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Studies on Bovine Electrocardiogram. II. Bundle Branch Block.*

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Recent work by Cardwell and Abramson[1] and Abramson and Margolin[2] has shown that, in some species at least, the arborizations of the Purkinje network of the heart are not confined to the subendocardium as is generally assumed. By means of an injection technic they demonstrated that in the ox heart branches of the Purkinje network pierced the ventricular septum and penetrated the outer ventricular walls nearly, if not quite, to the epicardium. The branches which pierced the septum made connections with the Purkinje network of the other side. Histological studies disclosed Purkinje tissue in all muscle layers of the ventricular septum and outer ventricular walls of the hearts of dogs, sheep and pigs, but in these animals the differentiation between the Purkinje tissue and the ordinary muscle was less pronounced than in the ox heart. For this reason and because the injection method failed in these animals, the distribution of the Purkinje tissue could not be worked out as completely in them as in the ox. Electrocardiographic observations by one of us[3] suggest that contrary to the conclusions of the authors quoted,[1, 2] there may be major differences between the intraventricular conducting system of the ox heart and that of the canine heart.

In comparison with the canine and with the human heart, the ox heart is very much heavier and its walls very much thicker. It would be expected, therefore, that the QRS interval of the ox would be much longer than that of the dog or of man. In a study of the normal electrocardiogram of dairy cattle it was found that this was by no means the case. In a group of 97 cattle the mean duration of QRS was 0.09 sec with a minimum of 0.06 sec and a maximum of 0.12 sec.[3] These findings suggested that it would be worthwhile to determine the effect of section of the bundle branches of the ox heart upon the bovine electrocardiogram. Since it is difficult to carry out experi-

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1 Cardwell, J. C., and Abramson, D. I., *Am. J. Anat.*, 1931, **49**, 769.

2 Abramson, D. I., and Margolin, S., *Am. J. Anat.*, 1936, **70**, 250.

3 Alfredson, B. V., unpublished data.

ments of this kind in mature cattle, we have used young calves. For comparison, a number of experiments have been performed on dogs.

Procedure. In all instances sodium pentobarbital[4] was administered intravenously until surgical anesthesia supervened. The animals were held in the dorsal recumbent position. The thorax was opened and held as widely open as possible throughout the experiment by means of hook spreaders. In some of the earlier experiments the slit pericardium was stitched to the edges of the thorax, thus forming a cradle for the heart.† This procedure interfered with the manipulations necessary for efficient sectioning of branches of the His-bundle and was abandoned in favor of simply replacing the heart in the slit pericardial sac within the opened thorax. Section of the right or left bundle branch was carried out by the method described by Lewis.[5] Electrocardiograms were obtained before and after section. In 6 instances the presence of complete bundle branch block was proved by the onset of complete A-V block following a cut on the opposite side of the septum later shown to have transected the remaining bundle branch. In all cases the heart was removed at the end of the experiment, opened according to the method of Cardwell and Abramson[1] and examined to determine the location of the cuts. In view of the very clear demarcation of the right and left bundle branches in the ox heart, it is easy to determine in this way whether the bundle branches have been completely divided. Bundle branch block was successfully produced in 14 calves and in 10 dogs. Measurements of the QRS interval were made in lead II throughout, as this is generally the most satisfactory lead in cattle.[3]

Results and Discussion. The changes in the duration of QRS after section of the right or left bundle branch are recorded in Table I.

The average increase in duration of QRS on section of the right bundle branch (8 calves) was 0.013 sec, and the average increase after section of the left bundle branch (6 calves) was 0.005 sec. Right bundle branch block in dogs increased the duration of QRS 0.021 sec. Left bundle branch block increased the duration of QRS 0.029 sec. These are average values. The change in the duration of QRS in calves as compared to the change produced in dogs was, therefore, relatively insignificant.

Fig. 1 shows changes in the form of QRS typical of those produced by section of right and left bundle branches in calves and in

[4] Hafkesbring, R., and MacCalmont, W., *J. Pharm. and Exp. Ther.*, 1938, **64**, 43.

† In the first 8 bovine subjects, only 2 of which (B4 and B7) were included in the data.

[5] Lewis, T., *Phil. Trans. Roy. Soc.*, 1916, **207**B, 254, 267.

TABLE I.
Duration of QRS in Lead II Before and After Section of Right or Left Branches of the His-Bundle.

Right Bundle Branch Block					Left Bundle Branch Block				
		Duration of QRS (sec)					Duration of QRS (sec)		
Animal No.	Age (days)	Before section	After section	Increase	Animal No.	Age (days)	Before section	After section	Increase
				Calves.					
B 7	14	.05	.06	.01	B 4	7	.04	.05	.01
B 9	21	.05	.06	.01	B19	44	.04	.05	.01
B10	21	.05	.06	.01	B20	3	.05	.05	
B12	14	.055	.07	.015	B21	28	.05	.05	
B13	14	.055	.07	.015	B22†	28	.055	.065	.01
B15	14	.055	.08	.025†*	B23	3	.05	.05	
B17	240	.06	.07	.01					
B18	46	.05	.06	.01					
Mean		.053	.066	.013			.047	.052	.005
				Dogs					
D 5		.08	.10	.02	D 2		.05	.08	.03
D 7		.05	.08	.03	D11		.055	.08	.025
D 8		.04	.07	.03	D12		.05	.08	.03
D13		.055	.065	.01					
D14		.065	.08	.015					
D15		.05	.08	.03					
D16		.055	.07	.015					
Mean		.056	.077	.021			.051	.08	.029

* The exact QRS interval was difficult to determine in this instance because the end of the QRS group was ill defined.

† Failure to record lead II in the control tracing due to insufficient opening of the camera shutter necessitated the taking of data from lead III in this subject.

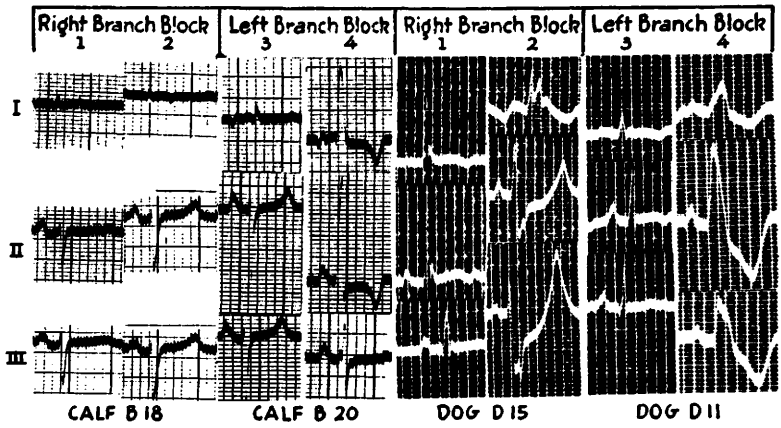

FIG. 1.

Electrocardiographic changes typical of those produced by section of the right and left bundle branches in calves and dogs. No. 1 and 3 are control records; No. 2 and 4 are records taken after section of the right or left bundle branches.

dogs. The canine left and right branch block curves are similar in form to those described by Lewis[5] and are very different from the control curves. The right branch block curves of the calves, however, were scarcely distinguishable from the control curves in the majority of instances. In some instances there was a slight increase in the size of S and in the voltage of T in leads II and III.

In comparison with the controls the left branch block curves of the calves showed much greater changes in the form of the ventricular complex but the character and magnitude of these changes varied greatly in different experiments. The form of the control curves was quite constant.‡ The deflections of Lead I were extremely small. In the other leads QRS consisted of an upright deflection (R) followed by a downward deflection (S). The relative size of R and S was variable but in most instances the latter was larger than the former. The T-waves were usually upright but of small voltage. After section of the left bundle branch the voltage of the largest QRS deflection was greater than in the control. In one instance QRS was represented by a large downward deflection in Lead I and a large upward deflection in Leads II and III. In this instance T_2 and T_3 were large and inverted. In 2 instances large R-waves and large inverted T-waves appeared in Leads I and II. In another experiment the changes were similar to those just described but less pronounced; in another the R deflection became larger and the T-wave became inverted in Leads II and III but the deflection in Lead I remained

‡ This uniformity is not seen in electrocardiograms of the normal bovine subject when taken in the standing position.[3]

small. In the remaining experiments the changes were very slight. Distinct notching of the larger QRS deflections did not occur in any experiment.

Compared to the electrocardiographic changes produced by right and by left bundle branch block in man and in the dog, those produced by cutting either of the bundle branches of the calf's heart are extremely small and as regards the form of the electrocardiogram conspicuously variable. This difference suggests that there is a decided difference in the distribution of the intraventricular conducting system between man and the dog, on the one hand, and the calf on the other. The smallness of the QRS interval of the bovine electrocardiogram points in the same direction. It is difficult to understand how the cardiac impulse can spread so quickly over the ventricular muscle of so large a heart if it spreads with approximately the same speed and in the same manner as in the human and the canine heart. The pronounced increase in the QRS interval produced by bundle branch block in man and in the dog has been attributed to the slow spread of the cardiac impulse through the ordinary muscle of the ventricular septum. The absence of a similar increase in the QRS following section of the bundle branches of the calf's heart suggests that in this animal the Purkinje networks of the 2 ventricles are connected by strands of specialized tissue which pierce the ventricular septum. Penetration of the outer ventricular walls by Purkinje tissue would for similar reasons account for the smallness of the QRS interval of the bovine electrocardiogram in comparison with the size of the ox heart. The differences between the branch block curves of the dog and those of the calf suggest that contrary to the conclusions of Abramson and his fellow workers the distribution of the Purkinje tissue is not similar in the two species, and that this tissue does not penetrate the ventricular septum of the canine heart. The same conclusion may be drawn with respect to the human heart and the hearts of other species in which bundle branch block induces electrocardiographic changes of comparable magnitude.

Summary. Changes in the duration and form of QRS after section of the branches of the His-bundle are much less pronounced in calves than in dogs. The difference between these two species is attributed to differences in the distribution of the intraventricular conducting system.

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