METHODS

Determination of the Sensitivity Reserve of Implantable Electrostimulator to the *R* Wave during Cardiomyoplasty

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Measurement of the *R* wave amplitude and evaluation of the sensitivity reserve of implantable apparatus during cardiomyoplasty make it possible to prevent postoperation desynchronization of the electrostimulator. The sensitivity reserve for an ECS-445 electrostimulator is established. Measurements of acute *R* waves in 15 patients are presented.

Key Words: *cardiomyoplasty; acute electrocardiogram; R wave; electrostimulator*

Desynchronization of implanted electrostimulator of the muscular blood pump (ESMBP) is a postoperation complication of cardiomyoplasty surgery. This complication very seldom arises from technical causes such as failure of myocardial electrode, pin jack, or ESMBP circuit. Desynchronization usually occurs when the amplitude of chronic *R* wave signal delivered by the myocardial electrode decreases below the sensitivity threshold of the implanted apparatus. This switches the cardiac channel of ESMBP to a regime of constant heart stimulation with a frequency below the proper heart rate. The interference of these rhythms may lead to grave ventricular arrhythmias up to ventricular fibrillation and, besides, it is usually accompanied by interference of muscular and cardiac contractions. When heart rhythm is out of control, some muscular contractions inevitably coincide with diastole.

The loss of ESMBP sensitivity can be prevented by measuring the amplitude of acute *R* wave in order to determine its reserve with respect to the sensitivity threshold of the implanted apparatus [2]. Here we describe the technique and results of such measurements.

The magnitude of this reserve should be specially discussed, since ESMBP produced by various manufacturers have different minimum, settled, and maximum sensitivity threshold of the myocardial channel to the *R* wave. For instance, the minimum threshold in an ECS-445 electrostimulator (Elestim, Russia) is 1.5 mV, manufacturer's setting is 2.5 mV, and the maximum threshold is 8 mV, while the respective values for an SP1005 apparatus (Medtronic) are 0.6, 1.25, and 2.5 mV, respectively.

Similar to implantable cardioverters, a 2-fold reserve of acute *R* wave with respect to minimum sensitivity threshold of the implanted ESMBP has been previously proposed [2]. Since the method for controlling the synchronization reliability was developed during clinical approbation of a STIMINAK-805 apparatus (Moscow Engineering and Physical Institute) with the only value of sensitivity threshold 3 mV [1], it was proposed that the amplitude of acute *R* wave (U_R) during fixation of the myocardial electrode should be no less than 6 mV (U_R>6 mV) to ensure reliable functioning of the stimulator during the postoperation period.

It should be noted that U_R=6 mV assures and even surpasses the 2-fold reserve of the sensitivity threshold with respect to manufacturer's setting (2.5 mV). The use of manufacturer's setting but not the minimum threshold in this procedure affords some advantages, namely, it relieves the surgeon of readjusting the ESMBP at the end stage of operation.

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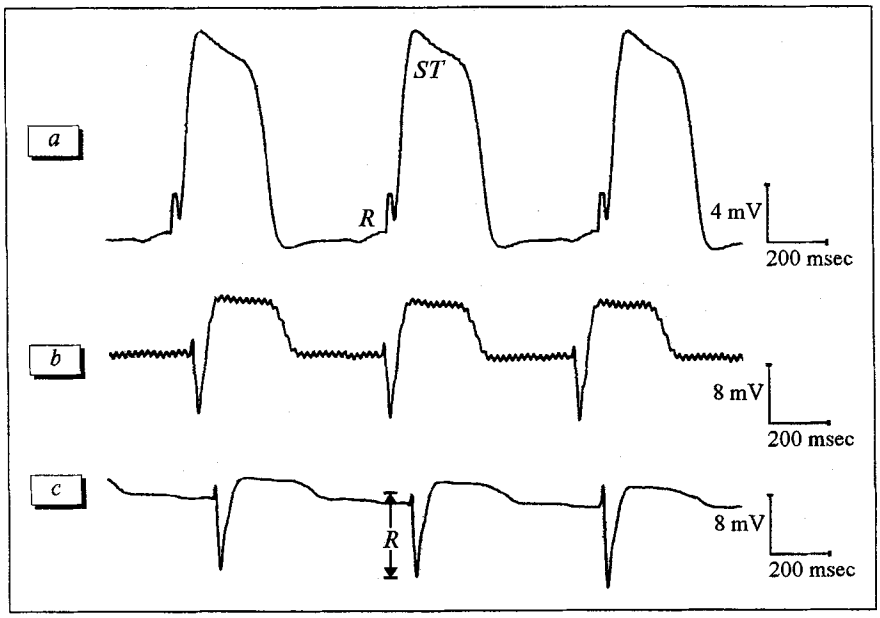

Fig. 1. Acute electrocardiogram recorded from a PEMB myocardial electrode; an indifferent electrode is placed in the left hypochondrium. *a*) prior to fixation of myocardial electrode, U_R=2.8 mV; *b*) after correction and fixation of myocardial electrode, U_R=9.6 mV; *c*) after closure of the operation wound, U_R=11.2 mV.

Moreover, this enables a more reliable synchronization, since the minimum sensitivity threshold provides an additional reserve.

MATERIALS AND METHODS

The amplitude of the *R* wave was measured on electrocardiograms. The electrograms were recorded three times (during localization of the myocardial electrode prior to and after its fixation, and before placing the implanted apparatus to the prepared bed) using myocardial and indifferent electrodes. Either PEMB (sutureless myocardial wire electrode) or, more seldom, PEMK-3 (myocardial wire electrode) were implanted into nonvascularized zone of the anterior surface of the right ventricle. In the first two cases, a PEVI-4 temporal indifferent wire electrode was stitched near the apparatus bed, while in the third case, a PEVI-1 electrode was placed directly into the bed (all electrodes were produced by Engineering Bureau of Medical Electric Equipment, Ukraine). When $U_R \geq 6$ mV was recorded at the first attempt, correction of the electrode position and the second recording were omitted.

A total of 22 acute electrograms were recorded in 15 patients undergoing cardiomyoplasty (in some patients the third electrogram was not recorded because of organization causes). These measurements should answer the question whether or not the proposed criterium $U_R \geq 6$ mV is a very strict or excessive requirement.

RESULTS

In 13 of 15 patients, the amplitude of *R* wave $U_R \geq 6$ mV was recorded during the first attempt and in 2 patients the initial values of U_R were 0.5 and 2.8 mV. In both cases the position of the electrode was corrected, after which the *R* wave amplitude constituted 11.2 and 9.6 mV. After these corrections, the mean amplitude of *R* wave in 15 measurements was 18 mV, and the minimum and maximum amplitudes constituted 6.4 and 35 mV, respectively. The mean amplitude was evaluated using the nonparametric Wilcoxon *U* test. The analysis showed normal distribution of U_R ($p \geq 0.90$), and therefore the criterium $U_R \geq 6$ mV is not very strict.

Figure 1 shows electrocardiograms recorded at different stages of the operation. The upper record indicates improper primary localization of the myocardial electrode (Fig. 1, *a*).

Prevention of possible desynchronization in 2 out of 15 patients justifies electrogram recording

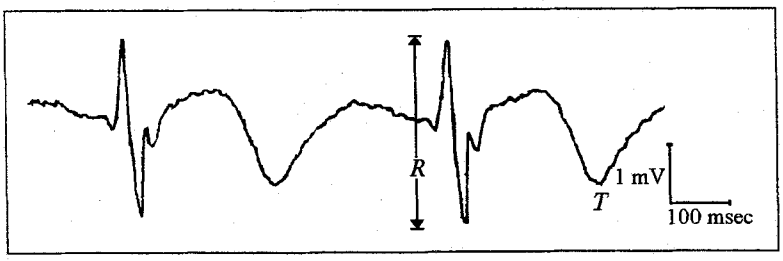

Fig. 2. Chronic electrocardiogram 6 months after cardiomyoplasty recorded from a PEMK-3 myocardial electrode. A PEVI-1 indifferent electrode is placed in the left hypochondrium, U_R=2.9 mV.

during the surgery. Previously, total or partial desynchronization of implanted ESMBP in the early and delayed postoperation period was noted in 2 patients (of 14 implantations). The ESMBP itself was operable in all cases. Figure 2 shows a fragment of electrogram recorded during reimplantation of a STIMINAK-805 apparatus (the operation was undertaken in order to determine the cause of desynchronization). The possibility of recording and test stimulation of the heart confirmed the serviceability of the myocardial electrode. Further tests confirmed that the device is completely operable. However, the amplitude of chronic *R* wave did not exceed the sensitivity threshold for the given ESMBP (3 mV), and this was the cause of improper functioning of the entire system of cardiac stimulation.

Similar failures after cardiomyoplasty operations have been previously reported (10 of 74 implantations for SP1005 apparatus) [4]. Additional advantages of a large reserve of the ESMBP sensitivity to the *R* wave are similar to those in traditional cardioversion [3].

Taking into account grave consequences of desynchronization of the cardiac channel of ESMBP and the difficulties in the diagnosis and correction of this disturbance, we believe that control over localization of the myocardial electrode (by the *R* wave amplitude) is an obligatory procedure during cardiomyoplasty.

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