Ventriculo-atrial conduction in the ovine heart, caused by premature ventricular complexes

J. KER[1] and E.C. WEBB[2]

ABSTRACT

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In humans, and certain animals, the atrioventricular conduction system is capable of bidirectional conduction. Depolarization impulses, originating in the ventricle itself, may thus be conducted in a retrograde direction towards the atria. Two common causes for this phenomenon of ventriculo-atrial (retrograde) conduction are premature ventricular complexes and ventricular pacing. The surface electrocardiogram can be used for the detection of such retrogradely conducted beats. The purpose of this study was to investigate the possibility of ventriculo-atrial conduction in Dorper sheep. Premature ventricular complexes in eight healthy Dorper wethers were induced and it was possible to document retrogradely conducted beats on the surface electrocardiogram in all of them. It is concluded that the Dorper sheep heart is capable of ventriculo-atrial conduction.

Keywords: Dorper sheep, electrocardiogram, ventriculo-atrial conduction

INTRODUCTION

The capability for bidirectional conduction by the atrioventricular (AV) conduction system has been demonstrated in humans and many classes of animals (Goldreyer & Bigger 1970). The AV conduction system is thus capable of conducting impulses from atrium to ventricle, as well as back in a retrograde direction from ventricle to atrium. Furthermore, various experiments suggest the existence of two inter-nodal pathways, each with a different refractory period (Mendez, Han, De Jalon & Moe 1965). Impulses originating in the atrium pass to the ventricle via one of these pathways. Occasionally a depolarization impulse originates in the ventricle itself and these impulses may be conducted in a retrograde direction towards the atrium via one of these two AV pathways (Mendez *et al.* 1965; Goldreyer & Bigger 1970). The most compelling evidence for this dual AV conduction system has been the demonstration of retrograde P waves and echo beats (Mendez *et al.* 1965).

These echo responses are an unusual type of coupled rhythm in which an impulse initiated in one cardiac chamber propagates to another and then returns to the chamber of origin (Mignone & Wallace 1966).

As stated above, ventriculo-atrial (VA) conduction may be seen when the depolarization impulse originates in the ventricle itself. The two main causes of this are premature ventricular complexes (PVCs)

[1] Department of Physiology, Faculty of Medicine, University of Pretoria, P.O. Box 24318, Gezina, Pretoria, 0031 South Africa. E-mail: james.ker@med.up.ac.za

[2] Department of Animal and Wildlife Sciences, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria, 0002 South Africa

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and ventricular pacing (Kistin & Landowne 1951; Schuilenburg & Durrer 1969; Goldreyer & Bigger 1970). It is important to note that this concept of a dual AV-pathway has been formulated based on observations made in cardiac conduction experiments and no histological evidence for two anatomically distinct pathways exists.

Ventriculo-atrial conduction can be detected on the surface electrocardiogram (ECG) but the high amplitude QRS complexes may obscure the retrograde P waves, thus hiding the existence of retrograde conduction (Goldreyer & Bigger 1970). In such instances intra-atrial electrograms can provide an accurate method for the detection of retrograde P waves (Goldreyer & Bigger 1970).

The purpose of this study was to investigate the possibility of ventriculo-atrial, or retrograde, conduction in the hearts of normal Dorper sheep. A search of the Medline and Premedline database from 1966 to the present did not reveal any studies on the possibility of this phenomenon in Dorper sheep.

MATERIALS AND METHODS

This study was performed with the approval of, and adherence to, the guidelines of the Pretoria Biomedical Research Centre`s Animal Use and Care Committee.

Eight clinically normal Dorper wethers, all between the age of 9 and 12 months, and weighing between 35 and 40 kg were used in this study. They were fed lucerne hay *ad libitum*, received 300 g per day of pelleted concentrate (10 MJ ME/kg DM with 14% crude protein) and had free access to water at all times.

The sheep were sedated and placed in the right lateral decubitus position.

There were two groups:

- The first group (n = 6) were sedated with Ketamine hydrochloride (Brevinaze) at a dose of 100 mg intramuscularly once only.
- The second group (n = 2) were sedated with Midazolam (Dormicum) at a dose of 30 mg intramuscularly once only. This was done to exclude the possibility that the choice of sedative may have electrocardiographic effects, either potentiating or inhibiting ventriculo-atrial conduction. After an interval of 10 min there were no spontaneous movements and baseline electrocardiographs (ECGs) were obtained from every wether.

Electrocardiography

- Einthoven`s triangle was moved from the frontal to the sagittal plane as described before by Schultz & Pretorius (1972) by moving the standard and unipolar limb electrodes as follows:
  (a) aVR moved from the right fore limb to the head between the ears;
  (b) aVL moved from the left fore limb to the sacrum;
  (c) aVF moved from the left hind limb to the sternal angle; and
  (d) the earth electrode was placed on the right hind leg, just above the hock.
- The six precordial leads were placed as follows:
  (a) V1 placed 7 cm to the right of the sternal angle;
  (b) V2 placed 7 cm to the left of the sternal angle;
  (c) V3 placed 4.5 cm below and 1 cm to the left of V2;
  (d) V4 placed 4.5 cm below and 1 cm to the left of V3;
  (e) V5 placed 4.5 cm below and 1 cm to the left of V4; and
  (f) V6 placed 4.5 cm below and 1 cm to the left of V5.
- Meditrace 200, disposable ECG conductive, adhesive electrodes were used. The skin areas where ECG electrodes were placed were shaven and the electrodes were secured with Super Glue (Bostik).
- A 12 lead electrocardiogram was performed with a Schiller AT-2 plus six channel electrocardiograph. The paper speed was set at 25 mm/s.

Premature ventricular complexes induced—right and left ventricles

We chose premature ventricular complexes (PVCs) to initiate depolarization impulses in the ventricles in order to detect any possible retrograde P waves, the presence of which will indicate ventriculo-atrial conduction.

After obtaining the normal, baseline ECG in every wether PVCs were induced in every animal. There were two groups: Right ventricular PVCs were induced in seven and left ventricular PVCs in one.

Right ventricular PVCs (n = 7)

A spring-wire guide, diameter 0.81 mm and length 60 cm, was advanced into the right ventricle via the left internal jugular vein, using the Seldinger technique. Right ventricular PVCs were induced by mechanical movement of the spring-wire guide and the position of the wire was confirmed by an X–ray.

Left ventricular PVCs (n = 1)

In this wether the spring-wire guide was advanced into the left ventricle via the left internal carotid artery. The position of the spring-wire guide was confirmed by fluoroscopy and PVCs were induced by mechanical movement of the spring-wire guide.

RESULTS

We were able to demonstrate ventriculo–atrial conduction in all eight Dorper wethers as they all developed retrograde P waves, clearly visible on the surface electrocardiogram (ECG).

In Fig. 1, ECG 1 is that of a normal Dorper wether at baseline. Note the presence of P waves (encircled) in front of every QRS complex, reflecting the normal sequence of activation of the heart—impulses initiated in the atria are conducted anterogradely to the ventricles via the AV-conduction system. Note also that the P waves in this lead (III) are inverted.

ECG 2 is that of the same Dorper wether during the presence of premature ventricular complexes (PVCs).

Note the P waves of the normal beats in lead III. They are inverted and have been encircled. They appear in front of the normal QRS complexes.

QRS complexes 2–5 in lead III are PVCs. Note the retrogradely conducted P waves, buried on the ascending limb of the T waves. They occur after the abnormal QRS complexes, indicating that the ventricle was activated first and the impulse was then conducted retrogradely to the atria, therefore the P wave is situated after the QRS complex. Further evidence for their retrogradely conducted nature in this case is their polarity—they are positive, contrasting with the inverted polarity of the normal P waves. Note the second run of PVCs. No retrograde P waves are visible. In the first run of PVCs the heart rate is 250/min, but in the second run it is much faster and is 300/min. At this heart rate retrograde P waves will not be visible as they are usually buried inside the high amplitude QRS complex, or their absence may be due to a gap phenomenon (see below).

DISCUSSION

This study demonstrates that the Dorper heart is capable of ventriculo-atrial (retrograde) conduction. Previous studies on this phenomenon in humans led to the hypothesis that there may be two internodal pathways, each with a different refractory period, and that this will permit an early premature beat to pass from ventricle to atrium (or vice versa) over the one pathway and to return to the chamber of origin over the other pathway (Mendez *et al.* 1965). However, the histological presence of such a dual atrioventricular system has never been documented and it`s existence, therefore, is still a hypothesis in search of confirmation. The atrioventricular (AV) node in the sheep lies at the base of the atrial septum, anterior to the coronary sinus and just above the tricuspid valve (Frink & Merrick 1973). Histologically, the node is an intricate network of anastomosing fibres, varying in size, but smaller than atrial fibres (Frink & Merrick 1973).

In our study not every PVC QRS complex is followed by a retrograde P wave on the surface ECG.

There are two possible explanations for this:

- Firstly, as stated above, in some instances the retrograde P waves may be obscured by the high amplitude QRS complexes or the T waves.
- Secondly, the presence of an intra-His Purkinje gap phenomenon has been described during retrograde conduction in the human heart (Reddy, Damato & Akhtar 1981).

  Gap phenomena occur when there exists a non-homogeneous refractoriness at different levels of the conduction system and in our study this refers to a possible zone in which PVCs will fail to conduct retrogradely to the atria. In experiments that demonstrated the gap phenomenon during ventriculo-atrial conduction in humans, the site of conduction block was either below the His bundle or within the AV node itself (Reddy *et al.* 1981). This means that the effective refractory period at these sites of conduction block is longer than at the site of initiation and early conduction of the PVC. This is due to the existence of a non-homogeneous refractoriness in different parts of the conduction system (Reddy *et al.* 1981).

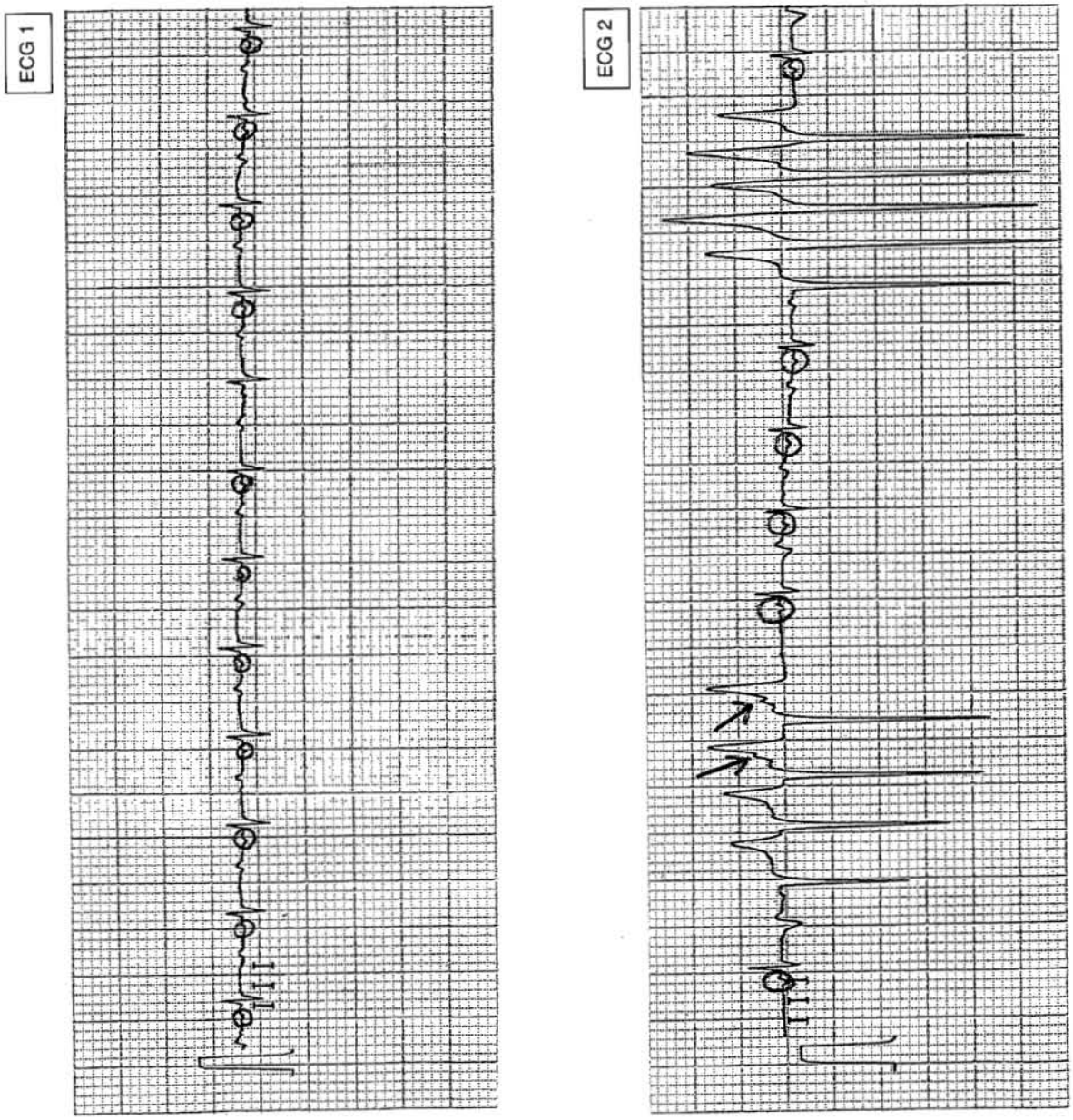

FIG. 1 Ventriculo-atrial conduction in a Dorper wether. ECG 1 shows a normal wether at baseline and ECG 2 demonstrates the same wether during the presence of premature ventricular complexes

One, or both, of these mechanisms may account for the variable retrogradely conducted PVCs induced in this study, but there is no doubt, as shown in this experiment, that the Dorper heart is capable of ventriculo-atrial conduction.

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