APPLICATION OF VECTOCARDIOGRAPHY IN CATTLE

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Introduction

Even if the anatomical cardiac axis is not identical to its electrical axis, it is well known that in various species, the cardiac morphological changes are reflected on the angle of electrical cardiac axis. In this way, it has been shown in man (1, 2), dog (3, 4) and horse (5, 6), that cardiac vectors amplitude and orientation are modified by growth, training or pathological ventricular hypertrophy induced by various cardiac disorders including right and left valvulopathy, hindrances in systemic blood circulation accompanying extracardial diseases and hypertension in pulmonary circulation. By contrast, in the bovine species, electrocardiography consisted up to now in a purely qualitative analysis of the cardiac electrical activity, whereas vectocardiographic studies were still lacking in this species. It was thus of great interest to perfect a vectocardiography technique for cattle. On the other hand, in ungulae, depolarisation pattern of the heart is specific because of a particular organisation of the Purkinje fibers in the myocardium (7). Accordingly, several specific lead systems have been developed in the horse to quantify tridimensional vectocardiographic parameters. Because of the similarities between cardiac electric activity and between heart position within the thorax in horse and cattle (7), the validity of four of these equine lead systems was compared when transposed in calves.

Material and method

Fifty seven electrocardiograms were collected from 33 male healthy calves (body weight: 107.1 ± 66.5 kg; age: 103.8 ± 91.0 days), 24 of them being investigated two times as they grew.

Electrocardiograms were obtained by means of a one-channel recorder (Cardiofax GEM, Nihon-Kondem, Japan) connected to a rapid writing polygraph (ES 1000, Gould, Belgium) which allowed recording at a paper speed of 100 mm/sec. Calibration was carried out before and after each investigation at a sensitivity ranging from 4 to 8 cm per mV.

Electrocardiograms were recorded according to four different lead systems successively, namely the Einthoven (Ei, 8, 9), Hamlin (Ha, 10), Muylle (Mu, 11) and Holmes (Ho, 9, 12) lead systems. For each lead system, electrodes location and leads used to record in the horizontal, transversal and sagittal planes are outlined in Table 1.

From the electrocardiograms, the algebric sum of positive and negative deflections was calculated. The P, QRS and T modal vectors were graphically constructed in the horizontal, transversal and sagittal planes and in space, and their amplitude and orientation measured. The method of measuring angles and viewing planes advocated in horses (13) was adopted.

In 10 calves (body weight: 178.3 ± 54.7 kg; age: 194.7 ± 92.4 days), the protocol was repeated within one day in order to evaluate the reproducibility of the results obtained by application of each lead systems.

The variance and the coefficient of variation relative to the tridimensional cardiac modal vectors orientation and amplitude were calculated on the 57 recorded electrocardiograms. The variances obtained by the application of the four lead systems were compared to each other by a F-test. A one-way analysis of variance was applied in order to compare day 1 and day 2 vectocardiographic results obtained in 10 calves. The mean percentage of error (M%E) between day 1 and day 2 measurements was calculated and a linear regression was fitted between day 1 and 2 measurements.

Table 1. Electrodes position and leads arrangement in the horizontal (Hor), transversal (Trans) and sagittal (Sag) planes, according to the Einthoven, Hamlin, Muylle and Holmes lead system.

	Einthoven		Hamlin		Muylle		Holmes	
	+	-	+	-	+	-	+	-
Hor	LF*	RF*	LF*	RF*	MP*	RF*	LT#	RT#
	LH*	LF*	LH*	RF*+LF*	MP*	LF*	XP*	MS*
Trans	WΔ	RF*	LF*	RF*	SM*	RSΔ	LT#	RT#
	WΔ	LF*	WΔ	RF*+LF*+LH*	SM*	LSΔ	WΔ	SM*
Sag	WΔ	LF*	LH*	RF*+LF*	WΔ	SM*	XP*	MS*
	LH*	LF*	WΔ	RF*+LF*+LH*	XP	WΔ	WΔ	SM*

*, Δ and #: alligator clip, disposable and tin plate electrode, respectively; + and -: positive and negative electrode; LF and RF: left and right foreleg respectively, medial aspect of the olecranon; LH: left hindleg, medial aspect of the patella; MP: abdomen midline at midway between left and right patellar regions; LT and RT: left and right lower third of the thorax respectively, just behind the elbow; XP: abdomen midline in front of the xiphoid process; MS: midway between the shoulders, in front of the manubrium process; W: withers, at the level of the dorsal spinous process of the sixth thoracic vertebra; SM: sternum midline, at midway between the elbows; RS and LS: posterior angle of the right and left scapula, respectively.

Results

Whatever the lead system applied, the one-way analysis of variance did not show any statistical difference ($P > 0.05$) between the amplitude or the orientation of the modal vectors obtained on day 1 and on day 2. The M%E relative to the cardiac modal vectors amplitude and orientation was generally higher in the horizontal than in the other planes. When compared with the 3 other lead systems, the Ho lead system gave lower M%E of cardiac modal vectors amplitude and orientation, this effect being the most marked for the vectors orientation when compared with vectors amplitude, and for the horizontal plane when compared with other planes. When the Ho lead system was applied, the correlation coefficients between day 1 and day 2 cardiac modal vectors amplitude and orientation measurements were higher than those obtained with the other lead systems.

Statistical comparison concerning the between-subjects variance of the vectocardiographic parameters is reported in Table 2. The between-subjects variance and coefficient of variation concerning the modal vectors amplitude were generally higher in the horizontal than in the other planes. This was also the case at a more pronounced level concerning the modal cardiac vectors orientation. Compared to the three other lead systems, the Ho lead system generated slightly lower between-subjects coefficients of variation concerning P and QRS modal vectors amplitude. When the Ha lead system was used, the amplitude of most of the QRS and T modal vectors was characterized by significantly lower between-subjects variance. Application of the Ho lead system greatly reduced the between-subjects coefficient of variation concerning the cardiac modal vectors orientation. This effect was more pronounced in the horizontal plane than in the other planes. When the Ho lead system was used, the variance of the cardiac modal vectors orientation was significantly lower than those obtained with the three other lead systems.

Table 2. Comparison of the between-subjects variance concerning the tridimensional and spatial cardiac modal vectors amplitude (in mV^2) and orientation ($^{o2}.10^{-2}$) obtained by application of the Ei, Ha, Mu and Ho lead systems.

		Amplitude variance				Orientation variance			
		Ei	Ha	Mu	Ho	Ei	Ha	Mu	Ho
P	Hor	2.8	2.0	1.9	1.3^{ab}	145.1	114.5	88.2^{a}	1.5^{abc}
	Trans	1.9	1.6	1.3	1.1^{a}	2.0^{c}	1.5^{c}	4.9	1.8^{c}
	Sag	1.8	0.6^{a}	1.3	1.3^{b}	2.9	3.4	1.8^{ab}	1.1^{abc}
	Spat	5.3	1.5^{a}	4.5^{b}	1.2^{ac}	1.1	1.2	1.0	0.9
QRS	Hor	56.0^{d}	48.4^{d}	52.0^{d}	95.0	134.7	150.6	134.2	4.7^{abc}
	Trans	15.4^{cd}	17.8^{cd}	58.2	37.1^{c}	4.0	4.1	0.6^{abd}	3.1
	Sag	32.1	19.8^{acd}	33.7	46.8	5.1	4.8	3.2	3.2^{a}
	Spat	38.6	30.0^{cd}	47.0	56.6	7.4	2.4^{ac}	8.6	3.0^{ac}
T	Hor	11.2^{d}	9.6^{d}	13.5^{d}	31.4	107.0	80.0	104.7	10.5^{abc}
	Trans	7.3^{cd}	6.6^{cd}	22.8	16.8	10.6	14.8	3.1^{ab}	4.2^{ab}
	Sag	11.9^{cd}	7.3^{acd}	21.0	29.1	9.8	9.8	6.2^{ab}	7.7
	Spat	26.4	9.2^{acd}	39.9	31.5	1.6^{bd}	2.5	1.3^{bd}	2.9

Hor, Trans, Sag and Spat : horizontal, transversal, sagittal and spatial modal vectors respectively; ^{a}, ^{b}, ^{c} and ^{d} : variance significantly lower than the variance obtained by application of the Einthoven, Hamlin, Muylle and Holmes lead system respectively, F-test, $p \leq 0.05$.

Discussion

When compared to the Ei, Ha and Mu lead systems, the Ho lead system produced the most reliable results, giving the lowest between-day and between-calves variations. In men (14) and horses (9), such an evaluation of the validity of a lead system by comparison with results generated by other lead systems was also performed. To be completely accurate, validation of a lead system in cattle should include isopotential maps studies as a standard for comparing the lead systems (12, 14). Indeed, integration of the cardiac electric activity recorded from a great number of body surface points allow to derive the resultant cardiac dipole moments, taking into account the body shape and the position of the cardiac generator within the thorax (15). However, the manual construction of isopotential maps distribution is time consuming (15) and consequently hard to apply to a large number of subjects. Moreover, isopotential maps were already studied in horses (8, 15) and because of the close similarity of equine and bovine cardiac depolarization pattern (7), the conclusions drawn in horses are probably extendable to cattle.

There are few studies reporting electrocardiographic measurements reproducibility (16). However, this way is interesting in order to validate a lead system. As the best reproducibility of tridimensional P, QRS and T modal vectors orientation and magnitude was obtained with the Ho lead system, this provides therefore a valuable argument to justify the selection of this lead system in cattle.

Although previously applied in other species, it is probably less valuable to justify the selection of a lead system on the basis of the variability of results issued from a large number of subjects. Indeed, the between-subjects variability obtained in the present study could be attributed not only to the technique, but also to confounding variables such as age (17, 18, 19, 20), breed (17, 21, 22), bodily conformation (16, 23) or sex (22) of the subjects. However, when the Ei, Ha and Mu lead system were used, the P, QRS and T modal horizontal vectors magnitude and angles showed very large differences between the calves. So large between-subjects variations may not be interpreted as physiological. Several authors (9, 12, 19, 23) also reported, in large animals, wide variations in electrocardiographic data measured in the horizontal plane when classical limb leads, or leads derived therefrom, are used. This may be due to the fact that the limb leads are unable to produce vectocardiographic data representative of the true cardiac electric field in these species (12). In the present study, the use of large electrodes in the right to left axis induced a significant reduction of the inter-individual variability in horizontal vectors magnitude and orientation, and gave results more comparable between calves. This was previously observed in horses (9, 12), and was explained by the fact that large electrodes in the X-axis give a more accurate representation of the cardiac electric field in the horizontal plane than the classical limb leads.

In conclusion, when compared to the three other lead systems, the Ho lead system is the most appropriate to further develop vectocardiography in the bovine species.

Summary

For spatial vectocardiography to become an useful tool for cardiac investigation in cattle, it was first necessary to develop a reliable standardized electrocardiographic lead system in this species. In this study, four tridimensional lead systems were compared in calves. Fifty seven electrocardiograms were collected. The between-subjects variability of the magnitude and angles of the tridimensional P, QRS and T modal vectors obtained by use of each lead system was compared. Reproducibility of vectocardiographic measurements was analyzed by comparing results obtained in 10 calves within one day interval.

The Holmes semi-orthogonal lead system, giving the lowest between-subjects variability and the highest between-days reproducibility, appeared to be the most reliable lead system in order to further develop vectocardiography in the bovine species.

Résumé

L'utilisation de la vectocardiographie en tant que technique d'investigation cardiaque dans l'espèce bovine supposait la mise au point préalable d'un système de dérivation standardisé et fiable dans cette espèce. Dans cette étude, 4 systèmes de dérivation tridimensionnels ont été comparés chez le veau. Cinquante quatre électrocardiogrammes ont été enrégistrés. La variabilité "entre individus" des résultats obtenus en ce qui concerne l'amplitude et la direction des vecteurs modaux P, QRS et T tridimensionnels a été comparée pour chacun des systèmes de dérivation. D'autre part, la répétabilité des mesures vectocardiographiques a été testée par comparaison des résultats obtenus à 1 jour d'intervalle chez 10 veaux. Le système semi-orthogonal de Holmes a permis d'obtenir la plus faible variabilité "entre individus" et la plus haute répétabilité d'un jour à l'autre. Dès lors, il a été conclu que ce système était le plus fiable pour l'application ultérieure de la vectocardiographie chez le bovin.

Zusammenfassung

Um die dreidimensionale Vektorkardiographie zu einer brauchbaren Technik für Herzuntersuchungen beim Rind zu entwickeln, war es zunächst erforderlich, ein zuverlässiges und standardisiertes elektrokardiographisches Ableitungssystems für diese Spezies zu finden. In dieser Studie wurden vier dreidimensionale Ableitungssysteme an Kälbern verglichen. Siebenundfünfzig Elektrokardiogramme wurden erfaßt und gespeichert. Zwischen den vier Ableitungssystemen wurden die interindividuelle Variabilität der Amplitude und der Richtung der dreidimensionalen Modalvektoren P, QRS und T verglichen. Die Reproduzierbarkeit der vektorkardiographischen Messungen wurde durch einen Vergleich der Ergebnisse, die im ein- Tages -Intervall an 10 Kälbern ermittelt wurden, untersucht.

Das semi-orthogonale Ableitungssystem von Holmes ergab die niedrigste Variabilität zwischen Individuen und die höchste Reproduzierbarkeit von einem Tag zum anderen. Somit scheint dieses System das zuverlässigste zu sein, um die Vektorkardiographie beim Rind weiter zu entwickeln.

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