The first gas-based echocardiographic contrast agent described and used in clinical practice was agitated saline (0.9% NaCl) solution. The primary use of agitated saline solution, which was dictated by the size of its gas particles and its limited stability, was for the detection of right-to-left intracardiac or extracardiac shunts. Because these particles are unable to flow through the pulmonary capillaries, the detection of bubbles in the left atrium or LV after venous injection implies the presence of a right-to-left shunt at some level in the circulation. Development of more modern contrast agents that have improved chemical stability and smaller particle size has allowed for a variety of uses. These second-generation contrast agents are characterized by particles that are smaller than RBCs, which means that they are not trapped by the pulmonary capillaries when injected in a peripheral vein and can opacify the left side of the heart. Thus, they can be used to improve delineation of the endocardial border in dogs.

Use of contrast echocardiography for quantitative and qualitative evaluation of myocardial perfusion and pulmonary transit time in healthy dogs

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Objective—To evaluate reproducibility of ejection fraction (EF), myocardial perfusion (MP), and pulmonary transit time (PTT) measured in a group of dogs by use of contrast echocardiography and to examine safety of this method by evaluating cardiac troponin I concentrations.

Animals—6 healthy dogs.

Procedures—2 bolus injections and a constant rate infusion of contrast agent were administered IV. Echocardiographic EF was determined by use of the area-length method and was calculated without and with contrast agent. The PTT and normalized PTT (PTT/mean R-R interval) were measured for each bolus. Constant rate infusion was used for global MP evaluation, and regional MP was calculated by use of a real-time method in 4 regions of interest of the left ventricle. Cardiac troponin I concentration was analyzed before and after contrast agent administration. Intraobserver and interobserver variability was calculated.

Results—EF was easier to determine with the ultrasonographic contrast agent. For the first and second bolus, mean ± SD PTT was 1.8 ± 0.2 seconds and 2.1 ± 0.3 seconds and normalized PTT was 3.4 ± 0.3 seconds and 3.5 ± 0.3 seconds, respectively. A coefficient of variation < 15% was obtained for global MP but not for the regional MPs. No differences were detected between precontrast and postcontrast cardiac troponin I concentrations.

ity images in animals when a poor acoustic window is used. The adoption of ultrasonographic contrast agents in such patients has the potential of improving image quality, but its use has been limited to research settings.

In humans, contrast echocardiographic examination for assessment of MP permits simultaneous assessment of global and regional myocardial structure, function, and perfusion, which enables optimal noninvasive assessment of patients suspected of having coronary artery disease. To our knowledge, echocardiographic contrast agents have not been used in the evaluation of MP in dogs. Coronary artery disease is not a common issue in veterinary patients, but defects in the coronary microcirculation have been described in dogs with various cardiac diseases. Small-vessel disease with narrowing of coronary vessels may lead to subendocardial ischemia, and the use of echocardiographic contrast agents could allow for the evaluation of MP and provide a clinically applicable tool for the noninvasive assessment of myocardial ischemia in these patients.

The PTT and nPTT have been evaluated as indicators of cardiopulmonary function in dogs with re-gurgitation through the mitral valve. In dogs with congestive heart failure, PTT and nPTT increase as a consequence of reduced cardiac output, increased pulmonary blood volume, or a combination of both. However, methods used in dogs in research settings have included injection of a radioactive contrast agent and the use of a costly gamma camera, which limits the use of these methods in clinical settings. The use of echocardiographic contrast agents could allow for the estimation of PTT in a minimally invasive manner, without the need for sedation or anesthesia of patients or administration of a radioactive contrast agent.

Evidence exists to support the contention that contraction and expansion of microbubbles of contrast agent in an acoustic field, a phenomenon known as cavitation, may cause local myocardial damage in dogs. In particular, the use of 1-second-generation ultrasonographic contrast agent has been associated with adverse reactions in humans. The release of cardiac biomarkers after contrast enhancement of the myocardium has been evaluated in humans. The measurement of cTn concentrations by use of a high-sensitivity assay may also help to identify cardiac damage secondary to the use of contrast agents in dogs.

The purpose of the study reported here was to evaluate reproducibility of the EF, MP, and PTT in a group of healthy dogs as determined by use of an echocardiographic contrast agent. Safety of this method was evaluated by measurement of cTn concentrations before and after administration of the contrast agent.

**Materials and Methods**

**Animals**—Six privately owned dogs were enrolled in the study. Inclusion criteria were the absence of any congenital or acquired cardiac disease and a body weight < 20 kg. Dogs comprised 3 Jack Russell Terriers, 1 Dachshund, 1 Bichon Frise, and 1 Australian Shepherd Dog. Three dogs were males, and 3 were females. Dogs ranged from 1 to 7.5 years old (mean ± SD, 4.4 ± 2.5 years) and weighed between 6.5 and 19.5 kg (mean, 10.7 ± 5.1 kg). Informed consent was obtained from owners prior to inclusion of their dogs in the study, and the study protocol was approved by the Institutional Animal Care and Use Committee at Kansas State University.

**Study protocol**—The study was conducted at the Veterinary Medical Teaching Hospital at Kansas State University, Manhattan, Kan. All dogs underwent a complete echocardiographic examination performed in accordance with guidelines described elsewhere.

The EF was measured via the area-length method by use of the left parasternal apical 4-chamber view. Two bolus injections of a second-generation contrast agent were injected IV in each dog for the evaluation of EF and PTT. The contrast agent was a suspension of stabilized gaseous microbubbles (perfluorocarbon gas) in saline solution. The solution for IV infusion was prepared by the addition of 5 mL of saline solution to the sealed vial, which was followed by manual agitation for 30 seconds. Each bolus of contrast agent (0.03 mL/kg) was manually infused IV through a 22-gauge catheter placed in a cephalic vein. Each bolus was administered over a 15-second period, and there was a washout period of 4 minutes between injections. Because of the small amount of contrast agent, the catheter was flushed with saline solution after the administration of each bolus.

Finally, contrast agent was infused continuously at each of 2 rates for the qualitative evaluation of global MP and regional quantitative evaluation of MP. Each CRI (0.012 and 0.035 mL/kg/min [the higher infusion rate was the rate recommended by the manufacturer]) was administered via an infusion pump set at an infusion rate of 20 and 60 mL/h, respectively. Duration of each CRI was the time required to complete image acquisition. During each CRI, the infusion pump was gently manually rotated to maintain the microbubbles in suspension.

**Echocardiographic system**—Images were acquired by use of a cardiovascular ultrasonographic system with a matrix array transducer. The contrast-specific application was a low-power real-time technique based on pulse inversion combined with power Doppler ultrasonography at a frame rate of 20 Hz. With this application and contrast agent, the optimal agent-to-tissue ratio can be achieved with an MI as low as 0.04 to 0.05 (MI is defined as the peak negative pressure divided by the square root of the ultrasonographic frequency). In an acoustic field, microbubbles have different responses depending on the MI of the insonating beam. At low ultrasonographic acoustic pressure (MI < 0.1), microbubbles enter a state of linear oscillation. With increasing peak ultrasonographic acoustic pressure (MI > 1.0), the expansion of the microbubbles is greater than the contraction, and this nonlinear oscillation state causes microbubbles to rupture. To optimize visibility of the LV, the focus was positioned close to the mitral valve plane. Depth was set to improve visibility of the LV, and color gain was adjusted to increase the signal-to-noise ratio to a point at which there was the least amount of noise within the tissue and cavity and the myocardium was still visible.
All images were acquired from the left parasternal apical 4-chamber view. When opacification of the myocardial contrast reached a steady state, a flash at high MI (1.0) was delivered to induce synchronous microbubble rupture. This was followed by an immediate automatic return to continuous low MI imaging during the phase of microbubble replenishment. The procedure was repeated twice for each infusion rate. A minimum of 15 cardiac cycles after microbubble rupture were recorded and stored digitally.

All images and cine loops were digitally stored and analyzed offline. Two observers (SC and MB) measured each variable 3 times, and the mean value of these measurements was used for statistical analysis.

PTT assessment—The PTT was estimated as the number of seconds from the first frame in which bubbles started to fill the right atrium to the first frame in which the contrast agent reached the left atrium (Figure 1). The nPTT was calculated by dividing PTT by the mean R-R interval of the measured heartbeats.

MP assessment—Qualitative assessment of global MP was performed as described elsewhere. Briefly, MP was visually estimated as the number of cardiac cycles required for the myocardium to regain complete opacification after microbubble rupture. Cardiac cycles were counted frame by frame, starting from the first systole after the frame of the high MI flash. The LV myocardium was regarded as refilled when it entirely regained signal intensity comparable to the state before the high MI flash, as visually estimated via side-by-side comparisons of the cine loops (Figure 2).

Regional quantitative assessment of MP was obtained by use of the software package embedded in the ultrasonographic unit for quantitative analysis. Quantification of mean signal intensity was obtained within manually placed oval ROIs of equal size (3 × 7 mm). The ROIs were located in 4 myocardial segments (BIVS, MIVS, BLVPW, and MLVPW). Orientation of the mid-LV and midinterventricular ROIs was arbitrarily tilted 8° toward the LV cavity to accommodate for the inward curvature of the midventricular segment. A semiautomatic tracking system was used to maintain the sample volumes on the desired portion of the ventricular wall throughout the cardiac cycle. This system frequently involved small manual frame-by-frame adjustments of the position of the ROI to maintain it in the desired myocardial segment (Figure 3). This system allowed us to avoid inclusion of high-intensity signals from the LV cavity, epicardium, and endocardium.

Myocardial signal intensity was plotted against time and fitted to the following exponential function: \( y = (A\left[1 - e^{-kt}\right]) + B \), where \( y \) is the signal intensity at any time (t) during contrast agent replenishment, \( A \) is the intensity of the contrast agent, \( B \) is the intercept at the origin (which reflects the background intensity), \( e \) is the natural logarithm, and \( k \) is a time constant reflecting mean bubble velocity or myocardial blood flow velocity. Segmental values of \( A \) and \( B \) were derived from the replenishment cycles via careful frame-by-frame analysis. A reduced \( k \) value indicated a reduction in the velocity of perfusion of the myocardium as a result of narrowing or partial occlusion of the arterial bed.

Measurement of cTnI concentrations—Venous blood samples (2.5 mL/sample) were collected into EDTA-containing tubes before and 1 hour after administration of the contrast agent. Plasma was harvested and stored at −80°C until analyzed by use of a high-sensitivity cTnI assay.

Statistical analysis—Statistical analyses were conducted with a commercially available software program. Continuous data were tested for normality by use of a Kolmogorov-Smirnov test with Dallal-Wilkinson-Lillie correction for the P value. Results for normally distributed data (continuous and discrete) were reported as mean ± SD.

A Wilcoxon signed rank test was used to compare results obtained by the 2 observers. A paired Student t test was used to compare the EF obtained with and without contrast agent.

A Friedman test with Dunn multiple comparisons was used to compare results obtained for the 4 ROIs. Bland-Altman analysis was used to graphically display intraobserver and interobserver variability and identify potential systematic biases. To estimate intraobserver variability, the offline analysis of each variable was repeated in random order 30 days later by the same ob-

Figure 1—Echocardiographic images of pulmonary transit of contrast agent in a healthy dog. The left image is the first frame in which microbubbles (orange arrow) can be clearly detected in the right atrium, whereas the right image is the first frame in which it is possible to recognize microbubbles (orange arrow) in the left atrium. Notice the ECG tracing at the bottom of each panel. The scale on the left side of each echocardiogram is in centimeters. HR = Heart rate.
servers, who were unaware of the results for the first analysis. Intraobserver and interobserver variability was quantified as the CV by use of the equation CV = (mean difference between measurements/mean of measurements)/100, as reported elsewhere.19

Results

EF—Delineation of the endocardial border was subjectively easier after administration of the contrast agent (Figure 4). The EF was obtained without use of the contrast agent in 5 of 6 dogs, with interobserver and intraobserver CVs of 3.9% and 2.1%, respectively. The EF was not measurable in the 1 dog because of a poor acoustic window and poor definition of the endocardial border. The EF was obtained in all dogs after both bolus injections of the contrast agent and yielded interobserver and intraobserver CVs of 2.4% and 4.8% for the first bolus and 0.2% and 1.2% for the second bolus, respectively. There

Figure 2—Echocardiographic images of the left parasternal apical 4-chamber view of a healthy dog. The frame for the steady state at end systole (left image) is immediately before microbubble rupture via a flash at high MI (middle image). Notice that the myocardium appears poorly delineated in the middle image. The frame obtained at end systole (right image) reveals that the myocardium appears subjectively comparable to the image obtained before microbubble rupture. Qualitative assessment of global MP is determined as the difference in the number of heartbeats between the left and middle images. See Figure 1 for remainder of key.

Figure 3—Echocardiographic image of the left parasternal apical 4-chamber view of a healthy dog (upper left) and myocardial replenishment curves for regional quantitative assessment of MP (right). The 4 ROIs have been positioned on the LV (top of the echocardiogram), with the ovals representing the BIVS (yellow), MIVS (blue), MLVPW (red), and BLVPW (green). The myocardial replenishment curves for each ROI are indicated on the trace (right), with measurement (in centimeters) on the y-axis and time (in seconds) on the x-axis. See Figure 1 for remainder of key.
were no significant differences in the mean ± SD EF obtained without the contrast agent (66.9 ± 11.2%), after the first bolus of contrast agent (74.0 ± 4.3%), or after the second bolus of contrast agent (74.5 ± 6.4%).

**PTT and nPTT**—The evaluation of PTT was subjectively easy to perform in all dogs. Mean ± SD PTT and nPTT were 1.8 ± 0.2 seconds and 3.4 ± 0.34 seconds, respectively, after the first bolus of contrast agent and 2.1 ± 0.3 seconds and 3.5 ± 0.3 seconds, respectively, after the second bolus of contrast agent.

**MP**—Evaluation of global MP was performed in all dogs. Bland-Altman analysis revealed evidence of a unilateral bias in the interobserver comparison when the low dose of contrast agent was used, with observer 1 consistently providing lower values, compared with the values provided by observer 2 (Figure 5). No bias was observed in the interobserver comparison when the higher dose (ie, recommended CRI) of contrast agent was used or in the intraobserver comparison when either CRI was used. It was feasible to evaluate MP with both CRIs of the contrast agent in all dogs. There were no differences in the measurements between the 2 observers, but the low-dose CRI was characterized by a higher CV (Table 1).

Regional quantitative MP could be obtained in all 6 dogs at the BIVS and MIVS, in 4 dogs at the BLVPW, and in 5 dogs at the MLVPW. The time constant did not differ significantly between the 2 observers, but CV was < 15% only for the BIVS (interobserver CV, 2.5%; intraobserver CV, 7.6%) and BLVPW (interobserver CV, 14.3%; intraobserver CV, 12.6%), although the time constant was obtained for only 5 dogs for the BLVPW. For both midparietal ROIs, the interobserver and intraobserver CVs were high. The interobserver and intraobserver CVs were 44.7% and 35.3% for MIVS and 22.1% and 61.6% for BLVPW, respectively.

**Concentrations of cTnI and overall outcome**—The mean ± SD cTnI concentration before administration of the contrast agent (0.031 ± 0.01 µg/L) did not differ significantly (P = 0.46) from the cTnI concentration after administration of the contrast agent (0.028 ± 0.02 µg/L). None of the dogs developed adverse reactions potentially attributable to the contrast agent immediately or 4 to 5 hours after the experiment.

![Figure 4—Echocardiographic image of the left parasternal apical 4-chamber view of a healthy dog obtained during diastole before (left) and after (right) injection of a bolus of contrast agent. Notice that the image obtained after injection of contrast agent provides easier identification of the myocardial borders. See Figure 1 for remainder of key.](image)

### Table 1—Mean ± SD values for regional quantitative MP determined by use of contrast echocardiography with a contrast agent administered at each of 2 CRIs* to 6 healthy adult dogs.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observer 1 (day 1)</th>
<th>Observer 2 (day 1)</th>
<th>Observer 2 (day 30)</th>
<th>Interobserver CV (%)†</th>
<th>Intraobserver CV (%)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of heartbeats for low-dose CRI</td>
<td>10 ± 1</td>
<td>10 ± 2</td>
<td>11 ± 1</td>
<td>20.8</td>
<td>14.0</td>
</tr>
<tr>
<td>No. of heartbeats for high-dose CRI</td>
<td>9 ± 2</td>
<td>11 ± 1</td>
<td>10 ± 1</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td>k for BIVS (s)</td>
<td>0.71 ± 0.18</td>
<td>0.69 ± 0.16</td>
<td>0.74 ± 0.21</td>
<td>2.5</td>
<td>7.6</td>
</tr>
<tr>
<td>k for MIVS (s)</td>
<td>0.71 ± 0.63</td>
<td>0.70 ± 0.20</td>
<td>0.64 ± 0.34</td>
<td>44.7</td>
<td>35.3</td>
</tr>
<tr>
<td>k for BLVPW (s)</td>
<td>0.46 ± 0.11</td>
<td>0.37 ± 0.08</td>
<td>0.69 ± 0.46</td>
<td>14.3</td>
<td>12.8</td>
</tr>
<tr>
<td>k for MLVPW (s)</td>
<td>0.81 ± 0.175</td>
<td>0.94 ± 0.535</td>
<td>1.06 ± 0.395</td>
<td>22.1</td>
<td>61.6</td>
</tr>
</tbody>
</table>

*The low-dose CRI was administered at 0.012 mL/kg/min, and the high-dose CRI was administered at 0.035 mL/kg/min (which was the infusion rate recommended by the manufacturer); CRIs were infused at a rate of 20 and 60 mL/h, respectively. Duration of each CRI was the time required to complete image acquisition. Interobserver variability was calculated for results obtained by observer 1 and 2 on day 1, whereas intraobserver variability was calculated for results obtained by observer 2 on day 1 and day 30; results for day 30 represent offline analysis of each variable repeated in random order 30 days later. †Represents results for only 4 dogs.§Represents results for only 5 dogs.

k = Time constant reflecting mean bubble velocity or myocardial blood flow velocity.
In the study reported here, we determined that contrast echocardiography was a safe and feasible technique for use in healthy dogs. Administration of a contrast agent made it easier to assess EF via the area-length method and allowed for the qualitative evaluation of global MP. In addition, administration of a contrast agent made it possible to rapidly and noninvasively estimate PTT. Data concerning the regional quantitative assessment of MP have poor reproducibility, which means this technique is not reliable in dogs.

One of the major uses of echocardiography is for the evaluation of systolic function. Accurate and reproducible measurements of LV volumes and EF provide valuable diagnostic and prognostic information in patients with cardiovascular diseases. Unfortunately, it is not always possible to obtain ultrasonographic images of sufficient diagnostic quality. Contrast echocardiography improves quantification of LV volumes and EF in humans. The present study revealed that the estimation of EF via the area-length method was possible in all dogs with the use of a contrast agent, but was accomplished in only 3 of 6 dogs without use of a contrast agent because it was not possible in 1 dog to entirely examine the endocardial border without contrast agent as a result of a small acoustic window. Ejection fraction determined with and without the contrast agent did not differ significantly. However, the calculation of EF was subjectively easier and could be performed more rapidly with the contrast agent. Lack of significant differences may have been attributable to the number of dogs used in the study. This may suggest that the use of a contrast agent could help investigators obtain more reliable and repeatable results, especially in dogs with a poor acoustic window.

Analysis of results of the present study suggested that PTT and nPTT may be obtained by use of contrast echocardiography, which is cheap, easy to perform, and noninvasive. The PTT is a measure of cardiovascular function, which may be altered by changes in cardiac output or pulmonary blood volume. In 2 studies in humans, investigators found that PTT can also be altered by acute expansion of the plasma volume and the number of WBCs in endurance athletes performing exercise. Investigators in 1 study found that PTT and nPTT were increased in dogs with preclinical chronic degenerative mitral valve disease. Further studies are needed to clarify whether PTT can add prognostic value in dogs with chronic degenerative mitral valve disease.
A subsequent study by that same group revealed that the increase in nPTT in the dogs with regurgitation through the mitral valve was primarily caused by an increase in pulmonary blood volume rather than by a decrease in LV forward stroke volume. The fact that the data obtained by the nPTT in the study reported here are similar to those obtained in clinically normal dogs by use of scintigraphy suggests that the data for the present study are valid. However, the values for the present study are not identical to those obtained by use of scintigraphy in clinically normal dogs, which is likely attributable to the differences in techniques used in the 2 studies. In particular, in the study on clinically normal dogs, PTT was calculated from the time of first appearance of the radioactive agent in the pulmonary trunk to the time of first appearance of the radioactive agent in the left atrium, whereas we estimated PTT from the first frame in which the bubbles were convincingly visible in the right atrium to the first appearance of bubbles in the left atrium. However, use of our approach means that transit from the right atrium through the right ventricle is included in the overall transit time and that the PTT and nPTT are slightly higher than those reported in the other study. We opted for use of this method because, with echocardiography, it is not practical to simultaneously view the pulmonary artery and a sufficient area of the left atrium. Use of this method implies that there are no shunts as well as no dysplasia of the tricuspid valve, both of which would invalidate the results.

In the present study, the regional quantitative assessment of MP was feasible for the basal LV ROIs only, with a high CV for the midventricular ROIs. Similar to data reported in humans, detection of the contrast agent was better in regions with good precontrast image quality of the myocardium. In some of the dogs in the present study, the image quality did not allow acquisition of an adequate number of cine loops for MP quantification. In particular, visibility of the apical portion of the left posterior wall was suboptimal in most dogs. We chose to tilt the midventricular ROIs 8° toward the center of the LV to allow the relatively long oval-shaped ROI to stay within the midventricular myocardium despite the natural curvature of the LV. This arbitrary and fixed-angle correction was used for consistency, and we recognize that it may not be optimal for dogs with different cardiac conformations. The quantitative MP assessment requires specific software, and despite the short acquisition time, the offline analysis was quite time-consuming. The high values for interobserver and intraobserver variability are similar to values reported for clinically normal humans. Such variability complicates interpretation of the replenishment curves. In addition, measurement of refilling with the contrast agent is also strongly influenced by the subjective selection of frames from a chosen cardiac cycle. To reduce this factor, we decided to start the analysis at the first frame after the T wave following bubble rupture. Nevertheless, even in controlled experimental procedures, the interobserver and intraobserver variability for regional evaluation of MP was high. This finding suggested that there may be severe limitations for the clinical applicability of this technique for the evaluation of MP.

Global MP evaluation was a feasible and reproducible technique in our laboratory. Intraobserver and interobserver variability was low for the recommended dose. This technique could be easily and quickly performed in the present study; moreover, it did not require any specific software, which makes it possible to use this technique with any echocardiographic platform.

One of the major uses of echocardiographic contrast agents in human cardiology is for the assessment of MP in patients with chronic or acute coronary artery disease, and they represent an important indicator of cardiovascular morbidity and fatal conditions. Coronary artery disease is not an issue in veterinary medicine; however, intramural small-vessel disease has been described in animals with various diseases such as myxomatous mitral valve disease, subaortic stenosis, and hypertrophic cardiomyopathy. Moreover, small-vessel disease in humans has been associated with sudden death, and the same association has been hypothesized in dogs. However, to the best of our knowledge, the MP evaluation has not been used in any species to evaluate microischemia attributable to small-vessel disease, and additional studies are needed to assess the use of this technique in the detection of subclinical myocardial ischemia in dogs.

Finally, no increase in cTnI concentration, as determined via analysis with a high-sensitivity assay, was detected 1 hour after injection of the contrast agent, compared with the cTnI concentration measured before injection of the contrast agent. This suggested that the technique used in the present study did not induce appreciable myocardial damage in healthy adult dogs. In humans, a second-generation contrast agent such as the one used in the present study is still considered contraindicated in patients with unstable cardiac symptoms or patients with recent (<7 days) coronary interventions.

The present study cannot rule out possible adverse effects of contrast echocardiography in dogs with cardiac disease or the possibility that there was late-onset (1 hour) myocardial damage in our study population. However, in humans, elevation of cTnI concentrations is evident by 15 minutes after injection of the contrast agent. The lack of any overt adverse reaction during the 4 to 5 hours after the experiment also indicated that the contrast agent was safe in our population of dogs.

In the study reported here, we determined that a second-generation contrast agent can be used safely in healthy dogs. Its use improves delineation of the endocardial border, which means EF evaluation can be performed more easily and more rapidly. It also allows the noninvasive estimation of PTT and nPTT. Qualitative assessment of global MP is feasible in dogs and has good reproducibility, but quantitative regional assessment of MP is reproducible only for the basal portions of the LV.

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a. BR38, provided by Bracco Research SA, Geneva, Switzerland.
b. MEDFUSION 2001, Medex Inc, Duluth, Ga.
c. Vivid 7 dimension cardiovascular ultrasound system BT 2006, GE Healthcare, Milwaukee, Wis.
d. M4S matrix array transducer, GE Healthcare, Milwaukee, Wis.
e. Access AccuTnI, Beckman Coulter Inc, Fullerton, Calif.
f. GraphPad Prism, version 5.00 for Windows, GraphPad Software Inc, San Diego, Calif.
References