SPREAD OF EXCITATION IN THE HEART DURING ELECTRICAL STIMULATION OF THE ATRIOVENTRICULAR VALVES

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Experiments on isolated rabbit and dog hearts involving synchronized recording of electrical activity of the right atrium, right ventricle, and tricuspid valve demonstrated the existence of functional connections between atrial, ventricular, and valvular depolarization. The dynamics of the spread of excitation in the heart was investigated during electrical stimulation of the atrioventricular valves. Impulses from a heterotopic focus of excitation localized in these valves were shown to be conducted to other parts of the heart and to lead to the development of cardiac arrhythmias.

KEY WORDS: spread of excitation in the heart; atrioventricular valves; cardiac arrhythmias.

Investigations on the whole organism and on preparations of the atrioventricular valves of the dog's heart have shown that the muscle of the valves becomes excited and actively contracts during the cardiac cycle [7-9]. Recently, spontaneous automatic activity has been recorded in isolated preparations of the atrioventricular heart valves of the dog, monkey, and rabbit [1-3, 5, 6, 11]. Under certain conditions this activity can be conducted from the valve to the atrial tissue [4, 10].

In the present investigation, on the whole heart, the spread of electrical activity was studied from a heterotopic focus of excitation localized in the tricuspid valve to other parts of the myocardium and the dynamics of excitation was compared in the atria, ventricles, and valves in the course of the cardiac cycle.

EXPERIMENTAL METHOD

Experiments were carried out on the hearts of 10 rabbits and five dogs isolated by Langendorf's method. The hearts were perfused (36-37°C) with Tyrode solution of the following composition (in mM): NaCl 137, KCl 2.7, $CaCl_2$ 1.8, $MgCl_2$ 1.0, $NaHCO_3$ 12.0, NaH_2PO_4 0.4, glucose 5.5; pH 7.3. The solution was oxygenated with a mixture of 95% O_2 and 5% CO_2. The rate of perfusion was 12 ml/min. Electrical activity was recorded synchronously by means of suction electrodes and pointed bipolar electrodes from the right atrium, right ventricle, and tricuspid valve. The anterior wall of the right ventricle was divided and bipolar recording and stimulating electrodes applied to the anterior or lateral cusp of the tricuspid valve. Recording suction electrodes and pointed stimulating electrodes also were applied to the endocardial surface (in its middle third) of the right ventricle and to the region of the sino-atrial node of the right atrium. Electrical activity was amplified and recorded by means of the UBP2-03 biopotentials amplifier and N-327-5 oscilloscope. The paper winding speed was 50 and 125 mm/sec. A heterotopic focus of excitation was created by electrical stimulation with above-threshold square pulses, 0.5 msec in duration, generated by an ÉSL-2 stimulator. The frequency of stimulation was usually 1.5-3 times higher than the initial frequency of excitation.

EXPERIMENTAL RESULTS

The spread of excitation in the heart in sinus rhythm and during electrical stimulation of different parts of the organ was investigated in 72 observations on 15 isolated hearts. Under sinus rhythm conditions, synchronized recording of electrical activity from the right atrium, right ventricle, and tricuspid valve revealed the following sequence of spread of excitation in these parts of the heart: The right atrium was excited first, a wave of excitation was then recorded in the cusp of the valve, and finally excitation spread to the right ventricle (Fig. 1). With an initial mean cardiac frequency of 140 ± 7.0 contractions/min, electrical activity of the tricuspid valve was delayed on average by 72.1 ± 4.5 msec after electrical activity of the right atrium, but

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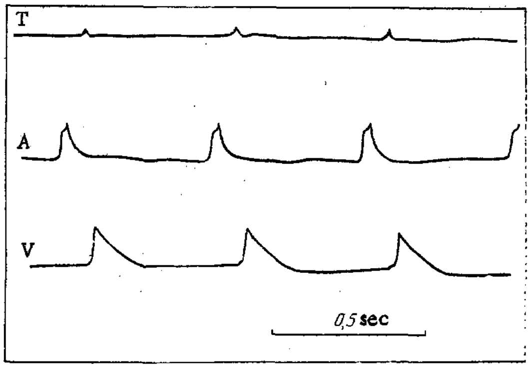

Fig. 1. Order of spread of excitation in different parts of rabbit heart under sinus rhythm conditions. Synchronized recording of electrical activity of right atrium (A), right ventricle (V), and anterior cusp of tricuspid valve (T).

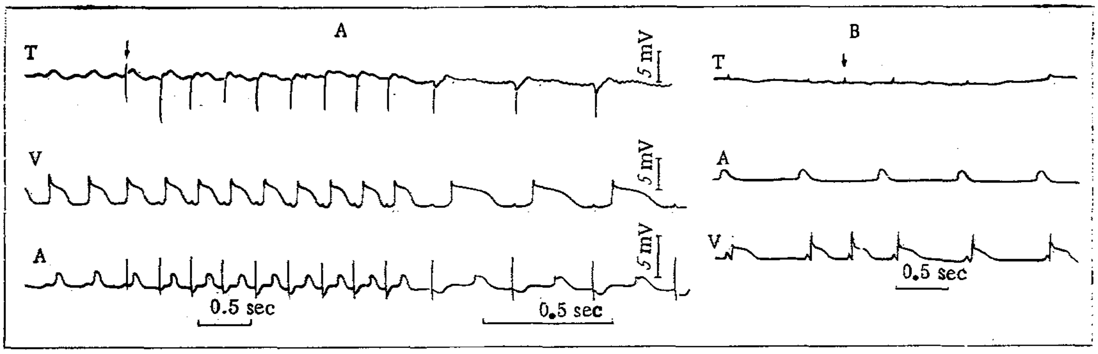

Fig. 2. Spread of excitation from heterotopic focus of excitation localized in tricuspid valve of rabbit heart to other parts of myocardium. A) Direct stimulation of anterior cusp of valve imposing frequency of stimulation of 190 pulses/min on atria and ventricles; B) appearance of ventricular extrasystoles during spontaneous depolarization of anterior valve cusp. Arrows indicate beginning of electrical stimulation and moment of spontaneous depolarization. Paper winding speed increased from 50 to 125 mm/sec in course of recording. Remainder of legend as in Fig. 1.

preceded depolarization of the endocardial surface of the right ventricle on average by 26.0 ± 7.6 msec (Table 1). The same order of spread of excitation in these parts of the heart was still observed when a higher frequency of excitation was imposed on the heart by stimulating electrodes located in the region of the sino-atrial node.

During electrical stimulation of the anterior or lateral cusp of the tricuspid valve, in 21 of 37 cases excitation spread from the valve to other parts of the heart: The atria and ventricles began to bind a faster rhythm than their own intrinsic rhythm. The typical sequence of spread of excitation for sinus rhythm in different parts of the heart was disturbed in this case and the time delays depended on the position of the stimulating and recording electrodes. If the valve cusp was stimulated with a frequency of 180-240 pulses/min the time of spread of excitation from the tricuspid valve to the right ventricle averaged 85.3 ± 4.4 msec, and to the right atrium 117.8 ± 4.8 msec (Table 1; Fig. 2A). Meanwhile excitation arising in the valve cusp spontaneously or in response to stimulation did not always spread to other parts of the heart. For instance, in nine of 37 cases during stimulation of the valve the ventricles bound the frequency of stimulation completely, whereas the atria continued to be excited in the previous rhythm. In five cases, electrical stimulation of the valve caused it to respond completely to the frequency of stimulation whereas the atria and ventricles continued to be excited by impulses from the sino-atrial node. In two experiments, with the onset of spontaneous depolarization in the valve cusp, extrasystoles were recorded in the right ventricle, but no electrical response whatever was found in the right atrium (Fig. 2B).

TABLE 1. Spread of Excitation in Rabbit Heart in Sinus Rhythm and during Electrical Stimulation of Atrioventricular Valves and Ventricles (M ± m)

Regions of heart	Time invervals, msec		
	sinus rhythm	electrical stimulation of	
		valve	ventricle
Atrium – valve	72.1±4.5 (48—112)	—	—
Atrium – ventricle	84.3±8.9 (32—152)	—	—
Valve – atrium	—	117.8±4.8 (104—160)	—
Valve – ventricle	26.0±7.6 (8—48)	85.3±4.4 (56—112)	—
Ventricle – valve	—	—	93.3±6.3 (72—136)
Ventricle – atrium	—	—	169.7±16.8 (136—240)

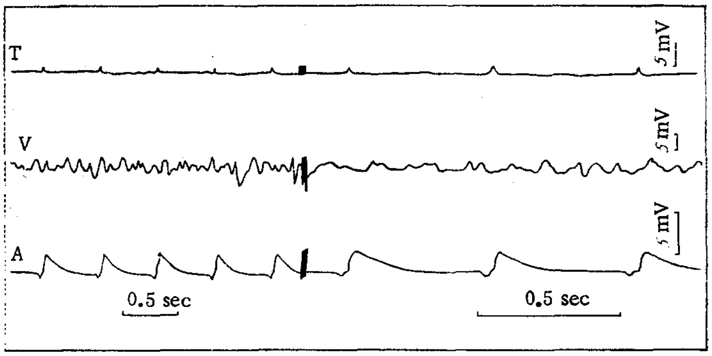

Fig. 3. Dissociation of electrical activity in different parts of dog's heart during ventricular fibrillation. Atria and valve excited rhythmically, ventricles fibrillate. Legend as in Fig. 1.

In response to electrical stimulation of the right ventricle, in 12 of 20 cases excitation spread to the atria and tricuspid valve; the time delays of the arrival of excitation were 169.7 ± 16.8 and 93.3 ± 6.3 msec respectively (Table 1). In five cases, despite an increase in voltage of the stimuli to twice or three times the threshold intensity, excitation did not spread from the ventricle to other parts of the heart. The same effect could be observed during ventricular fibrillation also (three experiments). Synchronized recordings of electrical activity of the right atrium, right ventricle, and tricuspid valve during ventricular fibrillation of the isolated dog's heart are illustrated in Fig. 3. Whereas the recording from the ventricle shows persistent fibrillation of the right ventricle, valvular activity was regular and followed depolarization of the atrium with a delay of 56 msec.

Under the conditions of normal sinus rhythm and also during direct electrical stimulation of the atria or ventricles, the atrioventricular valves are thus involved in the excitation process. On the other hand, the results showed that excitation in the valves may be relatively independent of simultaneous electrical activity in the atria or ventricles. This independence may be manifested as: binding of a higher frequency of stimulation by the valve than the sinus rhythm, whereas the atria and ventricles continued to be excited in their original rhythm; absence of excitation of the atria during electrical stimulation or spontaneous depolarization of the tricuspid valve; preservation of regular rhythmic activity in the valve cusp during simultaneous ventricular fibrillation. Other investigators have also concluded from experiments with division of the bundle of His that direct functional relations exist between depolarization processes in the muscles of the ventricles and valve, and that they are relatively independent of the atrial conducting pathways [7]. In the present writer's opinion since impulses in most of the experiments described in this paper were conducted from a heterotopic focus of excitation located in the atrioventricular valves to other parts of the heart, this focus may be the cause of development of cardiac arrhythmias.

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CHARACTERISTICS OF LATE VASOCONSTRICTOR A-RESPONSE IN CATS AFTER DECEREBRATION AT DIFFERENT LEVELS OF THE BRAIN STEM

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Single stimulation of A-fibers of the tibial nerve in cats decerebrated at the rostral border of the mesencephalon (mesencephalic animals) at various levels of the pons, including the region of the pontobulbar junction, and the most rostral levels of the medulla (pontine animals), or rather more caudally to this region (bulbar animals), evoked a late response in the renal nerve, consisting of excitatory and inhibitory components. In 53% of experiments on pontine animals, 42% of experiments on mesencephalic animals, but only 18% of experiments on bulbar animals the excitatory component of the response was small or even absent. The system generating the inhibitory component of the response was most active and most excitable in the pontine cats. However, features indicating relative potentiation of the inhibitory component of action of impulses in A-afferents on vasoconstrictor neurons in the pontine animals were not sufficiently constant to account for the switch from hypertensive reflexes to impulses from somatic A-afferents into hypotensive, taking place after disconnection of the structures of the pontobulbar junction and rostral levels of the medulla from the mesencephalon.

KEY WORDS: decerebration; somatosympathetic responses; blood pressure reflexes.

The A-afferent volley of spinal nerves can evoke discharges in sympathetic nerves which, depending on their latent period, are known as early, late, and very late A-responses [8,14,16,17]. The properties of the late A-response has been studied chiefly in experiments on anesthetized animals with an intact brain. Some workers [9,10] have also observed this response in cats after pre- or intercollicular decerebration, but the characteristics of the late A-response after transection of the brain stem at different levels has not been compared in detail.

The object of the present investigation was accordingly to study the reason why hypertensive reflexes to impulses in somatic A-afferents change into hypotensive when structures of the pontobulbar junction and rostral levels of the medulla are disconnected from the mesencephalon [1-3].

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