Two-Dimensional Echocardiographic Diagnosis of Bovine Congenital Heart Disease: Echocardiographic and Anatomic Correlations

Mitsuyoshi HAGIO, Takayuki MURAKAMI¹⁾, and Hiromitsu OTSUKA

Department of Veterinary Surgery and ¹⁾Department of Veterinary Anatomy, Faculty of Agriculture, Miyazaki University, 7710 Kumano, Miyazaki 889-21, Japan

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ABSTRACT. In order to investigate the usefulness and accuracy of two-dimensional echocardiography (2-D echo) for the diagnosis of bovine congenital heart disease, a series of 40 cases, mostly calves, with various types of cardiac malformations were studied prospectively. All but one case was confirmed postmortem. The patients were divided into 2 groups according to the 2-D echo methods used and the results for both groups were compared. The group studied initially (25 cases) using a linear scanner showed a substantially lower degree of diagnostic accuracy than the group studied subsequently (15 cases) using our new systematic 2-D echo approach with a sector scanner. With the latter approach, complex forms of cardiac defect such as transposition of the great arteries and double-outlet right ventricle were correctly diagnosed. However, difficulty was encountered in the definitive diagnosis of such extracardiac defects as patent ductus arteriosus and total anomalous pulmonary venous connection, in which the additional use of contrast or pulsed Doppler echocardiography was a great aid to confirmation. The 2-D echo technique is non-invasive and easily applicable. Therefore, it appears to be a very promising clinical procedure for the diagnosis of bovine congenital heart disease.—**KEY WORDS:** bovine, congenital heart disease, two-dimensional echocardiography.

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Nearly the same wide variety and complexity of congenital heart defects as those occurring in man have been found in cattle [12, 31], especially newborn calves. A correct diagnosis of bovine congenital heart disease is valuable when making decisions with regard to an animal's future productivity and performance or suitable therapy. Also, cows with known congenital heart defects can be utilized as a research model, or even for the education of students. In the past, many diagnostic techniques have been applied to cardiac diagnoses in large animals. These include: electrocardiography, phonocardiography, dye indicator dilution [6] or thermodilution technique [23], cardiac catheterization and angiocardiology [1, 5], M-mode [20, 21, 33] and two-dimensional (2-D) [11, 22, 34] echocardiography (echo), and M-mode [3, 19, 24, 26] and 2-D [10, 25] contrast echo. Among

these, catheterization and angiocardiology, especially selective angiocardiology, is a valuable method for definitive diagnosis of congenital cardiac defects, but the technique is invasive and usually requires multiple injections of contrast medium until a firm diagnosis is made, which is harmful in seriously ill animals. In addition, technically related limitations to angiocardiology are known to exist in the case of adult animals, due mainly to the large body size [5]. By contrast, 2-D echo is a non-invasive, complication-free procedure, easy to perform for serial examinations, and reliable with regard to the accurate description of cardiac anatomy. Thus, in human cardiology, it has become the most widely used non-invasive method for evaluation of patients with congenital heart disease and can even replace cardiac catheterization and angiocardiology as the procedure of choice prior

to surgery in selected human neonates with this type of disease [9, 27]. In cattle, several case reports have been described so far involving its application in the diagnosis of congenital cardiac anomalies [10, 11, 22, 25]. However, there have been few studies using a large series on the accuracy of this technique for diagnosing each of the various types of cardiac defect.

The purpose of the present study was to compare the findings of 2-D echo with those of autopsy (39 cases) or angiocardiology (1 case) in 40 bovine cases of various types of congenital heart disease, and also to evaluate the usefulness of our newly developed, systematic 2-D echo approach in cattle.

MATERIALS AND METHODS

Between May 1982 and December 1986, 40 consecutive cases of congenital heart disease were examined by 2-D echo, including contrast and pulsed Doppler echo in some cases, at our university hospital, by a single investigator (M. H.). Animals which had undergone incomplete echo examination due to death before or during the examination, were excluded from this study. The animals were aged between 1 day and 4 years, but they were mostly calves (Table 1). In each case, 2-D echo examination was completed before cardiac catheterization and angiocardiology and a prospective 2-D echo diagnosis was made.

Echo examination was performed either without sedation or with the use of light xylazine sedation. Calves were examined in right or left recumbency, while heifers and adult cattle were examined in a standing position. The animals were divided into two groups: 1) Group 1 consisted of 25 cases (Cases 1 to 25). 2-D echo examination was performed with a 3.5- or 5.0-MHz electronic linear array scanner (Hitachi Medico EUB-25M) and sometimes (Cases 15 and 21) with

a 3.0-MHz mechanical sector scanner (Aloka SSD-720). Multiple images were obtained using a right or left intercostal scan and, whenever possible, a subcostal scan. 2) Group 2 was composed of 15 cases (Cases 26 to 40). A 3.5-MHz mechanical sector or a 5-MHz electronic convex array scanner with pulsed Doppler capability (Hitachi Medico EUB-40) was used. In this group, our new systematic 2-D echo diagnostic approach for cattle, especially calves, was employed. The approach and tomographic sections, which have been previously reported in detail [14], are briefly described as follows. The viscerocardiac situs was determined by liver position using the subcostal scan and the posterior vena cava drainage into the right atrium (RA) using the left intercostal scan. Ventricular identification was determined by several anatomical features of each ventricle. For example, the morphologic left ventricle (LV) was recognized by its two discrete papillary muscles and the characteristic fish-mouth appearance of the mitral valve in diastole in a series of right intercostal short-axis views. The morphologic right ventricle (RV) was identified by the presence of the moderator band, the apical attachment of the ventricular valve leaflet to the interventricular septum (IVS), and the insertion of the chordae tendineae into the IVS when viewed from the right intercostal location. The identity of each great artery was determined on the basis of its morphologic features together with the spatial relationships of both great arteries by piling up a series of left intercostal short-axis views from the level of the atrio-ventricular valves through to the level of the bifurcation of the pulmonary artery (PA) (Figs. 1A, 2A). The atrio-ventricular connection was best evaluated by the left intercostal apical 4-chamber or right intercostal long-axis 4-chamber view. The ventriculo-arterial connection was best evaluated by the long-axis view of the left or right ventricular outflow tract

obtained from the right intercostal or subcostal location. Finally, the associated anomalies were checked carefully to ensure that nothing had been overlooked. The examination time required for this approach was usually less than 30 minutes.

The techniques of contrast and pulsed Doppler echocardiography have been described in other reports [3, 15, 19].

All the echocardiograms were recorded on 3/4-inch videotape using a videocassette recorder (Sony VO-5800) at a frame speed of 30/s for later evaluation.

Thirty-nine cases were confirmed at necropsy, and the disease in one animal (Case 36), which is still alive, was confirmed angiographically. Echocardiographic diagnoses were then compared with those obtained postmortem.

RESULTS

In our present series, all cases had atrial situs solitus. There was only one case (Case 14) of abnormal atrio-ventricular connection, in which the RA was connected to the morphologic LV of the main chamber and a rudimentary outlet chamber also existed. There were several types of abnormal ventriculo-arterial connection, such as discordant, double-outlet and single-outlet. The correlation between the 2-D echo and autopsy diagnoses is shown in Table 1. The cases in each group are arranged in the order in which they underwent 2-D echo examination.

Group 1: Of 25 cases, 15 (Cases 1, 4, 5, 6, 8, 9, 10, 11, 12, 13, 18, 19, 21, 22, and 24) were completely or almost completely diagnosed by 2-D echo. Aortic regurgitations in 3 cases (Cases 8, 21, and 24) were diagnosed by direct imaging of the valvular abnormalities, plus supporting findings of this disease such as volume-overloaded LV and diastolic fluttering of the anterior mitral valve on the M-mode echocardiogram (Case

8 only), followed by contrast echo for confirmation. Two calves (Cases 10 and 12) with aortic atresia were correctly diagnosed, and in Case 10, a site of rupture of the dilated sinus of Valsalva into the right ventricular outflow tract was demonstrated by 2-D echo. Of 3 cases of transposition of the great arteries (TGA) in this group, the first case (Case 9) was predicted by 2-D echo, on the basis of the fact that the postulated aorta (Ao) bearing the coronary artery originated from the postulated RV, while the postulated PA originated from the postulated LV, and that the courses of these two great arteries from their respective ventricle were demonstrated to be parallel in a right intercostal long-axis view. At necropsy, the transposed Ao was positioned cranial to the PA, in comparison with normal great-artery relationships, i. e., the Ao being caudal and to the right of the main PA, while the main PA was located more caudad than the normally positioned PA. The second case (Case 13) had similar 2-D echo findings to those in Case 9, being diagnosed as TGA. The third case (Case 25) of TGA with intact IVS was mistaken for ventricular septal defect (VSD) with overriding single great artery, but retrospectively, the source of the diagnostic error was obvious.

Six cases (Cases 2, 3, 7, 15, 16, and 23) were incompletely diagnosed by 2-D echo. In Case 2 of tetralogy of Fallot (TOF), a correct diagnosis of VSD with overriding Ao was made by 2-D echo; however, a mild right ventricular infundibular stenosis was missed. In Case 3, in which the main PA was not demonstrated by 2-D echo, both the pulmonary valve and PA were atretic at necropsy. A retrospective study of this case from the videotape recordings demonstrated a small right ventricular outflow tract which ended blindly. In the same case, a trivial patent foramen ovale (PFO) and a patent ductus arteriosus (PDA) were mis-

Table 1. Correlation between 2-D echocardiographic and postmortem diagnoses

Case	Breed	Age	Sex	2-D echo diagnosis	Postmortem diagnosis
Group 1 (25 cases)					
1	J	5d	F	VSD	Same
2	H	2d	F	VSD, overriding Ao	TOF
3	J	8m	F	VSD, overriding single great artery	TOF, pulmonary atresia, PDA, PFO
4	J	6d	F	VSD, overriding Ao	Same
5	J	11d	M	Dilated ascending Ao	Same
6	J	8d	F	Cardiomyopathy	Same
7	H	12m	F	VSD, overriding Ao	DORV, VSD
8	H	5m	F	AR due to AV anomaly (cont. echo)	Same, AV with one dysplastic valve leaflet
9	H	7d	F	(?) TGA, VSD	Same, TGA, VSD
10	H	3d	M	Aortic atresia, (?) rupture of SV into RV	Same, rupture of SV into RV
11	J	1d	M	DOLV, VSD	Same
12	H	6d	F	Aortic atresia, hypoplastic LV & MV	Same
13	M	3d	M	TGA, VSD	Same
14	J	51d	M	Mitral atresia with other anomalies	UVH with rudimentary RV, VSD, mitral atresia
15	J	6m	M	DORV, VSD	Same, PS, PLCVC, juxtaposed atrial appendages
16	H	4m	M	VSD	VSD, CoA, overriding PA
17	J	3d	M	Abnormal spaces behind LA	TAPVC
18	J	3d	F	VSD	Same
19	H	1d	F	VSD	Same, parachute TV
20	J	1d	F	Normal heart except dilated RA	Persistent fetal circulation
21	H	4y	F	AR due to (?) quadricuspid AV (cont. echo)	Same, quadricuspid AV
22	H	5d	M	VSD, overriding Ao	Same
23	H	6d	F	DORV, VSD	Same, CoA, PLCVC
24	H	8d	M	AR due to AV anomaly (cont. echo)	Same, bicuspid AV
25	H	3d	F	VSD, overriding single great artery	TGA
Group 2 (15 cases)					
26	H	1d	F	TGA, VSD	Same
27	J	3d	M	Normal heart, TR, PR (PD echo)	Same, TV anomaly
28	H	5d	M	DORV, VSD, AP window	Same
29	H	4d	F	DORV, AVD, common atrium, VSD	Same
30	H	1d	M	PLCVC (cont. echo)	Same
31	H	7m	M	TOF, PDA (cont. echo & PD echo)	Same, PFO
32	H	3d	M	VSD, overriding Ao, (?) CoA, PDA (PD echo)	Same, CoA
33	J	11m	F	TGA, VSD, PS	Same
34	J	33d	F	DORV, VSD, PFO	Same
35	H	4d	F	(?) TAPVC (cont. echo)	TAPVC
36	J	10d	M	Truncus arteriosus, VSD	Alive
37	J	12d	M	PDA (cont. echo & PD echo)	Same
38	J	42d	M	Mild IS, PA dilatation	Same
39	J	1d	F	Normal heart	PLCVC
40	H	2d	F	CoA, VSD, large PFO	Same, ASD, RCA from PA

Abbreviations: Ao=aorta; AP=aortopulmonary; AR=aortic regurgitation; ASD=atrial septal defect (secundum); AV=aortic valve; AVD=atrioventricular septal defect; CoA=coarctation of the aorta; cont. echo=confirmed by contrast echo; CS=coronary sinus; d=day; DORV=double-outlet right ventricle; F=female; H=Holstein-Friesian; IS=infundibular stenosis; J=Japanese Black; LA=left atrium; LV=left ventricle; m=month; M=mixed breed; MV=mitral valve; PA=pulmonary artery; PDA=patent ductus arteriosus; PD echo=confirmed by pulsed Doppler echo; PFO=patent foramen ovale; PLCVC=persistent left cranial vena cava (bilateral cranial vena cavae); PR=pulmonary regurgitation; PS=pulmonary stenosis; RA=right atrium; RCA=right coronary artery; RV=right ventricle; Same=same as echo; SV=sinus of Valsalva; TAPVC=total anomalous pulmonary venous connection to the left azygos vein; TGA=transposition of the great arteries; TOF=tetralogy of Fallot; TR=tricuspid regurgitation; UVH=univentricular heart; VSD=ventricular septal defect; y=year.

Fig. 1. Serial short-axis views of the great arteries from the atrioventricular valve level (section 1) to the supra-semilunar valvular level (section 4) obtained from a left third intercostal scan. Left column (A), a normal calf. The atrioventricular valve (tricuspid valve) of the right cranial ventricle (right ventricle) is seen in diastole in section 1. Further dorsal tilting of the transducer reveals the semilunar valves of the great arteries in section 2. By tilting the transducer more dorsally, the right caudal great artery (ascending aorta) is seen separating into two circular echoes in section 3. Further dorsal tilting shows the left great artery (main pulmonary artery) extending caudad and then at times branching off in section 4. Middle column (B), Case 26 with transposition of the great arteries. At the level of section 1 to section 2, the right cranial ventricle (right ventricle) is seen connecting with the right cranial great artery (ascending aorta) bearing a coronary artery. This great artery is then observed separating into two circular echoes in the same manner as that in a normal heart in sections 3 and 4, suggesting that this great artery is the aorta and that the great arteries have a parallel (nonspiral) relationship. Right column (C), Case 32 with coarctation of the aorta. In this case, a normal great arterial relationship is observed from section 1 to 4, except that the aortic arch, i. e., aortic isthmus, appears considerably small in comparison with the normal-sized brachiocephalic artery at the level of section 3 to section 4, suggesting the presence of coarctation of the aorta. AA=aortic arch; AO=ascending aorta; BA=brachiocephalic artery; LCA=left coronary artery; LPA=left pulmonary artery; LV=left ventricle; PA=pulmonary artery; RCA=right coronary artery; RPA=right pulmonary artery; RV=right ventricle.

Fig. 2. Left lateral views of the corresponding heart specimens from the same cases as in Fig. 1. (A) a normal calf. (B) Case 26 with transposition of the aorta. (C) Case 32 with coarctation of the aorta. LA=left atrium; Other abbreviations as in Fig. 1.

sed. In Case 7, the 2-D echo diagnosis was VSD with overriding Ao, because the degree of aortic override of the IVS appeared to be about 50% and also because some mitral-aortic valvular continuity was present; however, the autopsy diagnosis was double-outlet right ventricle (DORV) with mitral-aortic valve continuity, since about 70% of the Ao originated from the right ventricle. In Cases 15 and 23 diagnosed as DORV with VSD by 2-D echo, additional important associated anomalies were overlooked. Coarctation of the aorta (CoA) in Case 16 was, likewise, missed.

No definite diagnoses were made by 2-D echo in the following 3 calves. In one case of univentricular heart (Case 14), there appeared to be considerable difficulty in fully understanding the detailed morphology by 2-D echo prospectively, or even retrospectively, because of its anatomic complexity. In Case 17, in addition to the dilated RA accompanying the atrial septum bulging into the left atrium (LA), abnormal echo-free spaces behind the LA were found in the right intercostal long-axis view. Subsequent 2-D contrast echo using a peripher-

al intravenous injection of contrast material demonstrated pronounced interatrial right-to-left shunting of contrast echoes through a PFO, but the abnormal spaces were not opacified with contrast echoes. With these findings, however, it was not entirely possible to definitely diagnose this case as one of total anomalous pulmonary venous connection (TAPVC). In one calf (Case 20) with persistent fetal circulation, 2-D echo was normal except for the presence of enlarged RA, in which the atrial septum, including the foramen ovale flaps, bulged toward the LA. In this case, 2-D contrast echo by peripheral contrast injection showed a marked interatrial right-to-left shunt. The diagnosis of this case was confirmed by later pathologic studies [18].

Group 2: In the majority of cases the 2-D echo findings correlated well with autopsy findings. These included TGA in 2 cases (Cases 26 and 33), DORV associated with other cardiac anomalies in 3 (Cases 28, 29, and 34), TOF in 1 (Case 31), right ventricular infundibular stenosis in 1 (Case 38), and CoA with other cardiac anomalies in 2 (Cases 32 and 40). Using a systematic

Fig. 3. Two-dimensional echocardiograms of double-outlet right ventricle in Case 28 (A) and Case 23 (B). Note both great arteries originating entirely from the right ventricle in both cases. IVS=interventricular septum; RA=right atrium; Other abbreviations as in previous figures.

Fig. 4. (A) Two-dimensional echocardiogram from Case 30 with a persistent left cranial vena cava draining into the coronary sinus (CS). The dilated CS is seen adjacent to the septal leaflet of the tricuspid valve in a left intercostal 4-chamber view. (B) Contrast echocardiogram from the same patient. Following injection of contrast material into the left jugular vein, a cloud of contrast echoes appears through the orifice of the CS into the right atrium. STL=septal tricuspid leaflet; Other abbreviations as in previous figures.

approach, correct diagnoses of such complex cardiac malformations as DORV (Fig. 3A) and TGA (Figs. 1B, 2B) were consistently made in this group. The narrowed aortic isthmus present in 2 cases of CoA could be observed using a series of short-axis scans of the great arteries (Figs. 1C, 2C). In an isolated PDA case (Case 37) with

the typical continuous murmur, 2-D echo revealed probable imaging of a PDA, confirmation of which was possible by 2-D contrast echo. In Case 36 with suspected truncus arteriosus, crucial visualization of the origin of the PA was not obtained, even though echocardiographic evidence suggestive of truncus arteriosus such as a large

Fig. 5. (A) Two-dimensional echocardiogram from Case 35 with total anomalous pulmonary venous connection to the left azygos vein. Note the discrete abnormal spaces (arrows) dorsal to the left atrium. (B) Subsequent contrast echocardiography from a left-jugular-vein injection. The contrast echoes are seen filling the right atrium, right ventricle, left atrium due to interatrial right-to-left shunting, and the right pulmonary artery, but they do not fill the abnormal spaces. Abbreviations same as in previous figures.

single great artery overriding the IVS and an absent right ventricular outflow tract were clearly shown. Subsequent aortography demonstrated a small main PA originating from the truncal vessel at the level of the normally located ductus and shortly bifurcating into the right and left PA. Of 2 cases of isolated persistent left cranial vena cava (PLCVC), one (Case 30) showed clear evidence of an abnormally dilated coronary sinus in a left intercostal long-axis view (Fig. 4A) and subsequent 2-D contrast echo in the same 2-D image showed that following injection of contrast materials from the left jugular vein, contrast echoes appeared in the coronary sinus first and were then seen flowing into the RA (Fig. 4B). This confirmed the diagnosis of PLCVC. In another case (Case 39), 2-D echocardiograms were interpreted as normal; however, at postmortem examination, PLCVC was found. In one calf (Case 35) with suspected TAPVC by 2-D echo, anomalous echo-free spaces behind the LA similar to those found in Case 17, were shown in a right intercostal

long-axis view (Fig. 5A), and an enlarged coronary sinus was identified in a left intercostal long-axis view. There was also no visible pulmonary venous drainage into the LA. Unlike the findings in Case 30 with PLCVC, 2-D contrast echo from the left jugular vein opacified neither the abnormal spaces (Fig. 5B) nor the dilated coronary sinus.

VSD, existing as an isolated lesion or part of a complex malformation, was the most common anomaly, being present in 15 of the 25 cases in Group 1 and in 9 of 15 in Group 2. All 24 cases in both groups had solitary VSD. All but one false-negative case (Case 14) were correctly diagnosed by 2-D echo. One false-positive (Case 25) diagnosis of VSD was also made. At necropsy, the sizes of VSDs were approximately 1 cm or more in long diameter and the sites of VSDs were perimembranous, muscular outlet, or doubly committed subarterial. The sizes and sites of VSDs determined by 2-D echo roughly correlated with postmortem findings.

DISCUSSION

The present study and our previous reported series of cases of bovine congenital heart disease [12] have shown that a wide spectrum of congenital heart disease is present in calves. More than half of the cases presented here were complex forms of congenital heart disease. Therefore, awareness of the possibility of encountering calves with such complex cardiac defects and a profound knowledge of the individual cardiac defects, both anatomically and tomographically, is important for those performing and interpreting 2-D echocardiograms of calves suspected of having congenital heart disease. In order to fully analyze the complicated anatomy of congenital cardiac defects, an organized and detailed approach is required. A well-known approach among human cardiac pathologists is the so-called segmental approach [32]. This approach has been applied to the prospective diagnosis of congenital heart disease by 2-D echo [7, 8, 16, 17, 28, 30]. The principle behind this approach is, first, to identify the individual cardiac chambers, second, to determine atrio-ventricular connections and then ventriculo-arterial connections, and, finally, to find the associated anomalies such as VSD. We have applied a similar 2-D echo approach to normal and diseased cattle and shown its potential clinical utility in assessing congenital heart disease in our previous report [14].

In the present study also, the diagnostic accuracy was distinctly higher in Group 2 employing this systematic 2-D echo approach than in Group 1, as shown in Table 1. However, in the strict sense of the comparison, there might have been some problem as to which of these groups had a higher rate of accuracy, since both groups differed with respect to the number and age of the patients examined, the type of transducer used, the type of cardiac anomaly,

and the authors' experience of the 2-D echo technique, i, e., the greater the experience, the higher the rate of diagnostic accuracy (Group 2 was advantageous in this respect). With regard to patient age, the use of calves may be advantageous in that an increased number of echo windows, including the subcostal window, and improved signal-to-noise characteristics due to the short distance involved, are available when 2-D echo is performed. Another advantage is that because of the absence of heavily calcified ribs in calves, even a bulky linear transducer carrying an advantage of higher resolution and a larger area of near-field structures as compared with a sector scanner, can be utilized from various locations with only a minimal effect of acoustic shadow due to the ribs. However, a wide-angle sector scanner is indispensable in the full performance of systematic 2-D echo examination, especially when examining relationships of the great arteries. Hence, since a mechanical sector scanner or a convex array scanner (intermediate type between linear and sector) became available at our university in 1984, these have generally been used.

In our experience, although the number of animals examined was small, the 2-D echo appearance of extracardiac vascular anomalies appeared to be more difficult to diagnose than that of intracardiac anomalies. For instance, great difficulty was encountered in diagnosing with certainty the patency of the ductus in PDA and the site of pulmonary venous drainage in TAPVC. In such cases, the additional use of 2-D contrast echo assisted in the diagnosis. In the case of PDA, 2-D contrast echo using injection of contrast materials through a catheter into the Ao allowed demonstration of left-to-right-shunting through a suspected patent ductus. In the case of TAPVC, 2-D contrast echo from the left jugular vein was of great practical importance in excluding the possibility of PLCVC. Also, pulsed

Doppler echo with its advantage of being non-invasive was obviously valuable as an aid in determining the presence of left-to-right shunt flows across the ductus arteriosus (Cases 31, 32 and 37) by detecting abnormal Doppler signals in the main PA [13]. This technique also contributes significantly to the detection of valvular regurgitation (Case 27), since 2-D echo alone is limited in its ability to define the existence of regurgitation.

On the other hand, using a series of short-axis, left intercostal views of the great arteries, it may well be possible to diagnose such great arterial abnormalities as a narrowed ascending Ao or aortic isthmus and aortopulmonary window. However, there may be practical difficulty in defining a severely hypoplastic great artery resembling a string, as encountered in Case 3 with extreme TOF.

Among various types of intracardiac abnormalities encountered, 2-D echo was highly accurate in diagnosing VSD, whether it occurred in isolation or in association with other cardiovascular malformations. In general, the size and location of VSD and the resolution of the 2-D echo image are considered to be important factors determining the degree of success in detecting VSD. In the literature on human cases [4, 29], small defect or multiple defects, particularly within the trabecular septum, are thought to be easily overlooked. Fortunately, no trabecular defects were present in our study and the size of each VSD was sufficient to permit visualization with our echo instruments.

One confusing diagnosis we experienced was classification of hearts with an overriding arterial valve. The 50 per cent rule, as stressed by Becker and Anderson [2], seems to be a very simple and practical method for classifying the type of connection made by an overriding arterial valve to the ventricle, but precise determination of the degree of

override is not always easy with the 2-D echo technique and occasionally even on postmortem examination, especially when the pathologist is confronted with a situation in which the degree of override is almost 50%. Such situations were frequently encountered in our series, for example, when differentiating DORV from isolated VSD with overriding Ao. Therefore, in this study, we required more than two-thirds commitment of the Ao to the RV in cases of DORV. From our own experience, it should be emphasized that the degree of arterial override should be judged from more than 2 views from different scanner positions in order to reduce the diagnostic error mentioned above.

In conclusion, our experience suggests that 2-D echo is a very useful non-invasive diagnostic tool for defining the anatomic features of various types of congenital heart disease in cattle, especially when systematic 2-D echo examination is carried out. There are, however, limits to the diagnosis of some extracardiac vascular anomalies. For such cases, contrast and pulsed Doppler echo should be of great value for definitive diagnosis. We believe that such combined use of echocardiographic techniques will play an essential role in the anatomical and physiological assessment of bovine congenital heart disease, as it has done so already in humans.

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REFERENCES

1. Bayly, W. M., Reed, S. M., Leathers, C. W., Brown, C. M. Traub, J. L., Paradis, M. R., and Palmer, G. H. 1982. Multiple congenital heart anomalies in five Arabian foals. *J. Am. Vet. Med. Assoc.* 181: 684-689.
2. Becker, A. E., and Anderson, R. H. 1981.

- Pathology of Congenital Heart Disease, Butterworths, London.
3. Bonagura, J. D., and Pipers, F. S. 1983. Diagnosis of cardiac lesions by contrast echocardiography. *J. Am. Vet. Med. Assoc.* 182: 396-402.
 4. Capelli, H., Andrade, J. L., and Somerville, J. 1983. Classification of the site of ventricular septal defect by 2-dimensional echocardiography. *Am. J. Cardiol.* 51: 1474-1480.
 5. Carlsten, J., Kvart, C., and Jeffcott, L. B. 1984. Method of selective and non-selective angiocardiology for the horse. *Equine Vet. J.* 16: 47-52.
 6. Fisher, E. W., and Pirie, H. M. 1962. An Eisenmenger complex in an Ayrshire heifer. *Vet. Rec.* 74: 447-452.
 7. Foale, R., Stefanini, L., Rickards, A., and Somerville, J. 1982. Left and right ventricular morphology in complex congenital heart disease defined by two dimensional echocardiography. *Am. J. Cardiol.* 49: 93-99.
 8. Gussenhoven, E. J., and Becker, A. E. 1983. Congenital Heart Disease. Morphologic Echocardiographic Correlations, pp. 47-79, Churchill Livingstone, London.
 9. Gutgesell, H. P., Huhta, J. C., Latson, L. A., Ardms, D. H., and Mcnamara, D. G. 1985. Accuracy of two-dimensional echocardiography in the diagnosis of congenital heart disease. *Am. J. Cardiol.* 55: 514-518.
 10. Hagio, M., Udon, T., and Murakami, T. 1982. Tetralogy of Fallot in a calf. *Adv. Anim. Electrocard.* 15: 68-71 (in Japanese).
 11. Hagio, M., Otsuka, H., Murakami, T., and Tateyama, S. 1984. M-mode and two-dimensional echocardiographic diagnosis of bovine heart disease. *J. Jpn. Vet. Med. Assoc.* 37: 560-568 (in Japanese with English summary).
 12. Hagio, M., Murakami, T., Tateyama, S., Otsuka, H., Hamana, K., and Shimobepu, I. 1985. Congenital heart disease in cattle. *Bull. Fac. Agric. Miyazaki Univ.* 32: 233-249 (in Japanese with English summary).
 13. Hagio, M., and Otsuka, H. 1986. Combined use of M-mode, two-dimensional, and pulsed Doppler echocardiography in dogs, cats, and calves. In: 5th Congress Fed. Asian Vet. Assoc. Kuala-Lumpur (Malaysia).
 14. 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).
 15. Hagio, M., and Otsuka, H. 1987. Pulsed Doppler echocardiography in normal dogs and calves and three cases of valvular regurgitation. *Jpn. J. Vet. Sci.* 49 (6) in press.
 16. Huhta, J. C., Hagler, D. J., Seward, J. B., Tajik, A. J., Julsrud, P. R., and Ritter, D. G. 1982. Two-dimensional echocardiographic assessment of dextrocardia: a segmental approach. *Am. J. Cardiol.* 50: 1351-1360.
 17. Huhta, J. C., Smallhorn, J. F., and Macartney, F. J. 1982. Two dimensional echocardiographic diagnosis of situs. *Br. Heart J.* 48: 97-108.
 18. Komatsu, M., Hagio, M., Yoshimura, T., Murakami, T., Nasu, T., and Saito, I. 1984. Primary pulmonary hypertension in a Japanese Black calf. *Adv. Anim. Cardiol.* 17: 31-34 (in Japanese with English Summary).
 19. Kvart, C., Carlsten, J., Jeffcott, L. B., and Nilsfors, L. 1985. Diagnostic value of contrast echocardiography in the horse. *Equine Vet. J.* 17: 357-360.
 20. Lacuata, A. Q., Yamada, H., and Hirose, T. 1981. Tetralogy of Fallot in a heifer. *J. Am. Vet. Med. Assoc.* 178: 830-836.
 21. Lombard, C. W., Scarratt, W. K., and Buerget, C. D. 1983. Ventricular septal defects in the horse. *J. Am. Vet. Med. Assoc.* 183: 562-565.
 22. Machida, N., Yamaga, Y., Yasuda, J., and Too, K. 1986. Eisenmenger's complex in a Holstein heifer. *Jpn. J. Vet. Sci.* 48: 1031-1035.
 23. McGuirk, S. M., Welker, F. H., Muir, W. W., and Hull, B. L. 1984. Thermodilution curves for diagnosis of ventricular septal defect in cattle. *J. Am. Vet. Med. Assoc.* 184: 1141-1145.
 24. Pipers, F. S., Hamlin, R. L., and Reef, V. 1979. Echocardiographic detection of cardiovascular lesions in the horse. *Equine Med. Surg. J.* 3: 68-77.
 25. 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.
 26. Reef, V. B., and Hattel, A. L. 1984. Echocardiographic detection of tetralogy of Fallot and myocardial abscesses in a calf. *Cornell Vet.* 74: 81-95.
 27. Rice, M. J., Seward, J. B., Hagler, D. J., Mair, D. D., Feldt, R. H., Puga, F. J., Danielson, G. K., Edward, W. B., and Tajik, A. L. 1983. Impact of 2-dimensional echocardiography on the management of distressed newborns in whom cardiac disease is suspected. *Am. J. Cardiol.* 51: 288-292.
 28. Satomi, G. 1980. Two-dimensional echocardiographic method for diagnosis of congenital heart disease. *J. Tokyo Women's Med. Coll.* 50: 1-23 (in Japanese with English summary).
 29. Sutherland, G. R., Godman, M. J., Smallhorn, J. F., Anderson, R. H., and Hunter, S. 1982. Ventricular septal defects. Two-dimensional echocardiographic and morphological correlations. *Br. Heart J.* 47: 316-328.
 30. Sutherland, G. R., Smallhorn, J. F., Anderson,

- R. H., Rigby, M. L., and Hunter, S. 1983. Atrioventricular discordance. Cross-sectional echocardiographic-morphological correlative study. *Br. Heart J.* 50: 8-20.
31. Van Nie, C. J. 1966. Congenital malformations of the heart in cattle and swine. *Acta Morphol. Neerlando-Scandinavica.* 6: 387-393.
32. Van Praagh, R. 1972. The segmental approach to diagnosis in congenital heart disease. pp. 4-23. In: *Birth Defects: Original Article Series*, Williams and Wilkins, Baltimore.
33. Yamada, A., and Yoneda, Y. 1975. Studies on ultrasonic diagnosis in veterinary practice. I. Traumatic pericarditis and endocarditis in cows. *J. Jpn. Vet. Med. Assoc.* 28: 6-12 (in Japanese with English summary).
34. Yamaga, Y., and Too, K. 1986. Echocardiographic detection of bovine cardiac diseases. *Jpn. J. Vet. Res.* 34: 251-267.

要 約

ウシの先天性心疾患の超音波診断について——とくに本法の診断能について：萩尾光美・村上隆之¹⁾・大塚宏光（宮崎大学農学部家畜外科学教室，¹⁾家畜解剖学教室）——ウシの先天性心疾患40例に対して prospective な断層心エコー図診断を行い，剖検所見と対比検討した。主にリニア型探触子を用いて診断した25例（Ⅰ群）と著者らが考案したセクタ型探触子を用いた系統的アプローチにより診断した15例（Ⅱ群）とを比較すると，後者の診断能がより高かった。系統的アプローチを用いると，完全大血管転位，両大血管右室起始など複雑な心奇形の生前診断が可能であることが示唆された。しかし，動脈管開存，総肺静脈還流異常などの血管奇形は，本法のみで確診するのは必ずしも容易ではなく，これらに対しては断層コントラスト心エコー図法や超音波パルスドプラ法の併用が有効と思われた。