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Original Articles

# Morphology of Hearts with Discordant Atrioventricular Connection in Cattle

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**Summary :** Discordant atrioventricular connection was detected in eight (1.1 %) hearts among 740 bovine hearts showing congenital cardiovascular anomalies. The atrial situs was solitus in five hearts and inversus in three. Regarding ventriculoarterial connections, a double-outlet right ventricle was present in seven hearts and a concordant connection in one. All 8 of these cases were associated with ventricular septal defect.

**Key words :** Bovine, Discordant atrioventricular connection.

## Introduction

Atrioventricular discordance is a specific condition in which the morphological right atrium is connected to the morphological left ventricle via a mitral valve, and the morphological left atrium is connected to the morphological right ventricle via a tricuspid valve (Sutherland *et al.* 1983 ; Szufladowicz *et al.* 1996). This definition excludes hearts in which the atrial chambers connect to only one ventricle, such as those with a double-inlet ventricle or an absent atrioventricular connection (Sutherland *et al.* 1983). In humans, discordant atrioventricular connection is a rare congenital cardiac anomaly (Szufladowicz *et al.* 1996). In this anomaly, the ventriculoarterial connection may be concordant, discordant, double-outlet right or left ventricle or a single-outlet heart (Szufladowicz *et al.* 1996). Usually, the anomaly is complicated by associated cardiac anomalies (Jahangiri *et al.* 2001 ; Sutherland *et al.* 1983 ; Szufladowicz *et al.* 1996 ; Yeh *et al.* 1999), and the associated defects modify the pattern of circulation and clinical presentation (Szufladowicz *et al.* 1996). Discordant atrioventricular connection is less known in animals. To the best of our knowledge, only eight cases with such anomaly have been reported in cattle (Fukumoto *et al.* 2000 ; Murakami *et al.* 1995 ; Nakade *et al.* 1992 ; Okada *et al.* 2007 ; West 1988). The purpose of this report is to describe the frequency and morphology of hearts with discordant atrioventricular connection in cattle.

## Materials and Methods

The specimens comprised 740 bovine hearts with congenital cardiac anomalies. All the hearts were collected between 1979 and 2009 and preserved in 10 % formalin. During macroscopic examination, we identified hearts with atrioventricular discordance according the definition cited above. We excluded cases with overriding atrioventricular valves when more than half of the valve was connected to the same ventricle as the other atrioventricular valve.

## Results and Discussion

In humans, atrioventricular discordance is a rare congenital cardiac defect (Szufladowicz *et al.* 1996), and its correct incidence is presently unknown. In this study of a collection of 740 bovine hearts showing congenital malformations, eight (1.1 %) hearts from six male and two female cattle aged 4 days to 5 months had atrioventricular discordance (Table 1).

In humans, hearts with atrioventricurar discordance have been found in atrial situs solitus as well as

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**Table 1.** Morphology of the hearts with discordant atrioventricular connection in ten calves

| Case No. | Breed* | Sex | Age (days) | Atrial situs | Ventriculo-Arterial Connection** | Associated cardiac anomalies*** | References |
|---|---|---|---|---|---|---|---|
| 1 | JB | M | 4 | Solitus | DORV | ASD, VSD, Aortic stenosis, Right aortic arch | Fukumoto *et al.* |
| 2 | JB | M | 90 | Solitus | DORV | Anomalous pulmonary venous connection, ASD, VSD, PDA, Aortic stenosis | Murakami *et al.* |
| 3 | Hol | M | 5 | Solitus | DORV | Left atrial continuation of caudal vena cava, Right atrial continuation of right hepatic vein, Anomalous pulmonary venous connection, Premature closure of foramen ovale, VSD | Okada *et al.* |
| 4 | JB | F | 37 | Solitus | DORV | Left atrial continuation of left cranial vena cava, Anomalous pulmonary venous connection, PFO, VSD, PDA, Pulmonary atresia | Murakami *et al.* |
| 5 | JB | M | 134 | Solitus | DORV | Straddling mitral valve, PFO, VSD, PDA, Aortic stenosis | |
| # | JB | M | 13 | Solitus | Concordance | Ebstein-like anomaly, Tricuspid stenosis, ASD, VSD | Nakade *et al.* |
| # | Ays | F | 63 | Inversus | DORV | ASD, VSD | West *et al.* |
| 6 | JB | F | 4 | Inversus | DORV | Left atrial continuation of right cranial vena cava and right hepatic vein, Anomalous pulmonary venous connection, ASD, VSD, Pulmonary atresia, Vascular ring | Okada *et al.* |
| 7 | JB | M | 11 | Inversus | DORV | Left atrial continuation of right cranial vena cava, Atresia of common pulmonary vein, ASD | |
| 8 | JB | M | 168 | Inversus | Concordance | ASD, VSD | Okada *et al.* |

* Ays : Ayrshire, JB : Japanese Black, Hol : Holstein
** DORV : double outlet from the morphological right ventricle
***ASD : atrial septal defect, PDA : patent ductus arteriosus, PFO : patent foramen ovale, VSD : ventricular septal defect

in situs inversus (Jahangiri *et al.* 2001 ; Sutherland *et al.* 1983 ; Szufladowicz *et al.* 1996 ; Yeh *et al.* 1999). In this study, the atrial situs was solitus in five (cases 1 to 5) and inversus in three (cases 6, 7 and 8). In the cases with atrial situs solitus, a morphological right atrium was right-sided and a morphological left atrium was left-sided. In cases 1 and 5, both the atria and their tributary veins were morphologically normal. The right atrium in case 2 received blood from the cranial and caudal vena cava and from the common pulmonary vein via the left azygos vein. In case 3 the right atrium received from the cranial vena cava, right hepatic vein and common pulmonary vein, while the caudal vena cava opened into the left atrium. In case 4, the right atrium received from the right cranial and caudal vena cava and the common pulmonary vein ; however, the left cranial vena cava drained into the left atrium. Among these 5 hearts, 4 had interatrial communications, such as atrial septal defect (cases 1 and 2) or persistent foramen ovale (cases 4 and 5).

In all five cases with atrial situs solitus, there was abnormal bulboventricular looping to the left (l-loop), that is, the right-sided ventricle was a morphologic left ventricle, and the left-sided ventricle was a morphological right ventricle. The right-sided and posterior ventricle showed the left ventricular architecture throughout and had a smooth septal surface and a fine apical trabecular component. The right atrium connected to a right-sided morphological left ventricle through a mitral valve (Fig. 1, a). However, case 5 had a straddling mitral valve and some chordae from the valve inserted on the left side of the septal defect. In all five cases, the morphological left ventricle had no connection with the great arteries. However, these cases had ventricular septal defects, and this constituted the only outlet from the morphological left ventricle. The left atrium connected to a left-sided ventricle through a tricuspid valve. The left-sided and anterior ventricle showed right ventricular morphology and had a trabeculated septal surface and a coarse apical trabecular component. The type of connection between the ventricles and the great arteries in the five cases with atrial situs solitus was double outlet from the left-sided morphological right ventricle (Fig. 1, b) ; however, pulmonary atresia with an imperforate pulmonary valve was present in case 5. The relationships between the arterial valves were variable. The aortic valve was to the right and posterior (cases 1 and 2), to the right and side-by-side (cases 3 and 5), and anterior of the pulmonary valve (case 4).

In the three cases with atrial situs inversus, the morphological right atrium was left-sided, and the morphological left atrium was right-sided (Fig. 2, a). In case 6, the morphological right atrium received blood from the left cranial and caudal vena cava, but the right cranial vena cava and right hepatic vein

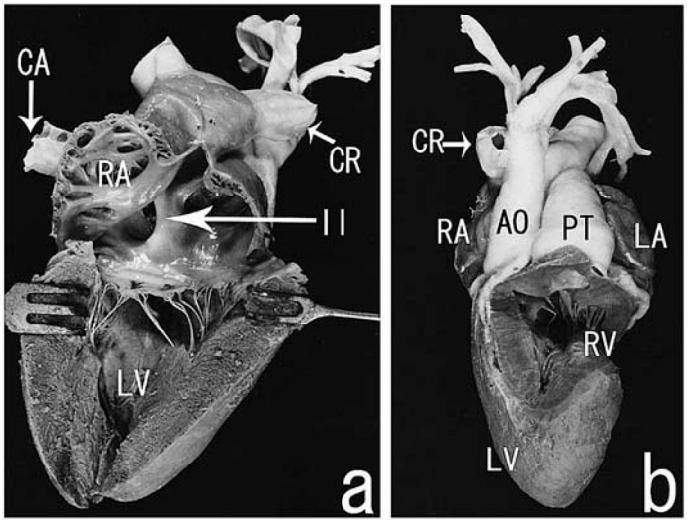


**Fig. 1.** Atrioventricular discordance (a, right lateral view) with double outlet from the left-sided morphological right ventricle (b, frontal view) in case 1.

AO : aorta CA : caudal vena cava CR : cranial vena cava LA : left-sided morphological left atrium LV : right-sided morphological left ventricle RA : right-sided morphological right atrium RV : left-sided morphological right ventricle II : secundum atrial septum

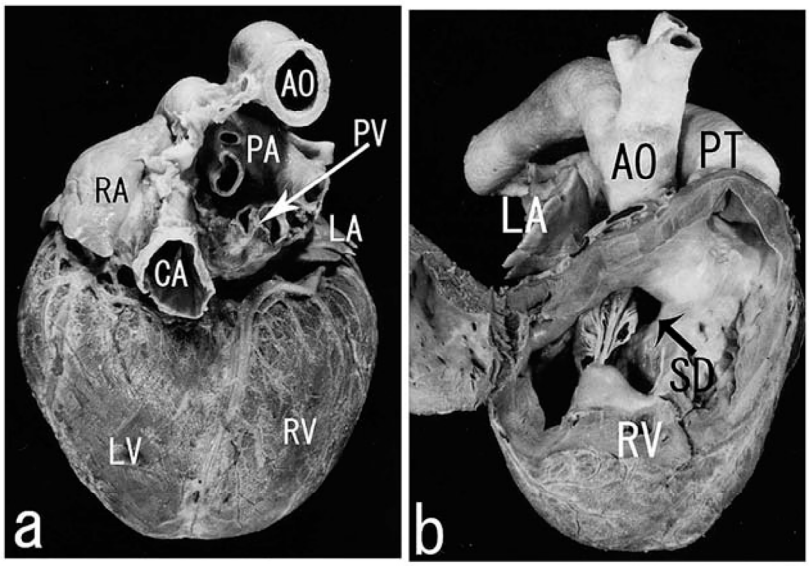


**Fig. 2.** Atrial situs inversus (a, posterior view) with concordant ventriculoarterial connection (b, frontal view) in case 8.

AO : aorta CA : caudal vena cava LA : right-sided morphological left atrium LV : left-sided morphological left ventricle PA : pulmonary arteries PT : pulmonary trunk PV : pulmonary veins RA : left-sided morphological right atrium RV : right-sided morphological right ventricle SD : ventricular septal defect

opened into the morphological left atrium. In case 7, the morphological right atrium received the left cranial and caudal vena cava, while, the right cranial vena cava opened into the morphological left atrium, and atresia of the common pulmonary vein was present. In case 8, both atria and their tributary veins were morphologically normal. In these three cases, there was bulboventricular looping to the right (r-loop), that is, the right-sided ventricle was the morphological right ventricle and the left-sided ventricle was the morphological left ventricle. The left-sided morphological right atrium connected to a left-sided morphological left ventricle through a mitral valve, and the right-sided morphological left atrium connected to a right-

sided morphological right ventricle through a tricuspid valve. The type of ventriculoarterial connection in cases 6 and 7 was a double-outlet from the right-sided morphological right ventricle ; however, pulmonary atresia was present in both cases. Case 8 had ventriculoarterial concordance (Fig. 2, b).

Atrioventricular discordance has been found in association with several types of ventriculoarterial connections : concordant, discordant, double-outlet ventricles and single outlet heart. In humans (Jahangiri *et al.* 2001 ; Sutherland *et al.* 1983 ; Szufladowicz *et al.* 1996 ; Yeh *et al.* 1999), discordant ventriculoarterial connection occurs most frequently (84.3 %, 306/363) and is known as congenital corrected transposition of the great artery. The second most frequent ventriculoarterial connection is the double-outlet right ventricle (11.0 %, 40/363). The concordant connection (2.5 %, 9/363) and double-outlet left ventricle (0.3 %, 1/363) are less common. However, in cattle in the present study, the double-outlet right ventricle was the most frequent (7/8) ventriculoarterial connection, and a discordant ventriculoarterial connection with atrioventricular discordance has not been observed until now. In humans (Jahangiri *et al.* 2001 ; Sutherland *et al.* 1983 ; Szufladowicz *et al.* 1996 ; Yeh *et al.* 1999), atrioventricular discordance is commonly associated with other cardiac anomalies, including ventricular septal defect (81.3 %, 295/363), pulmonary stenosis (62.5 %, 227/363), and tricuspid valve anomalies (19.8 %, 72/363). In this study, a ventricular septal defect was present in all the cattle with atrioventricular discordance (Table 1).

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# ウシの房室結合不一致心臓の形態学

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**要　約**

ウシの奇形心740例中８例（1.1％）に房室結合不一致が認められた．心房位は正位が５例，逆位が３例であった．それらの心室大血管結合は両大血管右室起始が７例，一致結合が１例であった．これら８例の全例に心室中隔欠損が合併していた．

**キーワード**：ウシ，房室結合不一致