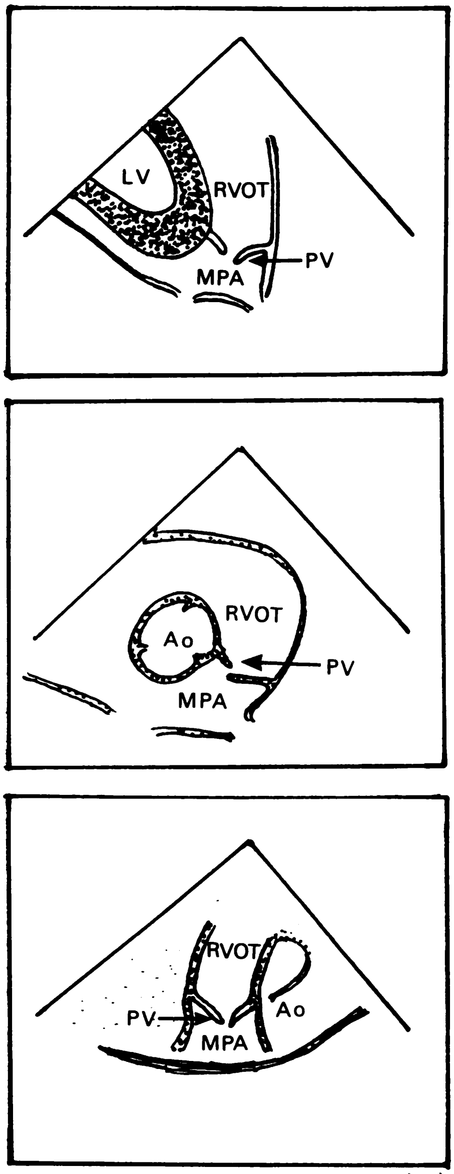

Fig. 3. Pulmonic valve views. 3a. A line drawing of the two-dimensional (2D) image utilized for the pulmonic valve right parasternal long axis views. 3b. A line drawing of the 2D image utilized for the pulmonic valve right parasternal short axis views. 3c. A line drawing of the 2D image used for the pulmonic valve left cranial parasternal views.
LV = left ventricle, RVOT = right ventricular outflow tract, MPA = main pulmonary artery, PV = pulmonic valve, Ao = aorta.

Mitral valve left apical long axis views (Fig. 5b) — The mitral valve left apical long axis left (MV3) and right (MV4) views were obtained by positioning the

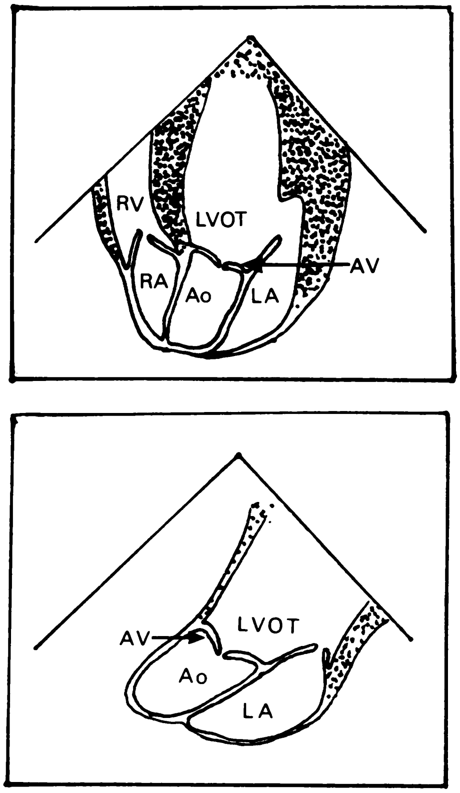

Fig. 4. Aortic valve views. 4a. A line drawing of the two-dimensional (2D) image used for the aortic valve left apical five chamber views. 4b. A line drawing of the 2D image utilized for the aortic valve left apical long axis views. RV = right ventricle, RA = right atrium, LVOT = left ventricular outflow tract, LA = left atrium, AV = aortic valve, and Ao = aorta.

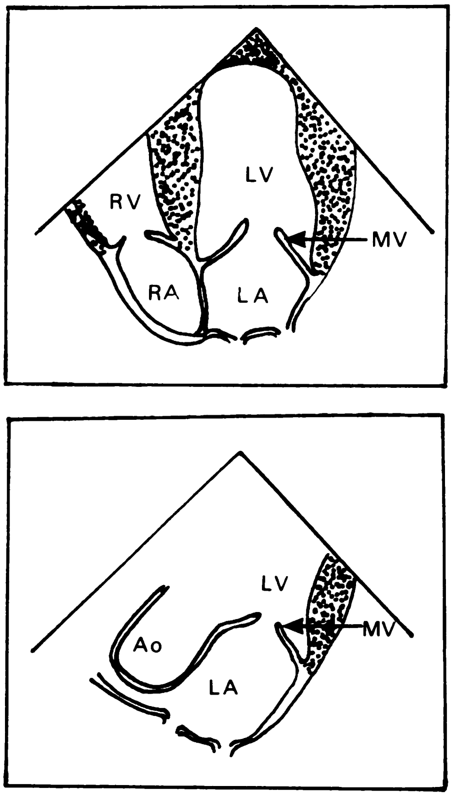

Fig. 5. Mitral valve views. 5a. A line drawing of the two-dimensional (2D) image used for the mitral valve left apical four chamber views. 5b. A line drawing of the 2D image utilized for the mitral valve left apical long axis views. RV = right ventricle, RA = right atrium, LV = left ventricle, LA = left atrium, MV = mitral valve, and Ao = aorta.

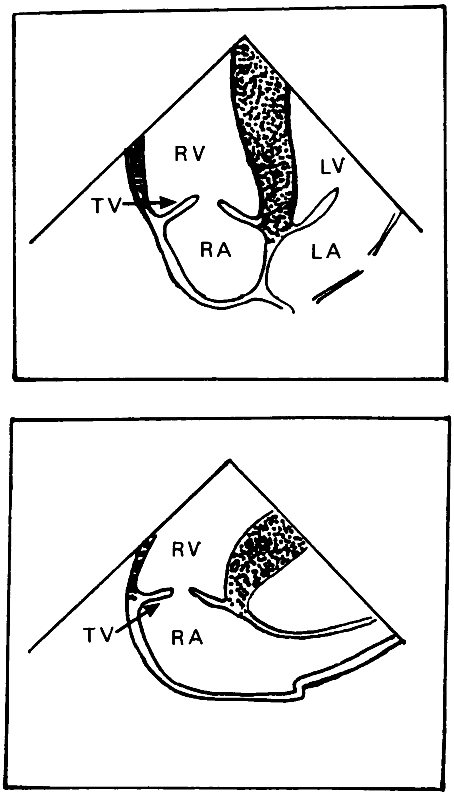

Fig. 6. Tricuspid valve views. 6a. A line drawing of the two-dimensional (2D) image used for the tricuspid valve left apical four chamber views. 6b. A line drawing of the 2D image utilized for the tricuspid valve left cranial parasternal views. RV = right ventricle, TV = tricuspid valve, RA = right atrium, LV = left ventricle, LA = left atrium.

transducer in the location described for the AV3 and AV4 views. Fine adjustments were made to the transducer orientation so that the Doppler cursor line was directed across the left ventricular inflow area.

Tricuspid valve left apical four chamber views (Fig. 6a) — The images designated as the tricuspid valve left apical four chamber left (TV1) and right (TV2) views were generated by positioning the transducer in the apical four chamber position and making fine adjustments to its orientation so that the Doppler cursor line was directed across the right ventricular inflow area.

Tricuspid valve left cranial parasternal views (Fig. 6b) — The two images analyzed from this orientation were designated as the tricuspid valve left cranial parasternal left (TV3) and right (TV4) views. The transducer was initially positioned as described for the PV5 and PV6 views, then tilted so that the ultrasonic beam was aimed towards the right sternal region. The resulting display showed the right atrium and tricuspid valve on the left side of the screen, with the tricuspid valve at the 9 o'clock position.

MEASUREMENT OF DATA

For each view of each cardiac valve, the three velocity profiles which demonstrated the maximal peak velocity were selected. These images were digitized and measured by the same observer (CDY) using a personal computer and a "mouse"-driven software program which was capable of incremental measurements of 6 cm/s. The vertical distance from the apex of a velocity profile to the zero baseline was measured and expressed in cm/s. In the case of the semilunar valves, measurements were taken during systole, while for the atrioventricular valves, measurements were taken at the peak of the "E-wave", during the early diastolic filling phase of the cardiac cycle. The heart rate was recorded for each velocity measurement.

STATISTICAL ANALYSIS

For each valve, the one view which demonstrated the highest peak velocity was selected. Its three measured values were averaged to produce a single peak velocity value for each valve in each dog. Since the pulmonic valve could be imaged from both the right and left parasternal positions, the maximum velocity obtained from the right side was recorded separately from that obtained from the left side. The data were analyzed using the SAS program "PROC UNIVARIATE" and the Pearson's correlational test (SAS User's Guide. Statistics Version. 5th Edition. 1985. SAS Institute Inc., Box

TABLE I. Continuous wave transvalvular velocity of blood flow in normal dogs[a]

Valve	N	Mean[b]	SD	Min	Max	Range	95%CI[c]
PVR	20	98.1	9.4	76.0	122.0	46.0	74.0–122.2
PVL	19	95.5	10.3	78.0	114.0	36.0	69.1–121.9
AV	20	118.1	10.8	104.0	138.0	34.0	90.4–145.8
MV	20	86.2	9.5	70.0	108.0	38.0	61.8–110.6
TV	20	68.9	8.4	52.0	92.0	40.0	47.4–90.4

[a]All measurements are in units of cm/s
[b]For each valve, the numbers used to generate the mean velocity of blood flow were obtained by averaging the velocity values measured from the three highest complexes from the view which demonstrated the highest velocity measurements
[c]95% Confidence intervals indicate that the velocity detected for a normal member of the population will fall within the defined limits, with a probability of 0.90 (Reference 10)
Abbreviations: N = Number of dogs; SD = Standard deviation; CI = Confidence interval (see c); PVR = Pulmonic valve, right parasternal; PVL = Pulmonic valve, left parasternal; AV = Aortic valve; MV = Mitral valve; TV = Tricuspid valve

8000, Cary, North Carolina). Confidence intervals were calculated at the 95% level by multiplying the standard deviation by the factor 2.5642, as recommended by Lumsden *et al* (10). For a sample size of 20, this factor will give a tolerance interval which has a probability of 0.90 of containing 95% of the population. Pearson's correlational test was used to assess the relationships between heart rate and flow velocity; body weight and flow velocity; and age and flow velocity.

RESULTS

VELOCITY VALUES IN NORMAL DOGS

The velocity values across each valve are summarized in Table I. The Pearson correlational coefficients for the relationship between body weight and peak flow velocity and between age and peak flow velocity were both zero, while that between heart rate and maximum velocity was 0.13786.

Regurgitation was detected across both valves of the right heart, but not across either valve of the left heart. Care was taken to ensure that the signal was not the result of normal flow simultaneously occurring in another region of the heart. Seventy percent of the dogs, or 14 of 20, demonstrated pulmonic regurgitation. In all cases, the regurgitant signal was a low velocity positive signal, was not identified in all views, and occupied a variable portion of the diastolic period (Fig. 7). Fifty percent, or 10 of 20 dogs, demonstrated tricuspid regurgitation. The signal did not display a good envelope in most cases, but did occur in systole and was a low velocity negative signal (Fig. 8).

TOMOGRAPHIC PLANES

The pulmonic valve was evaluated from both left and right parasternal positions. In ten dogs maximal peak velocities were obtained from the right side, in seven dogs maximal values were detected on the left side, while for the remainder values from both sides were the same.

For the aortic and mitral valves, the different designated views were obtained with the transducer in the same position on the left chest wall. Only the view denoted as AV3 was clearly inferior to the others, since the maximal velocity was never detected from this view.

The tricuspid valve was evaluated by positioning the transducer on the left chest wall in two distinct locations. In 16 of 20 dogs, the highest velocities were detected from the left cranial parasternal location.

DISCUSSION

DETERMINATION OF VELOCITY VALUES IN NORMAL DOGS

There is close agreement between the values obtained in this study and the results from another canine study (6), or from humans (4,5). The assumption that velocities in dogs parallel those in humans was presented by Colocousis *et al* (11) in 1977. Prior to the publication by Gaber (6), veterinary cardiologists compared the results from Doppler examinations of dogs to normal values extrapolated from the human literature. The results of the present study lend further support to the validity of this assumption. Table II compares the results of this study to those of Gaber. Disagreement between the two studies occurred with respect to the frequency of pulmonic valve regurgitation, and correlations between velocity and body weight.

The finding of mild, localized regurgitant signals across the tricuspid and pulmonic valves in many of the normal dogs parallels findings in normal humans (12,13). The disparity between the results of the two canine studies may have occurred for any of the following three reasons.

First, definitions of valvular regurgitation vary. Some authors (14) state that regurgitation is present only when the signal occupies the whole of systole (for atrioventricular valves) or diastole (for semilunar valves). Others state that mild valvular regurgitation is present when the regurgitant signal occupies only a portion of the cardiac cycle (4,13). In the present study, regurgitation was considered to be present if any signal in the direction opposite to normal forward flow occurred during the phase of the cardiac cycle when the valve should be closed. The definition of regurgitation used in the other canine study (6) was not stated.

Second, in studies of normal humans, there is a wide variation in the percent of pulmonic regurgitation detected in different sample populations, ranging from 40% (12) to 96% (13). In the absence of diagnostic clinical physical findings, most pulmonic valve regurgitation is believed to be hemodynamically insignificant in humans (15). Accordingly, there would be little evolutionary selection pressure to remove affected individuals from the population, and any variation would represent true differences in sample populations.

Third, the different technique in performing the examinations between the two studies could have caused a significant proportion of the disparity. Continuous wave Doppler echocardiography should be expected to be more sensitive than PW Doppler for the

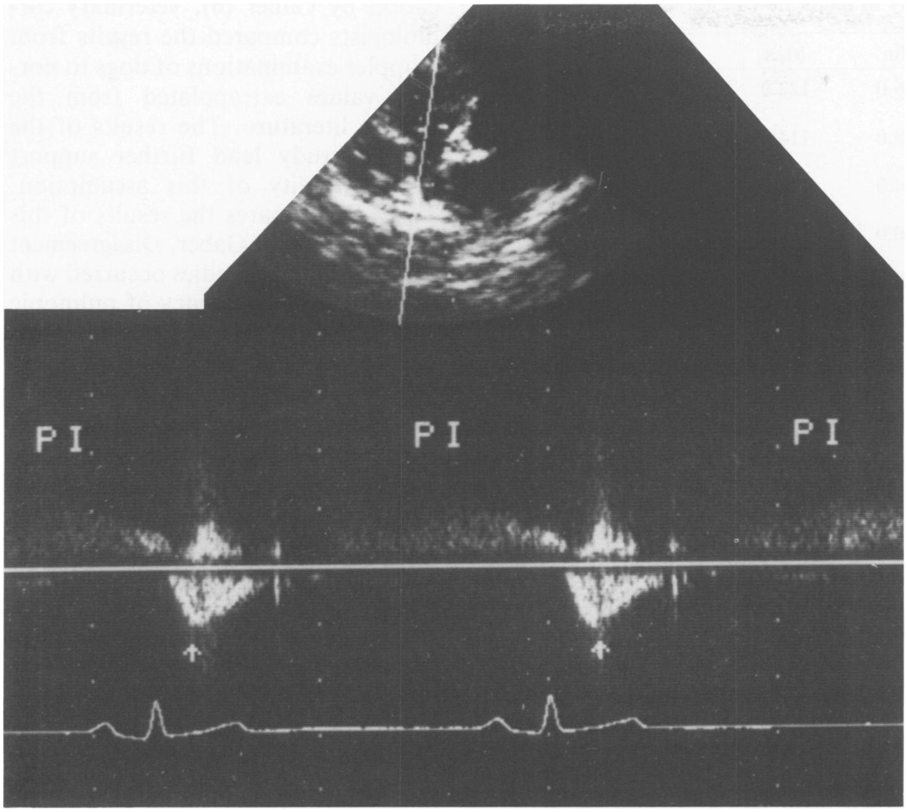

Fig. 7. Pulmonic valve regurgitation. The Doppler spectral display reveals a negative systolic signal typical of normal antegrade flow across the pulmonic valve (arrow). However, a diastolic positive signal typical of pulmonic valve regurgitation is also seen (PI).

detection of mild, localized regurgitant lesions. The length and width of the CW Doppler beam are such that the sample volume is large, whereas the PW sample volume is relatively small. This difference alone could have caused a higher level of detection of pulmonic regurgitation in the present study, while the other two factors could have contributed further to the disparity.

In the present study, no significant correlations between the velocity of blood flow and age, heart rate or body weight were found. A correlation between body weight and flow velocity across the atrioventricular valves was noted in Gaber's study (6). Two groups of dogs were examined for this study (6), with body weights either less than 10 kg or greater than 19 kg. The present study examined dogs which ranged in weight from 3 to 41 kg; seven dogs had weights between 10 and 19 kg (a weight range not evaluated by Gaber). The disagreement between the two studies with respect to the body weight correlation likely resulted from a true difference between the sample populations examined. Alternatively, the method of determining the peak velocity values may have caused the disparity. In Gaber's study, the peak flow velocity value was the average value obtained by measuring a series of consecutive flow profiles. In the present study, the peak flow velocity was the average value obtained by measuring the three highest flow complexes found for a given valve during the course of an examination, and were rarely consecutive. It has been shown by other investigators (16) that respiration has a significant effect on the flow velocity across the atrioventricular valves. The present study deliberately attempted to minimize this effect by selection of the highest complexes, while in Gaber's study no such restriction was imposed.

TOMOGRAPHIC PLANES

For the pulmonic valve, there is no clear evidence for preference of CW Doppler interrogation of the left side over the right side of the chest. Since the other three valves are imaged for Doppler purposes from the left side of the chest, it would simplify the performance of the total examination if there were no need to evaluate the pulmonic valve from the right side.

Imaging of the pulmonic valve was technically much easier from the right side. In most cases, the quality of the 2D image of the pulmonary outflow tract from the left side was very poor due to interference by the lung fields. When the Doppler cursor beam was activated, it was often difficult to obtain a consecutive series of optimal recordings. This problem could be attributed to interference from the lung fields, or to minor movements of either the transducer or underlying cardiac structures (4).

There was a clear indication that examination of the aortic valve from the view called AV3 was not useful for Doppler purposes. Inspection of the two-dimensional image suggested this at the time of examination since the Doppler cursor clearly crossed the aortic outflow area at a steep angle to the direction of flow. It was also not surprising that the AV2 view demonstrated the highest velocity in the greatest number of examinations, since it appeared on the 2D display that the Doppler cursor beam was aligned well with blood flow.

A more unexpected finding was that the view identified as AV1 was responsible for producing the maximum velocity in four normal dogs. Inspection of the two-dimensional image of this view revealed the Doppler cursor beam crossing the outflow tract at a relatively large angle to the presumed direction of blood flow, suggesting that the detected flow velocity would underestimate the true flow velocity. Instead, the detected velocity values were higher in three dogs than in the view AV2 which appeared to display better alignment between the Doppler beam and blood flow. The most likely explanation of this finding was that, for these examinations, the three-dimensional alignment of the Doppler cursor with respect to blood flow was optimal. The Doppler interrogation angle is a three-dimensional angle, with components in both the visualized plane and the azimuthal plane. The

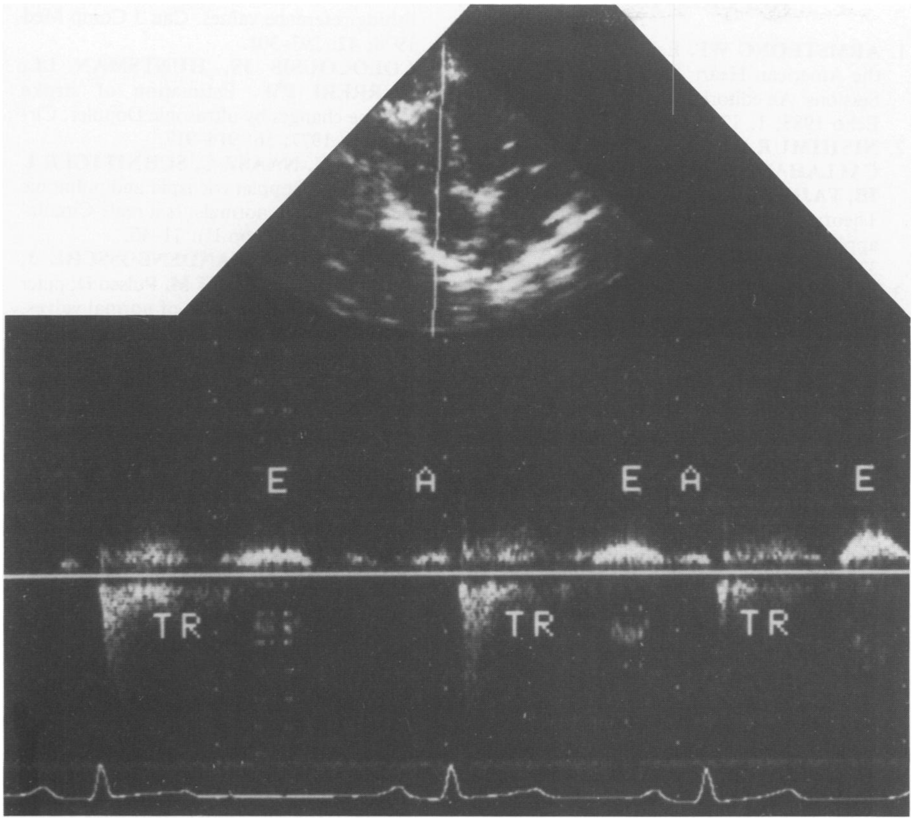

Fig. 8. Tricuspid valve regurgitation. The Doppler spectral display reveals a positive biphasic signal in diastole typical of normal antegrade flow across the tricuspid valve (E and A). However, a negative systolic signal is also seen. This latter signal is typical of tricuspid valve regurgitation and is best illustrated on the first complex on the left, in which it is holosystolic. The velocity envelope is not well defined.

TABLE II. Comparison of Doppler findings in normal dogs

	Yuill *et al*	Gaber (6)
Technique	Continuous wave	Pulsed wave
Sample size	20	28
Pulmonic flow velocity[a]	PVR 98.1 ± 9.4 PVL 95.5 ± 10.3	99.8 ± 15.3
% Pulmonic regurgitation	70%	25%
Aortic flow velocity[a]	118.1 ± 10.8	118.9 ± 17.8
Mitral flow velocity[a]	86.2 ± 9.5	75.0 ± 11.8
Tricuspid flow velocity[a]	68.9 ± 8.4	56.2 ± 16.1
% Tricuspid regurgitation	50%	50%

[a]These flow values represent the maximal peak velocity values found across a given valve, regardless of view. All flow velocities are measured in units of cm/s ± 1 Standard deviation
Abbreviations: PVR = pulmonic valve, left chest views; PVL = pulmonic valve, right chest views

component in the azimuthal plane cannot be measured. However, is has been observed that the azimuthal component of the angle is probably greatest, and therefore assumes more importance, when a short length of a vessel is visualized (17), such as in the apical five chamber views of the aorta. When the valve is examined from these positions, one could easily underestimate the true blood flow velocity unless care was taken to orient the transducer in the optimal position in the azimuthal plane. Contrast this to the apical long axis views (AV3 and AV4) in which a greater length of the aorta is visualized and the effect of the azimuthal angle is likely lessened. The results of the present study support this hypothesis since the lowest velocities were consistently detected in that view (AV3) which displayed a large interrogation angle between the Doppler cursor and the presumed direction of blood flow from the two-dimensional image. The key point that should be noted from these observations is the importance of evaluating blood flow velocity from directions that may appear to be poor on the 2D echocardiogram.

The optimal view for detecting maximal velocity across the mitral valve was MV1. However, it was not uncommon to find systolic signals from the left ventricular outflow tract when the Doppler cursor beam was positioned across the valve from the left. In clinical situations, care must be taken to differentiate between aortic outflow and mitral regurgitant signals when imaging from this direction. Technically, it was a simple matter to interrogate the mitral valve from both the four-chamber and long-axis positions.

For the tricuspid valve, in only two of the examinations did the TV2 signal alone yield the maximal velocity. Technically, this view was the most difficult to obtain since there were problems with positioning the Doppler cursor beam over the right heart, and aortic outflow signals often interfered with the spectral display. The two cranial views were much easier to image and the quality of the Doppler signals was generally much better. In 80% of the examinations, these two cranial views yielded the maximal velocities. In most veterinary patients, an evaluation of the tricuspid valve from the left cranial parasternal position should be adequate for screening purposes. If abnormalities are detected, then a complete examination of the valve in the four positions should be attempted.

To summarize, Doppler echocardiography is a valuable adjunct to a complete cardiovascular examination, complementing the information obtained from imaging echocardiography. Although velocities across normal valves can be detected by PW Doppler, the present study was performed with CW Doppler since many clinical cases will have velocities across one or more valves that exceed the limit of PW instrumentation. A complete Doppler echocardiographic examination should include interrogation of the valves from both sides of the chest and imaging of a given valve from all possible tomographic planes.

In most clinical cases, the focus of the detailed examination can be centred on a particular valve, while the other valves can be screened relatively rapidly for obvious flow abnormalities. Doppler-detected regurgitant lesions of the valves of the right heart should be interpreted in light of associated clinical findings.

Doppler echocardiography has major advantages over currently used invasive methods of obtaining physiological information with respect to intracardiac hemodynamics. The virtual lack of morbidity associated with Doppler echocardiography makes it a safer diagnostic technique than cardiac catheterization. This factor, plus the relative absence of stress to the animal make Doppler echocardiography a much more acceptable alternative to the veterinary patient and client.

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