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Onthogenic Changes in the Orientation of the Ventricular Activation and Recovery Mean Vector in Pig

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The effect of physical maturation on the ventricular activation and recuperation mean vectors has been analyzed in pigs during a period of time between 1 day and 6 months of age. The results showed that whilst the vectorial magnitude of ÂQRS on the horizontal plane was not affected by physical maturation, that of the spatial vector (SÂQRS) underwent an increase during the period of study. Likewise, it was determined that the ventricular activation front showed an inclination to change its orientation from caudal, sinistral or dextral, to dextro-cranial, maintaining the dorsal orientation in all individuals. For the ventricular recuperation mean vector the results showed that its vectorial magnitudes both on the horizontal plane and in space underwent an increase during the 6 months analyzed. As regards the direction of the recuperation front, it was established that, at any age, the preferential orientation is caudal, with a deviation to the left in a high percentage of the 20 day to 3 month old pigs, and ventral in all individuals.

Key words: ECG, Cardiac vectors, Maturation, Pig.

From an electrical point of view, each vector behaves like a dipole of variable direction and voltage, oriented in such a manner that the negative pole remains in the «tail» of the vector and the positive pole in the «head» (8).

Since the cardiac activation front moves to negatively charged areas leaving electrically positive areas behind it, the spread of the activation wave through the myocardium involves the creation of numerous dipoles. These dipoles are represented by vectors whose algebraic sum is a vector that symbolizes the general orientation of electrical activity in the myocardium.

The orientation of the QRS mean vector, which shows the general direction of ventricular depolarization, has been analyzed in pigs by numerous authors (1, 2,

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6, 13, 15, 16); HAMLIN (9) points out that the ventricular activation process in pigs is symbolized by three principal vectors with a similar direction to those of all mammals studied except ruminants and equines.

The ventricular recuperation can also be symbolized by a vector that is the result of the algebraic sum of dipoles originated as a consequence of repolarization of ventricular myocardic fibres. This vector that shows the general direction of the ventricular recuperation front is represented by the T mean spatial vector and, as in other species, in pigs there is limited information about its orientation (6, 9, 16, 17). The lack of patterns for each species could be attributed to the great lability of the ventricular recuperation wave (T wave), probably related to variations in the cancellation degree during recuperation (3).

This consideration and the fact that in bovines (21) and ovines (25) the orientation of the mean cardiac vector was notably affected by physical maturation has suggested the necessity of carrying out a profound analysis of ECG of swine from birth to 6 months of age in order to determine in which direction the activation and recuperation of the ventricular myocardium are verified and to study the possible influence of physical maturation on these processes.

Materials and Methods

This study was carried out on 30 (17 males and 13 females) Landrace X White Belgian bred pigs during the first 6 months of life. The electrocardiographic outline was obtained at different stages of maturation: in the first 24 hours of life, at 5, 20 and 45 days, and at 3, 4.5 and 6 months of age.

The ECG were recorded by a portable monochannel electrocardiograph (SAN-EI, Mod. 1E22), with a paper speed of 50 mm/s and a sensitivity of 10 mm/mV. The semiorthogonal lead system formed by I, aVF and V_{10} leads which supplied information on the cardiac activity in the three space directions was used. They were obtained by the implantation of alligator clips electrodes on both thoracic limbs at the humero-radio-cubital joint level (lead I), on the left pelvic limb at the femoro-tibio-rotuliana joint level (lead aVF) and at the dorsal spinal process of the seventh thoracic vertebrae (lead V_{10}) (10).

The deflections of the ventricular complex were added up and the values obtained in each of the three leads were displayed on their respective axes (X, Y, Z), permitting the determination of the magnitude of QRS mean vectors on the horizontal plane (V) and in space (V′). The V and V′ values were calculated by using the expressions (26):

$$V = \sqrt{x^2 + y^2} \quad V' = \sqrt{x^2 + y^2 + z^2}$$

It is possible to establish the ÂQRS position (left or right and cranial or caudal) by dividing the horizontal plane in 360° (14) and determining the angle that is made with the X axis. The angle that the spatial vector (SÂQRS) makes with the Z axis shows, moreover, its position in a dorso-ventral direction. Both angles can be determined geometrically.

The same methods used for the QRS mean vectors were also employed to obtain information about the vectors of ventricular recuperation (ÂT and SÂT).

The values obtained for each parameter analyzed were subjected to statistical treatment. In order to find out the influence of age, analyses of variance and, subsequently, a Q-test were carried out (22, 23).

Results

The magnitudes of the QRS mean vectors on the horizontal plane (VÂQRS) and in space (V'SÂQRS) are represented in

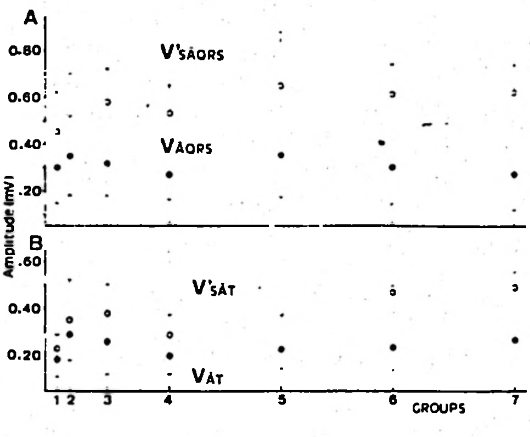

Fig. 1. *Representation of QRS and T vectorial magnitudes (media ± SD) in horizontal plane (V) and space (V') for each age analyzed.*
Number 1 to 7 refer to different stages of maturation; 1 = 1 day; 2 = 5 days; 3 = 20 days; 4 = 45 days; 5 = 3 months; 6 = 4.5 months; 7 = 6 months.

fig. 1. The results of the F-test do not show any significant variations for the QRS mean vectors magnitude on the horizontal plane (V); conversely, the spatial mean vector magnitude (V') experiences significant changes ($F[6, 203] = 4{,}835$; $p = 0.001$) in the whole group of individuals. Lastly, the Q-test confirms the existence of differences when the 1-day old pigs are compared with those of 20 days, 3, 4.5 and 6 months of age, these last groups showing the highest vectorial magnitudes for SÂQRS.

The mean values for T vectorial magnitudes on the horizontal plane (VÂT) and in space (V'SÂT) are plotted in the B graph of fig. 1. When the analysis of variance is applied to the magnitudes of the ventricular recuperation vector the results show variations for this parameter both on the horizontal plane ($F[6, 203] = 5{,}587$; $p = 0.001$) and in space ($F[6, 203] = 32{,}586$; $p = 0.001$) for the whole group of individuals. The Q-test carried out subsequently permitted us to confirm that differences in the ÂT magnitudes (V) appear when the 1-day old group is compared with the 5 and 20 days old groups, and with groups of older individuals (4.5 and 6 months). These results have also been noticed in relation to the magnitudes of the T spatial vector (V') and further significant differences between pigs of 4.5 and 6 months and the remaining younger ones have been observed.

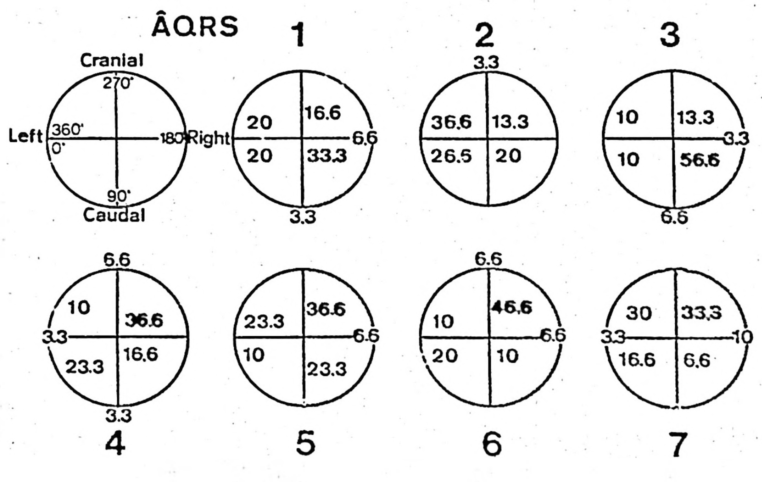

Fig. 2. *Percentage of each QRS mean vector orientations in horizontal plane obtained in each group of age.*
The shaded area indicates the preferential orientation. Number 1 to 7 as in fig. 1.

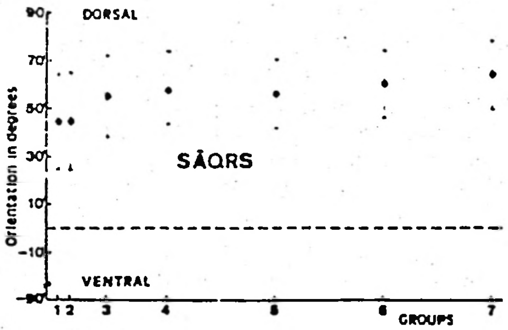

Fig. 3. *QRS mean spatial vector orientations (media ± SD) in dorso-ventral direction for each age analyzed.*
Legend as in fig. 1.

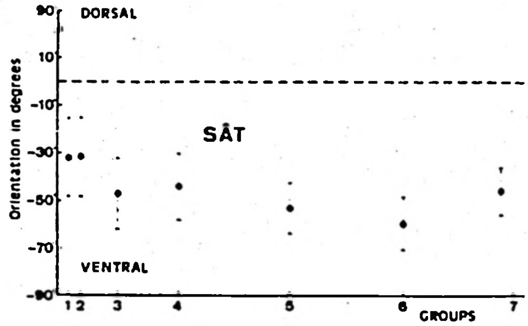

Fig. 5. *T mean spatial vector orientation (media ± SD) in dorso-ventral direction for each age analyzed.*
Legend as in fig. 1.

When the activation ventricular mean vectors are plotted on the horizontal plane (fig. 2) a great variability is observed in all 7 age groups analyzed. At 1 day and 20 days, in the majority of cases the ÂQRS is directed caudally, either to the right or to the left. On the contrary, in pigs that are included in groups 4, 5, 6 and 7, the preferential orientation is cranial with a deviation to the right prevailing. The graph of the mean values of the QRS spatial vector in dorso-ventral direction indicates that the vector takes a dorsal direction in all groups analyzed, with values ranging from 44° in groups of 1 day and 5 days to 63° in the group of 6 month old pigs (fig. 3).

When the ventricular recuperation mean vectors are represented on the horizontal plane a predominance of a caudal orientation in all groups analyzed is obtained with a deviation to the right in the groups of 1 day and 5 days, and 4.5 and 6 month old pigs, and to the left in 20 days to 3 months of age individuals (fig. 4).

In dorso-ventral direction the ventricular recuperation vector (SÂT) presents a ventral orientation in all cases with mean values ranging from −31° in 5 day olds to −59° in 4.5 months group (fig. 5).

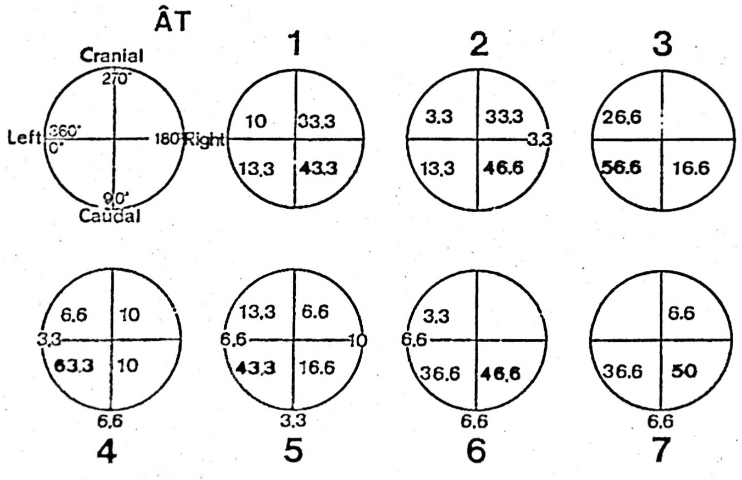

Fig. 4. *Percentage of each T mean vector orientation in horizontal plane obtained in each group of age.*
Legend as in fig. 2.

Discussion

The results obtained for the ÂQRS vectorial magnitude indicate that physical maturation does not affect the vectorial forces registered on the horizontal plane. In contrast, the SÂQRS vectorial magnitude increases from the first day of life coinciding with the increase of voltage registered in lead V_{10} (19) according to the increase in age. This change in the SÂQRS magnitude does not coincide with results obtained in ovines (25) in which a decrease with age increase is observed. These observations indicate that physical maturation affects the ventricular myocardium, increasing the vectorial forces that are registered in dorso-ventral direction, which suggests a greater development of the apical and/or basal ventricular areas.

With regard to the orientation of the mean QRS vector on the horizontal plane, there is a great variability coinciding with the diversity of configurations obtained for the ventricular activation complex in lead I and aVF (X and Y axes) (19). In spite of the great variability obtained in this study for the orientation of ÂQRS in pigs, confirmed by other authors (2, 15, 16), it can be affirmed that in the majority of the individuals and whatever the age, the ventricular activation front is directed to the right, contrary to what DUKES and SZABUNIEWICZ (6) pointed out in pigs of 2 to 4 months of age in which the QRS vector is directed to the left.

The changes in orientation that are observed up to 45 days of age (groups 1 to 3) could be linked to the maturational changes of the ventricular walls which would lead to a greater development of the myocardium areas free from Purkinje fibres that appear in some species of the B electrocardiographic category to which pigs belong, together with horses and ruminants (11). This evolution determined that, in our study, the direction of the ventricular activation acquired a greater uniformity from 45 days, in a similar manner to that occurring in bovines (21) and thus a cranial orientation predominated with a preferential deviation to the right.

The SÂQRS orientation in dorso-ventral direction indicates that the ventricular activation front spreads dorsally in all individuals at any age. This agrees with data given by other authors in pigs (6, 13, 15, 16), horses (7) and ruminants (21, 25, 26). This indicates that the ventricular activation front goes in an apicobasilar direction whatever the age or species, probably due to the heart position in the thorax being similar in all mammals.

The orientation of the recuperation vectors has not been established in pigs, probably because, as occurs in other species, the ventricular recuperation can be affected by numerous factors (4, 20, 24) that can cause changes in the sequence of this process and make the repolarization usually take an inverse route to that used by the depolarization waves, in such a manner that ventricular recuperation is initiated in areas activated later on.

In this work it has been verified that although throughout the study periods deviations of ÂT to left or right were observed, the general direction of the ventricular recuperation front on the horizontal plane is preferentially caudal in all age groups analyzed, which suggests that the recuperation process beging in the posterior ventricular walls.

The displacement of the T mean vector to the left or right during the study period could be related to the beginning of recuperation in the epicardial or endocardial areas due to the pressure changes probably caused by the closure of the ductus arteriosus (5) and the different development reached by the ventricular masses after birth (18).

In dorso-ventral direction a greater uniformity exists and the vector is directed ventrally in all individuals, which concurs with results obtained in ruminants (21, 25, 26), horses (7) and pinnipeds (12). This indicates that the recuperation front also spreads towards the ventricular basis independently of the physical maturation.

Resumen

Se analiza el efecto de la maduración física sobre los vectores medios de activación y recuperación ventricular en cerdos durante un período de tiempo comprendido entre el primer día y el 6.° mes de edad. Los resultados muestran que, mientras la magnitud vectorial de ÂQRS en el plano horizontal no es afectada por la maduración física, la del vector especial (SÂQRS) experimenta un incremento a lo largo del período estudiado. Además, se observa que el frente de activación ventricular muestra un cambio de una orientación caudal, izquierda o derecha, hacia la derecha-craneal, mateniéndose la orientación dorsal en todos los individuos. Para el vector medio de recuperación ventricular, las magnitudes vectoriales en el plano horizontal y en el espacio se incrementan durante los 6 meses analizados. Asimismo, el vector resultante del frente de recuperación ventricular para cualquier edad muestra una orientación preferentemente caudal, con una desviación hacia la izquierda en un alto porcentaje de cerdos de 20 días a 3 meses de edad, y ventral en todos los individuos.

Palabras clave: ECG, Vectores cardíacos, Maduración, Cerdo.

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