Echocardiography in the Bovine Animal

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Summary

Echocardiograms were obtained from 15 standing clinically normal cows using an ultrasonic recording device. The echo beam penetrated the right thoracic wall in the area of the fourth intercostal space with a frequency of 2.25 MH_3. Left ventricular wall thickness measured 2.00 ± .19 cm while the septal dimension was slightly higher at 2.24 ± .26 cm. Velocity of circumferential fiber shortening (Vcf), an index of contractility, was .87 ± .4 m/s and minor axis shortening fraction (%ΔD), an indicator of pump function, was 43.5 ± 5.8%.

Introduction

Echocardiography is a noninvasive, diagnostic procedure that utilizes reflections of ultrasound to visualize motion of the cardiac chambers and valves. Echocardiography is generally performed simultaneously with electrocardiography or phonocardiography, or both, and has the advantage of displaying alterations in function as well as lending itself to hemodynamic calculations without the requirement of costly and hazardous catheterization procedures.

The origin of ultrasound can be traced to the early 1800's, when Galton developed the ultrasonic whistle, but it wasn't until the 1950's that ultrasonic diagnostic capabilities in various organ systems were explored (2,3).

In the last twenty years, physicians have become increasingly aware of the benefits and usefulness of ultrasonics and have incorporated it in their routine diagnostic procedures. The echocardiographic pattern of mitral stenosis was the first valvular abnormality to be identified (10). Since then, pericardial effusion, valvular disorders, aberrant wall movements, congenital abnormalities, and prosthetic valve motion have been added to what is now a long list of lesions identified by echocardiography (5,9,11).

Cardiovascular examination in the bovine is generally limited to auscultation and electrocardiography. It has been our experience that pericardial lesions and vegetative endocarditis constitute the major portion of acquired lesions in the bovine. These conditions cannot be definitively diagnosed by the aforementioned techniques, whereas they lend themselves quite readily to detection by ultrasonic means. In addition to "visualizing" the lesions, echocardiographic techniques also provide accurate and reliable measurements of cardiac performance. This technique, then, enables the veterinarian to evaluate any compromise in cardiac performance, prognosticate and provides an opportunity to evaluate therapeutic measures instituted.

Basic Principles

Sound is the phenomenon of rarefaction and condensation of the particles of a medium which is transmitted at a frequency dependent on the nature and characteristics of that medium. If the frequency of a sound wave exceeds 20,000 Hz, it is defined as an ultrasonic wave, which obeys the principles of absorption, refraction, and reflection. Diagnostic ultrasonography is a process whereby a well-defined sound wave is beamed through soft tissue structures and a percentage of that wave is reflected each time the beam encounters differing biologic tissue. The reflected waves are then received and processed in a fashion suitable for interpretation.

At the hub of the ultrasonascope is a piezoelectric crystal, which when subjected to alternating current at high frequency will deform (thicken and thin) repetitiously and produce sound waves at a specific ultrasonic frequency. The piezoelectric crystal is also capable of generating a voltage upon being mechanically deformed by the reflected sound wave. Thus, the hand-held transducer (Figure 1) acts as both a transmitter (1%) and a receiver (99%). The reflected signal is then electronically processed and displayed in one of three modes (Figure 2) for interpretation and evaluation of the cardiovascular status. By assuming the velocity of sound transmission through soft tissue to be a constant (1,540 meters per second), and by transmitting 1,000 sound pulses per second, the ultrasonic recorder generates an almost

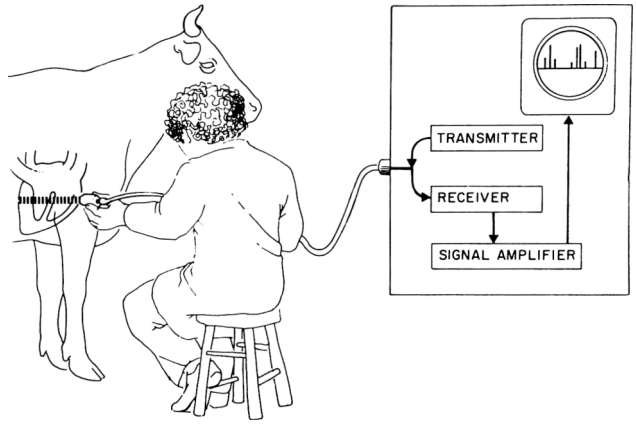

Figure 1. Line drawing of electrocardiographic examination in the bovine and schematic drawing of simplified circuitry.

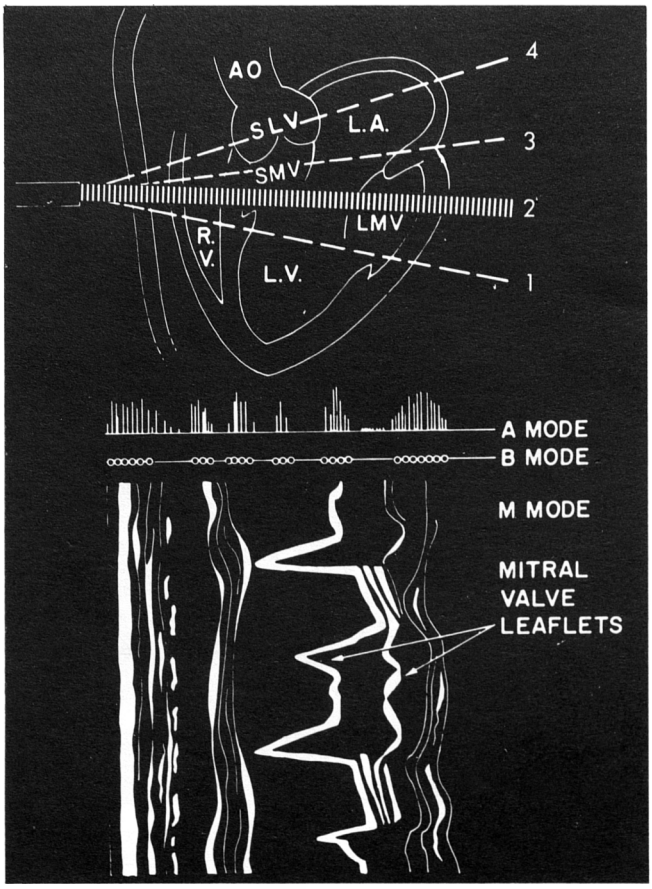

Figure 2. Diagrammatic illustration (above) of transducer positions during an echocardiographic scan. The amount of reflection (below) can be displayed as amplitude versus tissue depth (A mode), or as intensity versus tissue depth (B mode). The beam is portrayed as beaming through the heart at the level of the mitral valves, capturing both septal (SMV) and lateral (LMV) leaflets. Ao = aorta; SLV = semilunar valves.

continuous plot of distance between the transducer and the reflecting surfaces as these surfaces move over time. The A mode (Figure 2) is a presentation of echos in which distance from the transducer is displayed along one axis and amplitude (proportional to strength of signals) displayed along the other. The B mode presentation (Figure 2) converts echo spike to a dot of light, with the intensity of this dot proportional to the strength of the signal. When the film or paper is moved past this type of representation, the moving dots trace out their patterns of motion over time. This mode of display is referred to as the M mode (Figure 2).

Materials and Methods

Echocardiograms were recorded from 15 clinically normal (approximately 300 kg) cows of varying breeds. Examination was facilitated by extending the right forelimb forward or getting the cow to adduct the elbow. An ultrasonic recorder (Ekoline 20, Smith-Kline Instruments, Inc., P.O. Box 1947, Sunnyvale, Calif. 94088) and a 19 mm unfocused transducer emitting frequencies of 2.25 mHz at a repetition rate of 1 kHz was used. Clear, well-defined echocardiograms were obtained with the echo beam penetrating the right thoracic wall in the vicinity of the fifth intercostal space, approximately 25 cm from the right sternal border. A camera was placed over the cathode ray tube of the ultrasonic recorder, thus permitting photographic recording of signals.

The examination was begun by placing the transducer, covered with copious quantities of sonic coupling gel (Aquasonic 100 Transmission Gel, Parks Labs, Irvington, NJ 07111) at the right thoracic window (Figure 1). With the recorder in the A mode, the transducer was slowly moved caudad and ventrad until the "whipping" motion of the mitral valve was observed between the septum and left ventricular wall. The mode was then changed to the M mode position, at which time permanent recordings were made. Scanning was from the apices of the ventricles dorsad to the basilar positions of the interventricular septum, atrioventricular valves, and finally to atria and aortic root (Figure 2).

When satisfactory echos were clearly visible on the scope, the camera was activated and the next few cardiac cycles were recorded. The photographs were calibrated with dots, which were superimposed on the scope and were 1 cm apart vertically and the equivalent of 1 sec horizontally. Measurements of chamber diameters, aortic root dimensions, and mitral slopes were calculated, using the techniques developed for man (Figure 3) (5,6,8,10).

Although we observed that the echocardiograms derived from the bovine closely resembled those from man, the identity of each chamber was validated by means of a procedure utilizing injection of indocyanine green laden with microbubbles (7). The microbubbles generated by rapid injection produced "clouds" of echos when injected into the chamber (Figures 7 & 8).

In order to acquire measurements of ventricular function, one assumes the left ventricle to possess the geometric shape of a prolate ellipse (1). To obtain the left ventricular minor axis, one first scans the heart until the characteristic mitral valve echo is encountered. The ultrasonic beam is then directed ventrad to the mitral valve and dorsad to the papillary muscles, where the motion of the left ventricular wall

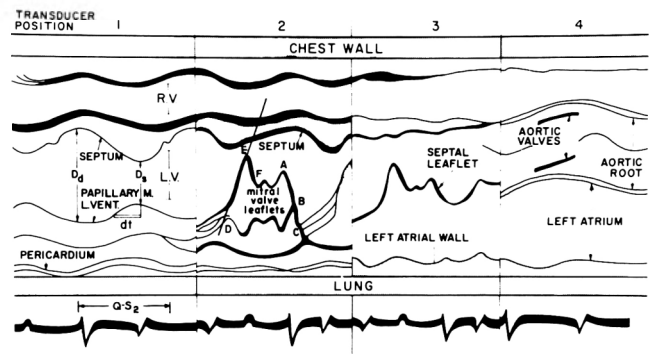

Figure 3. Schematic representation of returning echos from the transducer positions 1-4 shown in Figure 2. An ECG tracing is generally included for reference to time.

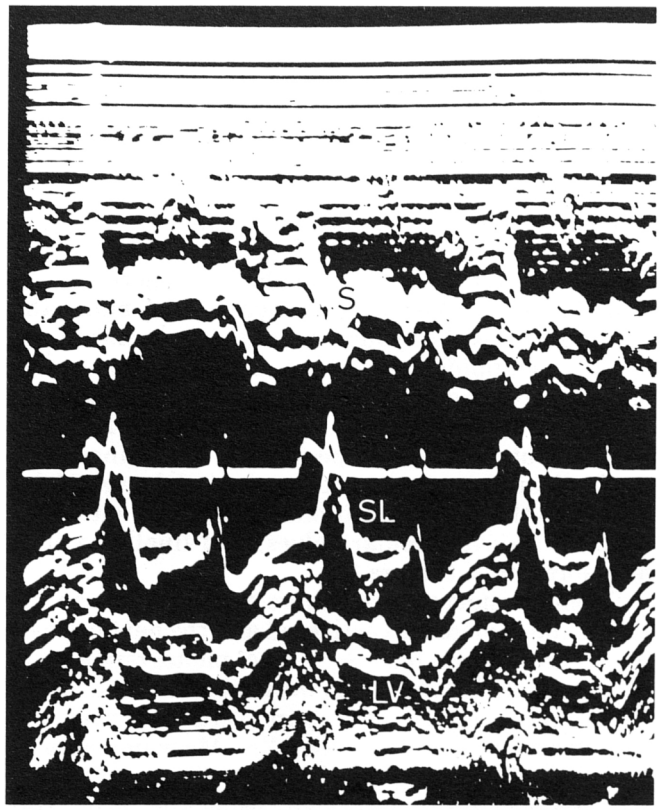

Figure 4. Recording of mitral valve leaflet action with ECG superimposed for timing. Leaflets open in early diastole during period of rapid filling and again after the P wave, during "atrial kick." The septical leaflets have characteristic M shape whereas lateral leaflets resemble W shape. S = septum; LV = left ventricle; SL = septal leaflet.

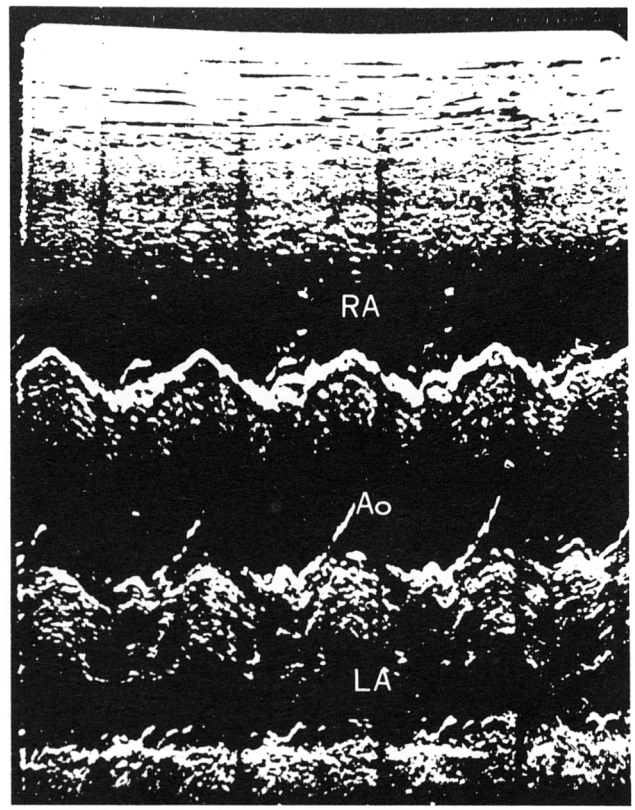

Figure 5. Actual recording of aortic root in which valves are visible. Notice opening of the valves in systole (QT interval) and single line closure pattern in diastole. LA = left atrium; RA = right atrium; Ao = aorta.

Table 1

Cow #	RV	LV_S	LV_D	LV_T	$Sept_T$	LA	Ao	MV (DE)	MV (EF)	$Q\text{-}S_2$	LVET	PEP	%ΔD	V_{cF}	LVOT	Amp Mit	HR
1	2.5	5.2	8.2	1.8	2.0	5.0	5.2	39.4	9.6	.53	.47	.06	37.0	.78	6.0	6.6	54.0
2	3.5	3.0	5.5	2.5	2.3	3.7	6.5	70.6	7.6	.78	.67	.11	45.0	.67	7.2	7.0	48.0
3	4.8	4.5	8.2	2.0	2.8	5.8	6.0	51.4	12.3	.56	.50	.06	45.0	.90	7.0	7.0	42.0
4	2.8	4.2	6.8	2.0	2.5	4.2	5.8	41.4	8.4	.50	.42	.08	38.0	.91	7.0	6.5	54.0
5	3.2	5.0	8.5	2.0	2.2	5.0	6.5	64.3	17.0	.50	.44	.06	41.0	.94	8.0	8.0	48.0
6	2.8	5.5	8.7	2.3	2.5	5.3	6.8	32.7	11.5	.67	.50	.17	37.0	.74	7.1	7.0	30.0
7	2.5	4.2	8.0	1.8	2.2	5.3	6.3	34.0	11.2	.50	.39	.11	48.0	1.20	6.7	7.2	54.0
8	2.9	3.4	7.3	2.0	2.6	4.1	5.8	34.7	13.2	.70	.59	.11	43.4	.90	7.0	7.0	48.0
9	2.8	3.7	6.9	1.9	2.0	4.6	6.0	44.3	10.1	.55	.47	.08	46.4	.99	6.9	6.6	46.0
10	2.7	4.4	7.4	2.0	2.1	4.5	5.8	51.2	12.4	.59	.50	.09	40.5	.81	6.7	7.1	50.0
11	3.1	4.6	7.7	2.1	2.2	4.9	5.7	41.6	13.4	.61	.51	.10	40.3	.79	7.2	7.2	48.0
12	2.9	3.8	7.6	1.8	2.0	5.1	6.1	47.0	9.6	.62	.54	.08	50.0	.93	7.0	6.9	52.0
13	3.0	3.6	7.4	1.9	2.0	4.2	5.6	39.9	8.8	.59	.53	.06	51.4	.97	7.2	7.0	46.0
14	2.8	4.4	7.9	1.9	1.9	4.9	5.9	45.5	9.0	.57	.50	.07	44.3	.89	7.0	8.0	48.0
15	3.3	4.6	7.0	2.1	2.4	5.4	6.0	46.2	12.4	.64	.54	.10	34.3	.63	6.8	7.0	49.0
$\bar{x}$	3.04	3.973	7.54	2.00	2.24	4.8	6.0	45.6	11.1	.594	4.08	.551	43.5	.87	6.9	7.07	47.8
S.D.	.56	1.163	.802	.190	.255	.573	0.40	10.5	2.45	.079	13.8	1.784	5.8	.14	.41	.43	5.9

RV = Right ventricle
LV_S = Left ventricular systolic dimension
LV_D = Left ventricular diastolic dimension
LV_T = Left ventricular thickness
$Sept_T$ = Septal thickness
LA = Left atrial dimension
Ao = Aortic root
MV_{DE} = Mitral valve slope opening
MV_{EF} = Mitral valve slope closing
$Q\text{-}S_2$ = Electromechanical systole
LVET = Left ventricular ejection time
PEP = Pre-ejection period
%ΔD = Shortening fraction
V_{cF} = Velocity of circumference
LVOT = Left ventricular outflow tract dimension
Amp Mit = Amplitude of mitral valve opening
HR = Heart rate

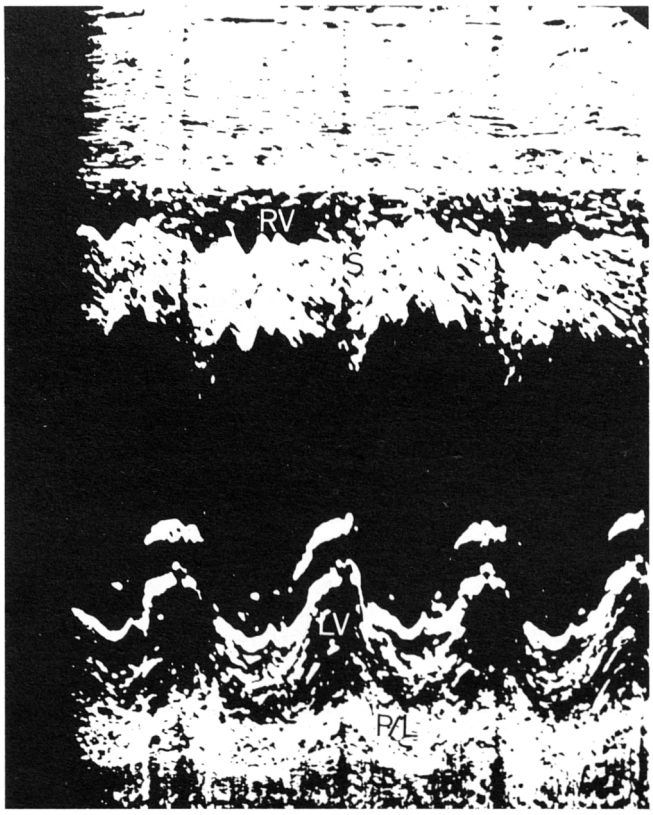

Figure 6. Echocardiogram of ventricular cavities showing systolic contractions. Thick white line (P/L) denotes pericardial-lung interface. RV = right ventricle; S = septum; LV = left ventricle.

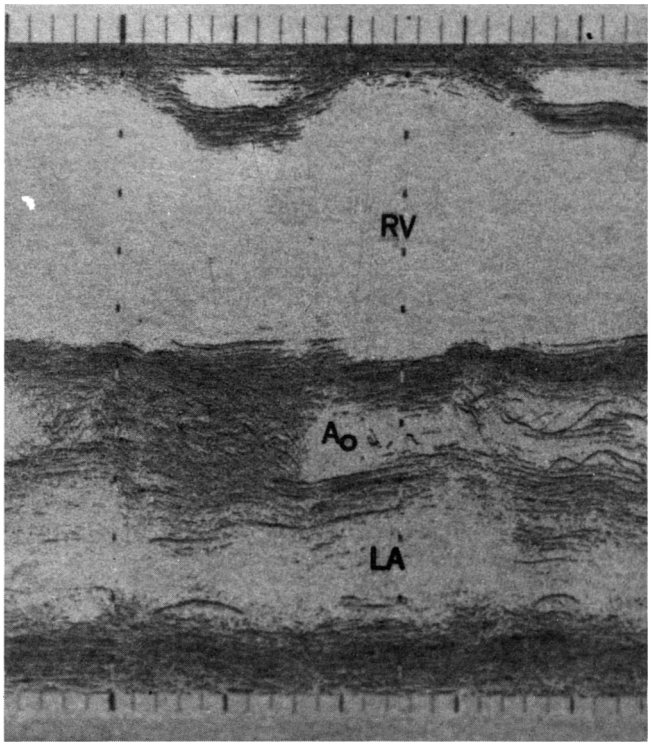

Figure 7. With a catheter in the aorta, microbubbles are injected into the aortic root (Ao) and appear as dark areas clouding the root. RV = right ventricle seen on top of aorta. LA = left atrium, pictured below.

and interventricular septum is observed.

The minor axis end diastolic dimension (Dd) was measured at the time the Q wave on the electrocardiogram was recorded; end systolic dimension (Ds) was measured at the point where the septum and ventricular wall achieved greatest proximity (Figure 3).

Systolic time intervals can generally be acquired with the transducer in position 4 (Figure 2). The aortic root and one or two semilunar cusps are visible along with a superimposed electrocardiogram. The cusps can be seen to open in systole and occupy a mid root position in diastole (Figure 5). Since S_2 and the closing of the aortic valve are coincident, measurements of Q-S_2 and LVET are made directly while PEP-([Q-S_2]-[LVET]).

Results

Typical echocardiograms acquired from fifteen clinically normal cows are shown in Figures 4, 5 and 6 and correspond to transducer positions 1, 2 and 4, respectively, in Figure 2. Seventeen measurements of structure size and motion were made and are summarized in Table 1.

Velocity of circumferential fiber shortening (Vcf) was slightly lower, at the value of .87 m/s, than was reported (9) in another species of animal of comparable size which generated values for this parameter around 1.3 m/s. The only other noteworthy parametric deviation was in minor axis shortening fraction which was 43% ± 1.2, a value slightly higher than observed in other species (9). Occasionally, especially in older cattle, a thickened aortic root would be noted which, during the postmortem comparisons, was determined to be the os cordis.

Discussion

Ultrasonic examination of the bovine heart has been demonstrated to be an informative, innocuous and inexpensive adjunct to the diagnosis of cardiovascular disease. Having established a small data base of parameters which describe size and function

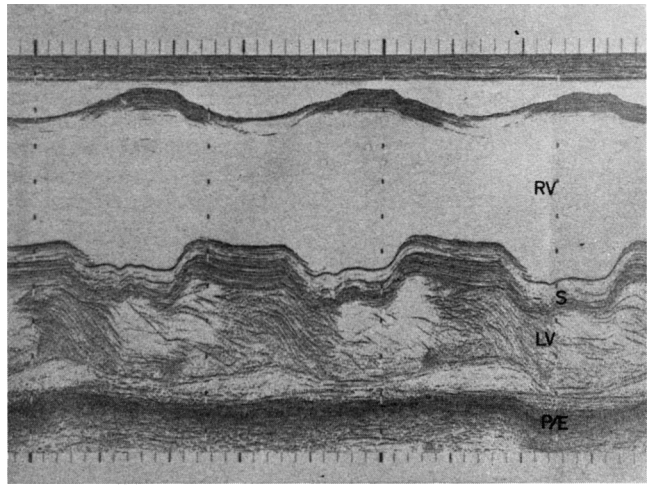

Figure 8. Microbubbles seen as dark areas in LV = left ventricle. S = interventricular septum and RV = right ventricle. PE = pericardial epicardial interface.

in clinically normal bovine, we are now in a position to provide a comparison against which diseased animals can be judged. In addition to identifying the lesion present, a concomitant assessment of cardiac function can be acquired. As mentioned earlier, the bulk of acquired disease falls in the two categories of pericardial and endocarditis lesions. Echocardiographic detection of these types of lesions is particularly reliable in man (4) and as indicated by our own preliminary studies, is also reliable for the bovine. In addition to acquired disease echocardiography is valuable in the assessment of congenital lesion in both man (7) and dog (4) and suggests yet another field of application. A four-month-old Guernsey calf suspected of having a ventricular septal defect on the basis of auscultation and radiographic findings had a catheter placed in the left ventricle. A 5 ml bolus of indocyanine green was injected and seen to illuminate the left ventricle but no targets were seen on the right side of the septum (Figure 8). It was concluded that the calf did not have any ventricular shunting, a conclusion that was verified on postmortem inspection.

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