PHYSIOLOGY

Wenckebach Arrhythmia Produced in Cats by Vagal Stimulation with Volleys of Electric Pulses

O. E. Osadchii and V. M. Pokrovskii

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 120, № 7, pp. 13-15, July, 1995
Original article submitted August 11, 1994

A model permitting second-degree atrioventricular block (Wenckebach arrhythmia) to be reproducibly elicited in experimental animals (cats) by vagus nerve stimulation with volleys of electric pulses is described.

Key Words: *vagus nerve; atrioventricular conduction; Wenckebach arrhythmia*

Second-degree atrioventricular (AV) block, first described by Wenckebach, involves progressive slowing of AV conduction, leading to the complete failure of atrial impulses to be conducted. This is manifested on the electrocardiogram in a progressive prolongation of the *PR* interval to the point that the ventricular complex due to appear fails to do so. The indicated periodic events are then repeated [1,3]. Although clinical observations implicating the vagus nerve in second-degree AV block (Wenckebach block or arrhythmia) are well known, attempts to produce this block in experimental studies by vagus nerve stimulation are far from always successful, and in view of this there are few reports in which the vagal mechanisms responsible for this phenomenon are analyzed [9]. One reason for the failure to elicit Wenckebach arrhythmia may be the employment of inappropriate methods for vagal stimulation. The traditionally used stimulation of this nerve with a continuous flow of electric pulses does not reflect the natural impulse traffic in efferent vagal fibers, which consists of short volleys timed to occur at each cardiac contraction [8].

Department of Normal Physiology, Kuban Medical Institute, Krasnodar (Presented by B. I. Tkachenko, Member of the Russian Academy of Medical Sciences)

In this study, we followed the changes in AV conductivity induced by vagal stimulation with volleys of pulses.

MATERIALS AND METHODS

The study was conducted on 10 random-bred adult cats of both sexes (body weight 2.5-3.5 kg) anesthetized intraperitoneally with a mixture of chloralose (75 mg/kg) and Nembutal (15 mg/kg) and artificially ventilated. In all tests the left vagus nerve was stimulated, as this nerve exerts the major influence on AV conduction, whereas the right vagus nerve is more concerned with the regulation of cardiac rhythm [7]. The left vagus was transected in the neck at the thyroid cartilage level, and bipolar platinum electrodes were applied to its peripheral end and embedded in a mixture of wax and liquid paraffin. The nerve was stimulated with volleys of rectangular pulses from an electrostimulator. The pulses in a volley each lasted 2 msec and were generated at a frequency of 40 Hz; their amplitudes equaled 5 or 6 threshold values. An electrogram of the right atrium was recorded with an electrocardiograph using a unipolar probe inserted through the femoral vein. Cardiac contractions were recorded with an interference-suppressing intervalometer. The time of AV conduction

0007-4888/95/0007-0658$12.50

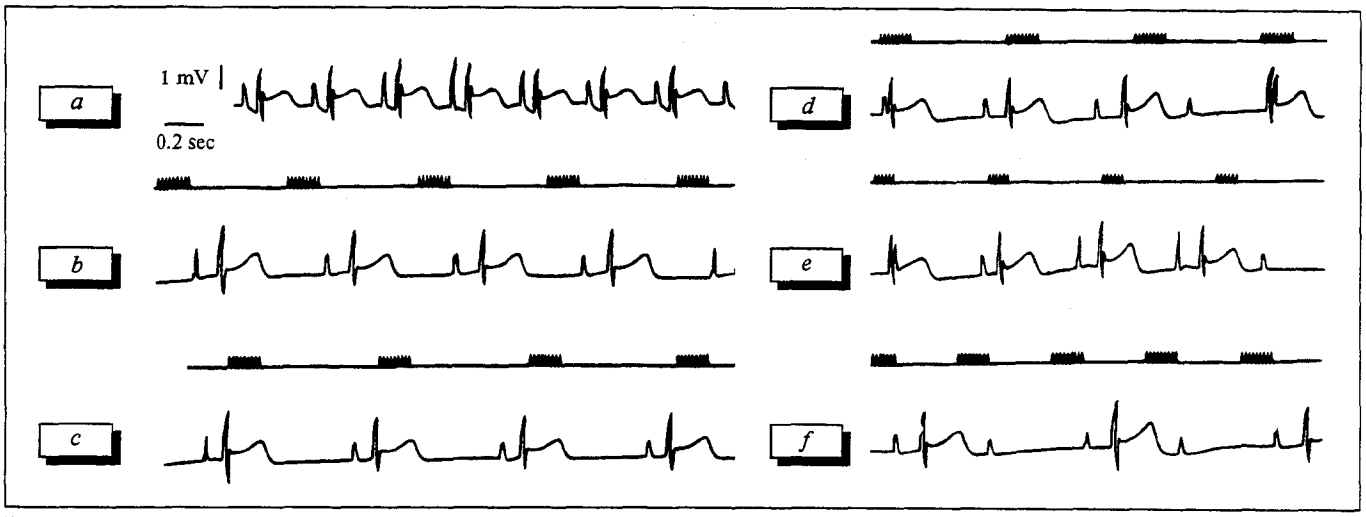

Fig. 1. Effect of vagal stimulation with volleys of pulses on atrioventricular (AV) conduction in cats. *a*) initial heart rate; *b* and *c*) upper and lower limits, respectively, of the range within which the cardiac and vagal rhythms were synchronized; *d*, *e* and *f*) Wenckebach arrhythmias arising when an attempt was made to impose on the heart a contraction rate higher than that at the upper limit of the synchronization range. *d*) 4:3 AV block with 9-pulse vagal stimulation at 480-msec intervals between volleys; *e*) 5:4 AV block with 6-pulse vagal stimulation at 480-msec intervals between volleys; *f*) 2:1 AV block with 9-pulse vagal stimulation at 320-msec intervals between volleys.

was determined from the duration of the *PR* interval on the atrial electrogram. The results were statistically evaluated by a method of direct differences [4].

RESULTS

After vagus nerve transection in the anesthetized cats, the mean heart rate was 193.3±7.8 beats/min and the mean *PR*-interval duration was 69.2±5.8 msec. When the vagus nerve was stimulated with volleys of 9 pulses each, the vagal and cardiac rhythms were synchronized in a range within which the heart responded by a separate contraction to every volley delivered to the vagus nerve (Fig. 1, *b* and *c*). Any change in the frequency at which volleys were delivered was synchronously reproduced by the heart, so that the cardiac rhythm could be accurately controlled within the indicated range [5,6]. The changes in AV conduction time that then occurred had at least two special features. First, the *PR*-interval duration was strictly dependent on the cardiac cycle phase during which the vagus was stimulated. The greatest prolongation of the *PR* interval was invariably observed when the artifact of vagal stimulation was 150-200 msec ahead of the *P* wave in the atrial electrogram. When each subsequent pulse volley coincided with the *T* wave of the electrogram, the *PR*-interval duration was minimal. Because of this, the length of the *PR* interval could be adjusted in a range from 71.9±7.9 to 117.3±6.8 msec ($p<0.01$) by varying the time at which the vagal stimulus was applied. In this case, not only the heart rate but also the AV conduction time could be controlled.

Second, the AV conduction time was inversely related to the current duration of the cardiac cycle (Table 1). At the upper limit of the range, corresponding to the smallest possible prolongation of the cardiac cycle, the *PR* interval was the longest. However, when the decrease in heart beat frequency was controlled, the *PR*-interval duration progressively shortened to reach its minimal value at the lower limit of the range, corresponding to the maximally possible prolongation of the cardiac cycle.

An attempt to impose on the heart, by means of vagal stimulation, a contraction rate exceeding that recorded at the upper limit of the range resulted in desynchronization of the vagal and cardiac rhythms, whereupon the strict correspondence

TABLE 1. Effect of Vagal Stimulation on Cardiac Cycle Duration and AV Conduction Time in Cats (9-Pulse Stimulation of the Vagus Nerve)

Parameter	Baseline value	Limits of synchronization range	
		upper	lower
R–*R* interval, msec	310.4±12.1	610.4±15.3*	783.5±20.8*
PR interval, msec	69.2±5.3	117.3±6.8*	71.9±7.9

Note. *$p<0.01$ relative to baseline value.

between the moment of vagal stimulation and the start of atrial excitation broke down, with the result that the vagal stimulation artifact changed its position with each subsequent cardiac cycle. The latter circumstance accounted for the periodic changes in cardiac cycle duration and AV conduction time that were then observed. The *PR* interval progressively increased from one cycle to the next and eventually a ventricular complex that was due to appear failed to do so. Thereafter the above-mentioned periodic events were repeated. The cardiac cycle duration also varied periodically, but in a reverse manner: in the framework of the periodicity achieved, the cardiac cycle duration decreased rather than increased with prolongation of the *PR* interval, so that a complete AV block was always preceded by the shortest cardiac cycle. The latter phenomenon is known to be a characteristic sign of second-degree AV block (Wenckebach type) [1,3].

The number of cardiac cycles constituting the Wenckebach periodicity depended on the intensity of vagal stimulation. Figure 1, *d* shows one fragment of a record made when Wenckebach arrhythmia was produced by applying volleys of 9 pulses at 480-msec intervals to the vagus nerve. This arrhythmia was characterized by 4:3 AV conduction, i.e., only 3 of every 4 atrial impulses were conducted to the ventricles. When the number of pulses per volley was reduced to six, vagal stimulation at 480-msec intervals between volleys caused a 5:4 AV block (Fig. 1, *e*); the delay in AV conduction thus became less marked. The opposite effect was observed when the volleys of pulses were applied to the vagus nerve at higher frequencies. Stimulation with 9-pulse volleys at 320-msec instead of 480-msec intervals transformed the 4:3 block to a 2:1 one, i.e., every second atrial impulse was blocked in this case (Fig. 1, *f*).

Decreasing the frequency at which volleys were applied to the vagus nerve led in all cats to the disappearance of arrhythmia and restoration of a regular rhythm. Their hearts then regained the capacity to accurately reproduce the rhythm of vagal volleys and responded to each volley with a separate contraction. The latter observation indicates that the Wenckebach arrhythmia was of a purely functional nature, being associated with the phasic changes in AV conductivity resulting from the lack of correspondence between the vagal and cardiac rhythms.

In 3 of the 10 cats we did not succeed in producing a typical Wenckebach block initially. Although progressive *PR*-interval prolongation was observed in those cats, the periodicity indicated above did not culminate in complete AV block. The dromotropic effect of the vagus was potentiated by injecting the cats with the drug Obsidan (1 mg/kg intravenously), which decreases AV conduction velocity [2]; vagal stimulation 2-3 min postinjection led to the development of complete AV block.

Analysis of the animal model we have proposed for producing Wenckebach arrhythmia suggests that the latter may arise if the heart is no longer capable of synchronizing the rhythm of its own contractions with the frequency of volleys arriving along vagal fibers from the central nervous system. When the frequency of vagal volleys has exceeded a certain limit, the cardiac and vagal rhythms become desynchronized, and this results in periodically repeated phase-dependent changes in AV conductivity and cardiac cycle duration, which is manifested as Wenckebach arrhythmia.

The authors are grateful to the Soros Foundation for supporting this study (Grant № RKL 000).

REFERENCES

1. A. Bayes de Luna, *Clinical Electrocardiography: A Textbook*, Futura Publ. Co. (1993).
2. V. L. Doshchitsyn, *Treatment of Arrhythmias* [in Russian], Moscow (1993).
3. M. S. Kushakovskii, *Cardiac Arrhythmias* [in Russian], St. Petersburg (1992).
4. E. V. Montsevichyute-Eringene, *Pat. Fiziol.*, № 4, 71 (1964).
5. V. M. Pokrovskii and Yu. R. Sheikh-Zade, *Fiziol. Zh. SSSR*, **66**, № 5, 721 (1980).
6. V. M. Pokrovskii, *Fiziol. Zh. SSSR*, **74**, № 2, 259 (1988).
7. N. Sperelakis (Ed.), *Physiology and Pathophysiology of the Heart*, 2nd ed., Kluwer Acad. Publ. (1989).
8. D. L. Kunze, *J. Physiol. (London)*, **222**, 1 (1972).
9. D. W. Wallick and P. J. Martin, *Amer. J. Physiol.*, **257**, № 3, Part 2, H935-H941 (1989).