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Are "Alertness" and "Excitement" Two Different Cardiovascular Response Patterns in Dogs ?

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Fisiologia. — *Are "Alertness" and "Excitement" Two Different Cardiovascular Response Patterns in Dogs?* (*). Nota di ANTONIO CEVESE e LINO GRANATA, presentata (**) dal Corrisp. O. PINOTTI.

RIASSUNTO. — Furono studiate le risposte emodinamiche a diversi stimoli emotivi (suoni lievi o forti rumori), in 5 cani con una zampa posteriore cronicamente simpaticectomizzata. Si registravano contemporaneamente il flusso di sangue nelle arterie iliache esterne destra e sinistra, la pressione arteriosa e la frequenza cardiaca. Dopo gli stimoli lievi si otteneva soltanto una risposta vasodilatatoria limitata all'arto normalmente innervato, con un aumento del flusso ematico del 38% («reazione di orientamento»); la risposta compariva con un ritardo di 3–5 sec dopo la presentazione dello stimolo ed era abolita dall'atropina. Tutti gli altri parametri da noi misurati rimanevano invariati. Al contrario, dopo gli stimoli forti avevano luogo risposte cardiovascolari integrate, comprendenti anche una vasodilatazione dell'arto denervato, con un periodo latente trascurabile. Si avanza l'ipotesi che la «reazione di orientamento», piuttosto che una «modica reazione di difesa» debba essere considerata un tipo diverso di risposta.

The association of cardiovascular changes with behavioral responses to naturally elicited emotional stimuli has long been known [16]. Most of the available information on this subject has been obtained from studies on the effects of electrical stimulations of the structures in the central nervous system involved in emotional reactions (hypothalamus and other brain stem areas) [1, 4, 11]. The integrated response, generally indicated as the " defence reaction ", has been interpreted teleologically as a preparation of the animal for " fight and flight " [3, 7]. Perhaps the most constant and characteristic feature in this complex reaction is the well known vasodilatation of the skeletal muscle compartment due to the activation of specific sympathetic fibers, cholinergic in nature [1, 2, 5, 10]. The cholinergic muscle vasodilatation has generally been described to be associated with a series of other circulatory effects, namely increase in heart rate, blood pressure, cardiac contractility, and constriction of other vascular beds [3, 4, 15]. The extent of the cardiovascular component of the defence reaction certainly depends on the strength of the stimulation as well as on the degree of emotional involvement of the animal [7, 9, 13, 14].

In the experiments we present in this paper, the cholinergic muscle vasodilatation was the sole statistically significant cardiovascular effect we observed during orienting reflexes elicited by very mild stimulations in dogs. This led us to postulate the existence of two separate response patterns to either light or strong stimulations, or qualitative rather than purely quantitative differences between " alertness reaction " and " defence reaction ".

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(**) Nella seduta dell'11 marzo 1978.

Methods

Experiments were performed on 5 dogs of both sexes, weighing 14 to 19 kg. Prior to operation the animals underwent repeated training sessions in which they became familiar with the experimental environment and learned to lie unsedated in the recording cage. Surgery was performed under phentobarbital anesthesia (30 mg/kg, i.v.). Through a long midline laparatomy the left lumbar sympathetic chain was dissected free and stripped from L2 to L 7, for complete left hindlimb sympathectomy [8]. An electromagnetic flow probe and a pneumatic cuff for artery occlusion were implanted around both external iliac arteries. A PE catheter for arterial pressure recording was inserted into the abdominal aorta and a second small catheter for intra-arterial drug administration was slipped into the aorta via a lumbar branch, and approached to the origin of the external iliac arteries.

The recording sessions started at least 10 days after surgery. The dogs were placed in a closed cage, and connected to the recording apparatus, which consisted of two BL-310 sine wave electromagnetic flow meters and a Statham P 23 Gb pressure transducer. Arterial blood pressure (BP), innervated (limb) blood flow (IBF)—i.e. blood flow in the right iliac artery—and denervated (limb) blood flow (DBF)—i.e. blood flow in the left iliac artery—were recorded on photographic paper by an EFM DR 8 polygraph after electronic damping for mean values. Heart rate (HR) was recorded as well by a cardiotachometer triggered by a pulsatile signal.

The experiments consisted in gently calling the dogs or whistling for " alertness " and firing a dummy pistol for " excitement ". Both stimuli were given only after the dogs had been lying in the cage apparently quiet and relaxed for reasonably long control periods.

A total of 70 " alertness reactions " are reported. Data are expressed as mean $\pm$ SE; the statistical significance was determined by the Student t-test [12].

The effectiveness of the sympathetic denervation was repeatedly tested in all the dogs by occluding the common carotid arteries with two cuffs fitted at the time of operation [8]. This resulted in an increase in vascular resistance confined to the limb with intact sympathetic nerve supply (decrease in IBF in the face of arterial hypertension).

Results

The graphs in Figs 1 and 2 illustrate the averaged data from 70 experiments in which an orienting reflex was obtained as indicated above. Absolute values ($\pm$ SE) and percent variations are reported, respectively. All parameters were measured in the control periods and 10, 20 and 30 sec after the onset of the vasodilator response. As can be seen, IBF increased 38 % ($P < 0.001$) within 10 sec, was still 31 % above control ($P < 0.001$) after

20 sec, and returned to essentially control values within the subsequent 10 sec. Since the blood pressure did not change significantly, the calculated vascular resistance in the right (innervated) hindlimb (IMR) was decreased 31% and 21 % at 10 and 20 sec, respectively. The other parameters did not show any statistically significant change ($P > 0.1$). The 10 % increase in DBF at 30 sec shown in Figs. 1 and 2 cannot be attributed to active vasodilatation since it paralleled BP and, as a consequence, vascular resistance in the denervated

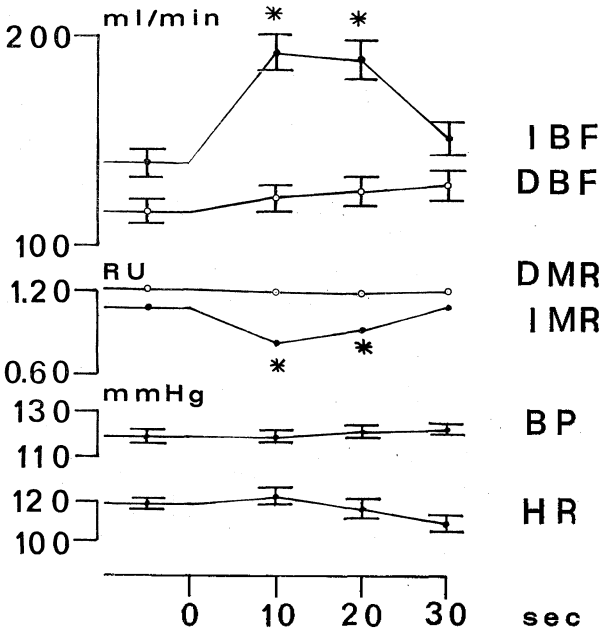

Fig. 1. – Averaged data (mean ± SE) of 70 " alertness reaction " experiments, obtained from 5 dogs instrumented for recording in conscious conditions and with one hindlimb chronically sympathectomized. The following parameters are reported: IBF = innervated limb blood flow; DBF = denervated limb blood flow; IMR = innervated muscle vascular resistance (in arbitrary units, RU); DMR = denervated muscle vascular resistance; BP = blood pressure; HR = heart rate. " O " on the abscissa refers to onset of the hemodynamic response. The only statistically significant changes observed after mild acoustic stimulations were an increase in IBF and a decrease in IMR, indicating active vasodilatation in the innervated limbs. (* $P < 0.001$).

hindlimb was not changed significantly. It is also apparent from Fig. 1 that the control values of DBF were slightly but significantly lower than IBF (16 %, $P < 0.01$).

Fig. 3 shows the original record of a typical " alertness reaction ". As for the averaged data, there was a great increase in blood flow to the normal limb, while all the other values were essentially unchanged. In this figure, in which the time of the stimulation is marked, there is also evidence of a considerable delay (4 to 5 sec) of the onset of the vasodilator response. This delay was a constant finding in the " alertness reaction ", but could not be statistically evaluated owing to the difficulty of exactly locating the stimulus in the records. To assess the cholinergic nature of the vasodilatation in the innervated hindlimb we repeated the experiments during the infusion of atropine sulfate (0.25 μg/kg/min) into the terminal abdominal aorta. Fig 4 shows that atropine led to the disappearance of any vasodilator response to the alerting stimulation.

Finally, we present in Fig. 5 the cardiovascular changes associated with a typical " defence reaction " (or excitement) elicited by a sudden loud noise.

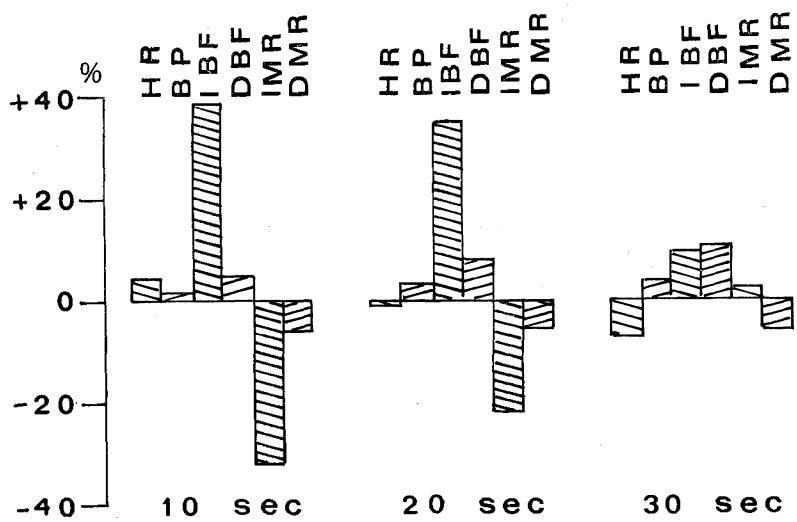

Fig. 2. – Percent variations relative to control values in the same experiments reported in Fig. 1, at 10, 20 and 30 sec after onset of the response.

In the present report we will not describe in detail the excitement experiments but will only outline the most salient differences between this reaction and alerting. Fig. 5 shows sudden changes in all parameters, with no measurable delay on the stimulus. In general, during the " defence reaction " the blood flow increased, though to a different extent, in both innervated and denervated hindlimbs, heart rate rose suddenly 30 to 50 % or even more, blood pressure rose, though in some experiments it exibited the tendency to fall or to fluctuate in either direction over a period of about 30 sec. Although not

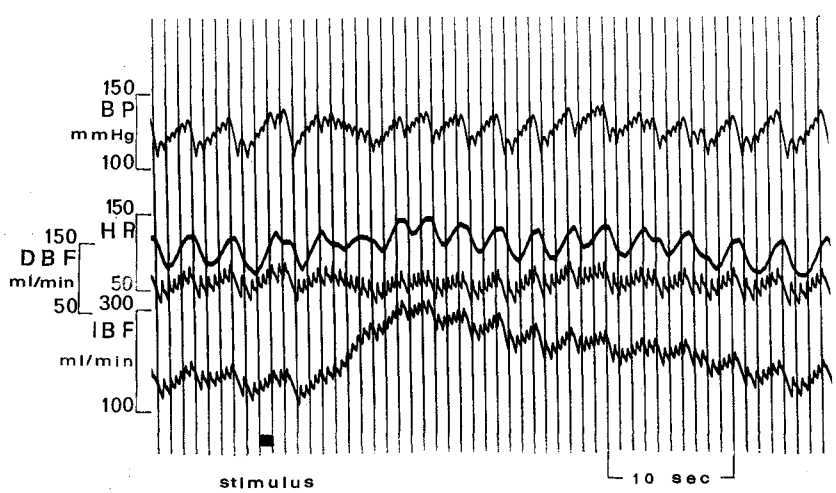

Fig. 3. – Original record of an " alertness reaction " experiment. Symbols as indicated in Fig. 1. At the signal the dog was called by the experimenter: after a few-second delay IBF increased from 145 ml/min to 285 ml/min; all other parameters remained practically unchanged.

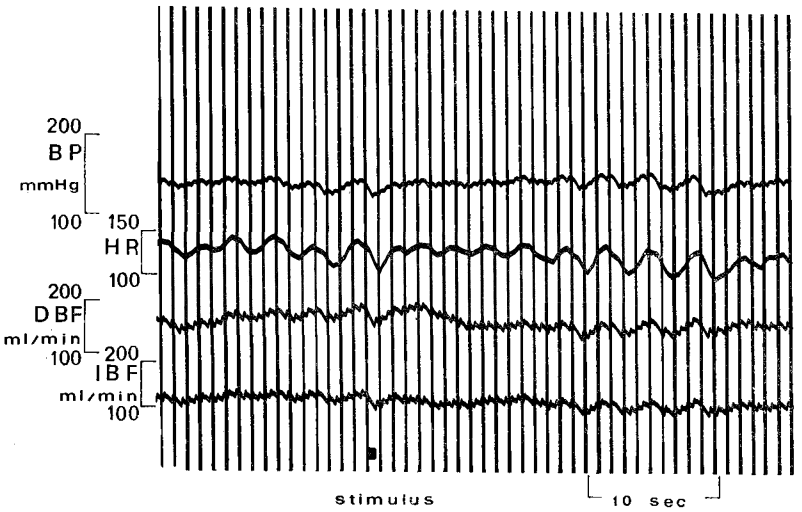

Fig. 4. – Original record of an "alertness reaction" experiment during administration of atropine (0,25 μg/kg/min) into the terminal abdominal aorta. Symbols as indicated in Fig. 1. The stimulus was not followed by any vasodilator response.

specifically reported here, the vascular resistances in both muscular territories were always consistently decreased, as the iliac blood flows rose 3 to 4 times even when the rise in blood pressure was absent or delayed. Thus "alertness reaction" differed from "defence reaction" in that: 1) neurogenic vasodilatation in skeletal muscles was considerably delayed, 2) muscle vasodilatation was absent in the sympathectomized hindlimb, and 3) heart rate and blood pressure were not significatly affected.

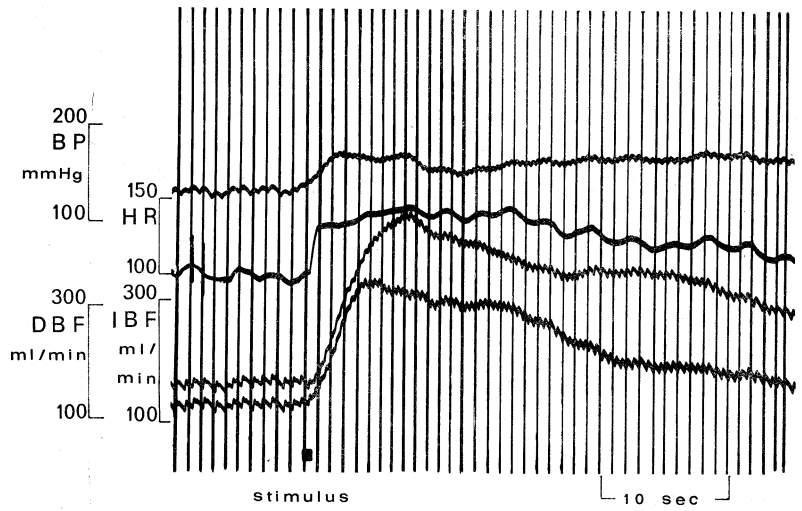

Fig. 5. – Original record of a "defence reaction" experiment or "excitement". Symbols as indicated in Fig. 1. At the signal a dummy pistol was fired, which was followed by an almost immediate increase of all parameters, including DBF, indicating a fully integrated cardiovascular response. (IBF is the first trace from the bottom).

Discussion

The present study was undertaken with the aim of comparing the hemodynamic responses to different emotional stimuli in two virtually identical vascular beds, namely those of the right and the left external iliac arteries, one of which had been surgically deprived of its autonomic nerve supply. It has been clearly stated that the sympathetic vascular control of the hindlimb is satisfactorily abolished after removal of the lumbar paravertebral ganglionic chain from L 2 to L 7 and that it is still absent 3 months after sympathectomy [8].

Immediately after surgery and for a few days thereafter the sympathectomized limb generally becomes vasodilated. This transient state, however, was certainly over at the time of our experiments, as attested by comparatively higher vascular resistances in the denervated limb (Fig. 1).

During the experiments the dogs were continually observed in order to record their behavioral responses to the stimulations. When they reacted by just moving the ears or slowly turning the head towards the experimenter, we considered the experiment as an " alertness reaction " or " orienting reflex ", while whenever the dogs became even moderately excited, shaking their tails or exhibiting a start, rapid movements and trembling, the experiment was discarded from this group. In such typical " alertness reactions ", the only hemodynamic change we observed was a moderate, delayed, vasodilatation in the innervated limb, which constantly accompanied the behavioral signs of awareness. The statistical significance of this finding was very high ($P < 0.001$) despite the relative variability of control values. This vasodilator response was cholinergic in nature, as attested by its disappearance after atropinization of the hindlimbs (Fig. 4), which might not be due to possible actions of atropine on the central nervous system, since the drug was administered directly into the terminal abdominal aorta and the control values did not change after atropinization.

Although we were not measuring the blood flow to other vascular beds, we may infer from previous work that the splanchnic and renal circulations are generally not involved in the " alertness reactions " [6], and therefore a definitive redistribution of cardiac output is not likely to occur. Unlike the isolated muscular vasodilator response elicited by very mild stimuli, in the defence reaction with overt excitement, fully integrated cardiovascular changes take place [6, 7, 15] after barely detectable latent periods.

We conclude that the " alertness reaction " rather than a " mild defence reaction " might be considered a different type of response, which probably involves much slower nervous pathways as attested by considerably longer latent periods, and is mainly, if not exclusively, characterized by cholinergic muscle vasodilatation.

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