Habituation of vasodilatation in the calf elicited by repeated sensory stimulation in man

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Summary. In 28 subjects the cardiovascular response to repeated stimulation was monitored during six daily sessions. Calf blood flow was measured with mercury-in-silastic venous occlusion plethysmography, blood pressure with electronic sphygmomanometer. The stimuli used were: 1 kHz sound of 90 dB and 100 dB intensity and immersion of one foot for 60 s in water at 4°C. Initially sounds induced large vasodilatation in the calf, immersion of one foot in the water induced in the contralateral calf vasodilatation in one group and vasoconstriction in another group of subjects. The blood pressure changes were less prominent and less consistent. After the first session of repeated stimulation the vascular response during the second session was significantly diminished. The reduction of the vasodilatation was the most rapid. During the remaining 5 days the responses were suppressed. It has been established that in the patients in the initial stage of hypertension the ability to habituate vascular response is impaired (Zbrożyna and Krebbel 1985). It is therefore suggested that the test of the ability for long-term vascular habituation could be used as a supplementary diagnostic test.

Key words: Vasodilatation — Long-term habituation — Man

Introduction

Vasodilatation in the skeletal muscles occurs as a part of an alerting response to sensory stimulation in cats (Abrahams et al. 1964; Mancia et al. 1972) and in dogs (Caraffa-Braga et al. 1973). The cardiovascular pattern of changes elicited by sensory stimulation is identical with the changes occurring in the defence reaction (Abrahams et al. 1960) or in fear or aggression (Forsyth 1972; Martin et al. 1976): arterial blood pressure and heart rate increase, vasodilatation in the skeletal muscles, vasoconstriction in the renal, mesenteric and cutaneous vascular beds. The same cardiovascular changes, including muscle vasodilatation, have been described in man under mental or emotional stress (Fenz et al. 1959; Smith 1940; Golenhofen and Hildebrandt 1957; Blair et al. 1959; Brod 1963; Kelly and Walter 1968). It has been shown that repeated exposure to a situation or a stimulus leads to gradual alteration of the cardiovascular response. Due to habituation some components may be completely abolished while some others might be less affected, or even sensitized (Martin et al. 1976; Zbrożyna 1982). Muscle vasodilatation appears to be particularly susceptible to habituation.

In the present investigation auditory stimuli of two intensities and a cold stimulus were used to activate muscle vasodilatation in man and the rate of habituation of this vasodilator response to repeated stimulation was studied. Part of the results has been briefly published elsewhere (Zbrożyna 1982; Zbrożyna and Krebbel 1985).

Materials and methods

Subjects. All subjects were healthy volunteers aged between 18 and 33 (mean 20.3 years), 15 men and 13 women, who were asked to refrain from physical exercise for at least one hour before each experiment.

Measurements. Blood flow was measured at regular intervals by venous occlusion plethysmography, using mercury-in-silastic gauges (Whitney 1953) placed around the calf. This method was shown to have good correlation with the electromagnetic method of muscle blood flow measurement in a single individ-
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Habituation (Longhurst et al. 1974). In addition it has been shown that when the strain-gauge is placed at the level of the largest circumference of the limb the circumference changes are mainly due to muscle blood flow changes (Clarke et al. 1958). Although changes in the cutaneous blood flow may have had some influence on our data this was also minimised by cutting off blood flow through the foot in addition to placing the gauge at the largest circumference of the calf. Blood pressure was recorded at the same time as the flow with an electronic sphygmomanometer (model ES-12). Heart rate was continuously recorded from a rate meter signal (Ormed Ltd) obtained from an ECG recording.

Procedure. The experiment was carried out in a quiet room, with an ambient temperature of 18-20°C, on six consecutive daily sessions, at the same time. The subject was seated comfortably in a semirecumbent position, and after a rest of 10-20 min the session started. The sessions lasted 30-60 min.

The stimuli used in these experiments were: (i) immersion of one foot in water at 4°C for 60 s, (ii) 90 dB, 1 kHz sound, (iii) 100 dB, 1 kHz sound. Some subjects served for both cold stimulus and a sound of one of the intensities. The experiments with 90 dB and 100 dB were never carried out on the same subject. Immersion of one foot in water at 4°C was applied 6-7 times during each session and the blood flow measurements were taken from the contralateral calf. At the beginning of each session and in the intervals between the immersions in water at 4°C the foot was placed in a water bath at 36°C. The length of the intervals were varied at random to avoid conditioning to time. During the cold immersion either one or two readings were taken. The tail end of the response was considered to occur during the first 60 s after the cold immersion.

The 1 kHz sound at 90 dB was applied 9 times and 100 dB 7 times during each session for 30 s. Again the lengths of the interval were varied to avoid conditioning to time and a single reading was taken midway through each stimulus.

Whenever possible the regression line of the best fit was calculated for all parameters — and for each session. Vascular conductance (flow/mean pressure) was used throughout in preference to resistance as the best way of describing direction of vascular changes. The blood flow values alone would not be adequate to describe vascular changes. For the long term habituation (Fig. 3) the vascular response (conductance) for the whole session was considered the area contained between the regression lines for the response and the control values (Zbrożyna and Krebbel 1985) and the intercept with 0 and 30 mins. The percentage change of conductance was expressed in relation to the area contained between x axis and the regression line for the control values.

Results

Short-term habituation

The initial response. Vasodilatation in the calf occurred in all subjects (11) presented with the sound (1 kHz 90 or 100 dB) for the first time. The cold stimulus induced vasodilatation in the calf in 11 subjects and vasoconstriction in 6.

The effect of repetition (Fig. 1). In 16 subjects out of 28 vasodilatation in the calf elicited by repeated stimulation was becoming smaller (habituation): in 8 subjects habituation was complete and in 8 was partial (from increase in vascular conductance of 37%±16 to an increase of 18%±7).

During habituation to sound (n=5) the response was reduced from 42%±19 to 10%±13 (examples shown on Fig. 2A, B).

The initial vasodilatation to cold (n=8) of 41%±30 was as a result of repetition reversed into vasoconstriction by 17%±38 (Fig. 2C). The initial vasoconstriction to cold stimulus (n=3), reduction of conductance by 37%±6 was diminished to 21%±11 (example is shown on Fig. 2D).

In a few subjects the response increased during repetition (sensitization). To 1 kHz 90 dB the vasodilatation increased in one subject by 28% and in one by 562% (Fig. 1A). To 1 kHz 100 dB the response increased in 3 subjects by 160%±6. To cold stimulus the vasodilator response increased in 3 subjects by 50%±29 and the vasoconstrictor response increased in 3 subjects by 23%±19.

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![Fig. 1. The best fitting regression lines of the vascular response in the calf during repeated stimulation in the first session for all subjects under investigation. A — repeated 1 kHz 90 dB sound, B — repeated 1 kHz 100 dB sound, C and D — repeated immersion of the contralateral foot in water at 4°C](image-url)