Repolarization of the Rabbit Cardiac Ventricles after an Increase of Potassium Concentration in the Plasma

J. E. Azarov, N. L. Simakova, V. A. Vityazev, and D. N. Shmakov

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The sequence of ventricular epicardium repolarization in rabbits with hypokalemia is directed from the apex of the heart to its base in accordance with distribution of local repolarization intervals. Under conditions of hyperkalemia, the propagation of excitation wave is inhibited without changes in its sequence; while the duration of repolarization decrease mainly in zones where it was initially long (the base of the right ventricle), as a result of which the distribution of local repolarization intervals becomes more uniform and a relationship between the repolarization and activation sequences is formed.

Key Words: *activation; hyperkalemia; rabbit; repolarization; epicardial mapping*

Increase of intracellular potassium concentration leads to deceleration of pulse conduction in the myocardium and shortens the cardiomyocyte action potentials [3]. These changes are observed in ischemic myocardium, forming a functional arrhythmogenic substrate at the site of impaired bloodflow. Higher sensitivity of left ventricular subepicardial myocytes to hyperkalemia in comparison with subendocardial ones has been demonstrated [5,6], but no data on the differences in electrophysiological effects of hyperkalemia in various sites of the right (RV) and left (LV) ventricles *in situ* and on its effects on the depolarization and repolarization sequences of ventricles in general have been published.

We studied the sequence and dispersion of the rabbit cardiac ventricular epicardium repolarization and the factors essential for it (sequence of activation and distribution of local repolarization intervals) under conditions of high potassium concentration in the arterial blood.

Laboratory of Cardiac Physiology, Institute of Physiology, Komi Research Center, Ural Division of Russian Academy of Sciences, Syktyvkar, Russia. ***Address for correspondence:*** azarov@physiol.komisc.ru. J. E. Azarov

MATERIALS AND METHODS

Experiments were carried out on urethane narcotized (1.5 g/kg intraperitoneally) chinchilla rabbits (n=5). After opening the chest a system of 64 epicardial electrodes was applied to the cardiac ventricles; unipolar electrograms (in relation to the Wilson's terminal) were recorded from these electrodes under conditions of sinoatrial rhythm. The following parameters were determined for each epicardial lead: activation time (depolarization, onset of activation wave; evaluated by the potential derivative minimum time during the *QRS* period); time of repolarization completion (by the potential derivative maximum time during the *ST-T* period); local duration of repolarization (activation-recovery interval, ARI), determined as the interval between activation and repolarization moments) [4], including ARI value corrected by cardiac cycle length using Basette's formula. The method of epicardial potential mapping was described elsewhere [2].

Extracellular potassium concentrations was changed from 3.02±0.19 to 8.01±0.47 mmol/liter by

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intravenous infusion of potassium chloride (0.1 N in saline, drip infusion) with monitoring of arterial blood electrolyte composition.

The dispersion of activation characterizing the duration of stimulation propagation on ventricular surfaces was calculated as the difference between the maximum and minimum activation time in the mapped area. The dispersion of repolarization completion and dispersion of local ARI were evaluated similarly.

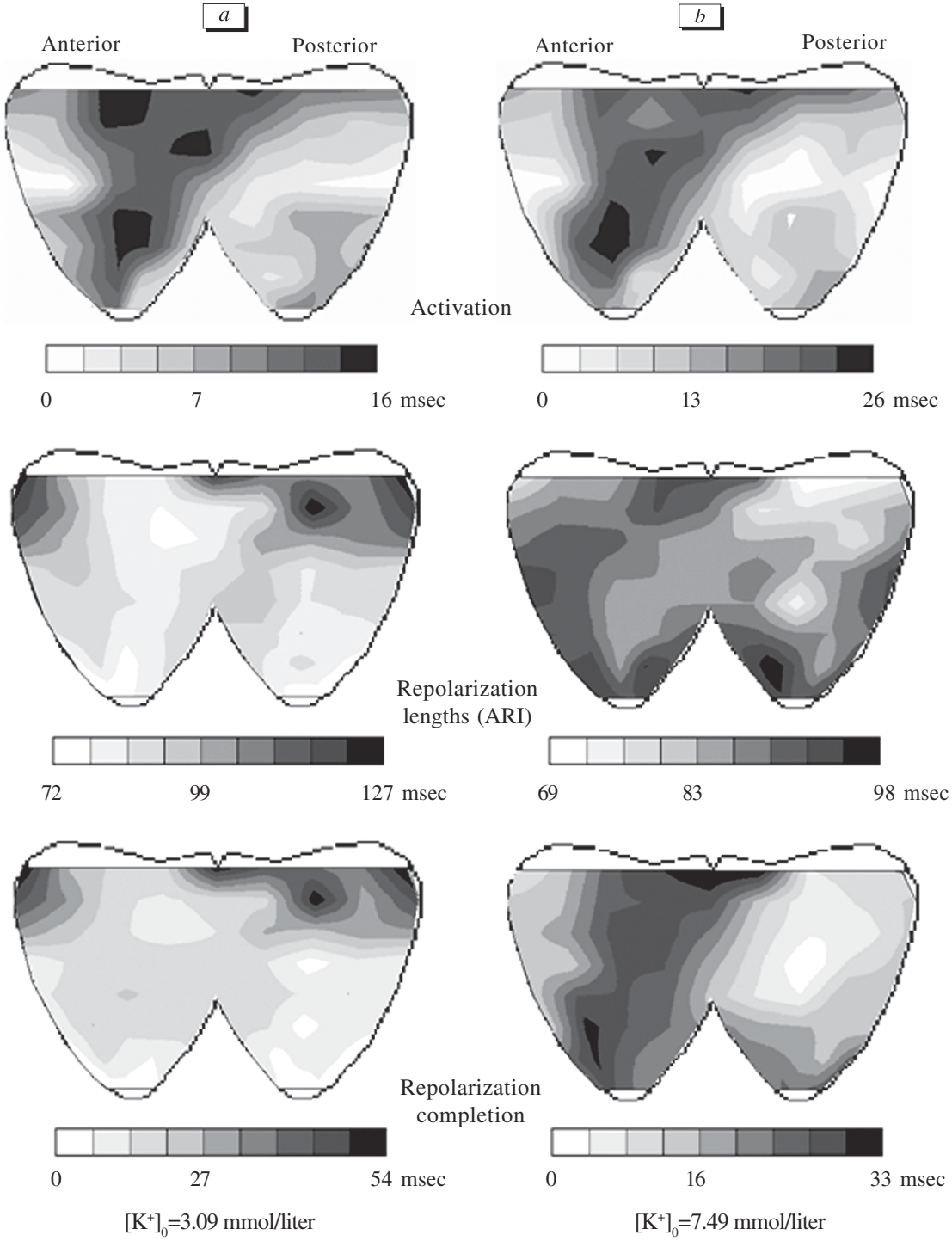

Fig. 1. Representative maps of activation sequence, ARI distribution, and repolarization sequence for the rabbit cardiac ventricular epicardium in hypokalemia (*a*) and hyperkalemia (*b*). Each map presents the ventricular epicardium surface. Left half of the map corresponds to the anterior surface, right half to posterior surface; the upper part corresponds to ventricular base, lower part to the apex. Time of repolarization completion is shown for the minimum value.

The data were statistically processed using Student's *t* test for repeated measurements with Bonferroni correction. The differences were considered significant at $p<0.05$.

RESULTS

Activation sequences, distribution of local repolarization intervals, and repolarization sequences recorded on ventricular epicardium under conditions of hypokalemia (3.02±0.19 mmol/liter) virtually did not differ from the values previously determined in normal potassium concentration [1,2]. Activation sequence in general is characterized by two foci of stimulation wave break-through in the upper thirds of both ventricles and propagation of the excitation wave from these zones towards the cardiac base and lateral LV area. The minimum local repolarization intervals were recorded on the heart apex and the adjacent part of free LV wall, the longest ones on RV base. Ventricular epicardium repolarization sequence did not repeat the depolarization sequence ($r=0.10$, $p<0.001$), but corresponded to ARI distribution ($r=0.97$, $p<0.001$): repolarization was over sooner in areas with the shortest ARI and later in areas where it was the longest (Fig. 1, *a*). The time of excitation was significantly shorter than local ARI dispersion and repolarization completion time (Table 1).

The propagation of the excitation wave was decelerated in hyperkalemia (8.01±0.47 mmol/liter), which was confirmed by an increase in activation dispersion (Table 1), while the sequence of depolarization remained unchanged under these conditions (Fig. 1, *b*). The duration of repolarization decreased, but this decrease reached the level of statistical significance only for RV base (Fig. 2). The degree of ARI shortening depended on its initial length: the longer ARI in hypokalemia, the greater it shortened in hyperkalemia (Fig. 3). Because of heterogeneous shortening of ARI in various epicardial areas, the distribution of local repolarization intervals was in fact inverted: the shortest intervals were recorded for RV base and the longest ones for LV apex (Fig. 1, *b*); in addition, ARIc dispersion decreased significantly (Table 1). Since excitation wave propagated slowly in hyperkalemia and the distribution of local repolarization intervals was more or less uniform, the repolarization sequence (Fig. 1) repeated activation sequence ($r=0.88$, $p<0.001$). Dispersions of activation, local lengths, and time of repolarization completion in hyperkalemia did not

TABLE 1. Dispersions of Activation, ARI, and Time of Repolarization Completion in Hypo- and Hyperkalemia ($M\pm m$; $n=5$)

Dispersion of parameter	Hypokalemia	Hyperkalemia
Activation, msec	17±2	56±32$^+$
ARI, msec	55±11*	41±17
ARIc, msec	110±12	78±20$^+$
Repolarization completion, msec	54±5**	58±32

Note. *$p<0.01$, **$p<0.001$ compared to activation dispersion; $^+p<0.05$ compared to hypokalemia.

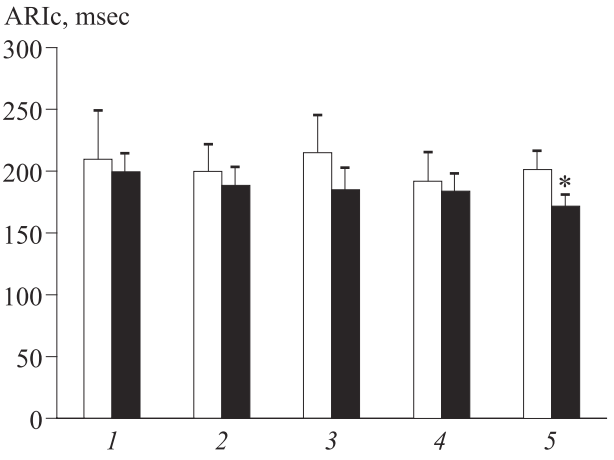

Fig. 2. Local activation-recover intervals evaluated as corrected ARI values, in various epicardial areas in hypokalemia (light bars) and hyperkalemia (dark bars). *1*) apex of the heart; *2*) LV middle; *3*) RV middle; *4*) LV base; *5*) RV base. *$p<0.05$ compared to hypokalemia.

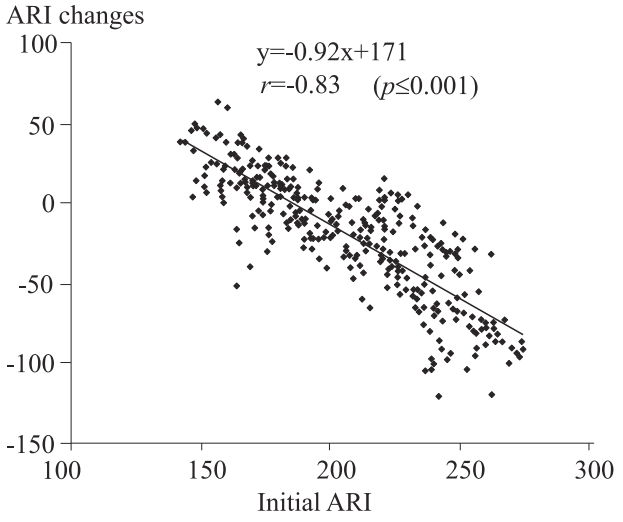

Fig. 3. Relationship between ARI in hypokalemia and its shortening under conditions of hyperkalemia. Regression equation parameters and coefficient of correlation between the independent and dependent variables are shown. The data on 5 animals are grouped; $n=320$. *x*: initial length of activation-recovery intervals; *y*: its alteration in hyperkalemia.

differ from each other (Table 1), which indicated greater contribution of activation sequence to the formation of ventricular epicardial repolarization sequence under these conditions.

Hence, our studies showed that the excitation wave propagation in hyperkalemia was inhibited without modification of its epicardial sequence: local repolarization inetrvals decreased mainly in zones with their initially high values, while repolarization sequence formed a relationship with activation sequence.

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