J. Physiol. (1949) 109, 392–401 612.014.424.089:612.14

EFFECTS OF ELECTRICAL STIMULATION OF THE AORTIC NERVE ON BLOOD PRESSURE AND RESPIRATION IN CATS AND RABBITS UNDER CHLORALOSE AND NEMBUTAL ANAESTHESIA

By E. NEIL and C. R. M. REDWOOD

Department of Physiology, School of Medicine, Leeds

and A. SCHWEITZER

Department of Physiology, University College, London

(*Received* 20 *November* 1948)

The effects of rectangular wave electrical stimulation of the carotid sinus nerve in cats, in rabbits and in dogs have been reported in previous papers (Neil, Redwood & Schweitzer, 1948, 1949*c*, *d*). It was found that the effect of such stimulation upon the arterial blood pressure was dependent upon the type of anaesthetic employed and on the pulse duration of the stimuli used. Thus, in cats under nembutal (pentobarbital sodium) or chloral hydrate anaesthesia, or, in decerebrate cats, stimulation of the carotid sinus nerve, caused a fall in blood pressure irrespective of the pulse duration of the stimuli used. Under chloralose anaesthesia, however, stimuli of short duration (0·05–0·1 msec.) invariably produced a marked pressor response, whereas longer pulses (0·5–1·0 msec.) occasionally lowered the blood pressure. It was also found that intravenous injection of 0·05 g. or more of chloralose into cats under nembutal anaesthesia or in decerebrate cats, converted the fall in blood pressure, consequent on stimulation of the carotid sinus nerve, into a rise.

Analysis of these phenomena showed that chloralose diminished the sensitivity of the carotid baroceptors and also reduced the vasomotor centre response to stimulation of the carotid sinus nerve fibres. The rise in blood pressure caused by stimulation of the carotid sinus nerve in cats under chloralose anaesthesia was thought to be due to excitation of the chemoceptor afferent fibres contained in the nerve trunk.

Similar experiments showed that rectangular wave stimulation of the carotid sinus nerve in rabbits and in dogs caused a fall in arterial blood pressure, irrespective of the anaesthetic used or of the pulse duration of the stimuli employed.

It is generally held that the carotid sinus nerves and aortic nerves form a functional entity. Consequently, the effects of stimulation of the aortic nerves have been examined in cats and in rabbits. A short summary of the results of these experiments has previously been presented (Neil, Redwood & Schweitzer, 1949*a*).

METHODS

Cats and rabbits were anaesthetized with chloralose (0·08–0·1 g./kg. body weight, intravenously) or nembutal (35–40 mg./kg. body weight, intraperitoneally).

The aortic nerves were isolated in the neck at the site of their junction with the superior laryngeal nerve. The nerves were stimulated by means of fine shielded silver wire electrodes (mounted in perspex). A rectangular wave electronic stimulator which allowed independent variations of frequency of stimulation (1·5–1000 cyc./sec.), pulse duration (0·02–10·0 msec.) and intensity (0–100 V.) was used.

Blood pressure was recorded from the femoral artery. A tracheal cannula was inserted. Respiration was recorded by a stethograph or from changes in intratracheal pressure.

In some animals left intraventricular or intra-aortic cannulation was effected (Comroe, 1939). Injections of nicotine (0·04–0·10 mg.) or α-lobeline (0·3 mg.) were given through the cannula in order to stimulate the chemoceptors of the aortic body. Intraventricular position of the cannula was verified by post-mortem examination.

RESULTS

Effects of stimulation of the aortic nerves in rabbits

Stimulation of either the left or right aortic nerve in the rabbit with constant frequency (50 cyc./sec.) of stimulation produced a fall in arterial blood pressure, which varied directly with the pulse duration (Fig. 1). Increasing the frequency of stimulation, with pulse duration constant (1 msec.), increased the hypotensive effects (Fig. 2).

The anaesthetic used did not affect the type of response to aortic nerve stimulation. The tracings for Fig. 1 were obtained under chloralose anaesthesia; those for Fig. 2 were obtained under nembutal anaesthesia.

It was impossible to convert the fall of arterial blood pressure, caused by stimulation of the aortic nerve in rabbits under nembutal anaesthesia, into a rise by repeating the stimulation after intravenous injection of chloralose (Fig. 3*A*, *B*). These results are similar to those found in experiments in which the carotid sinus nerve in rabbits was stimulated (Neil *et al.* 1949*d*).

Effects of stimulation of the aortic nerves in cats and modifications caused by the anaesthetic

'Nembutal' anaesthesia. Stimulation of the left or right aortic nerves caused a fall in the arterial blood pressure, influenced only in magnitude by variation of the pulse duration. A typical response to stimulation is shown in Fig. 4. Only if the animal was heavily overdosed with nembutal (e.g. 100 mg./kg., intraperitoneally) was a pressor response obtained (cf. Douglas, Innes & Kosterlitz, 1948).

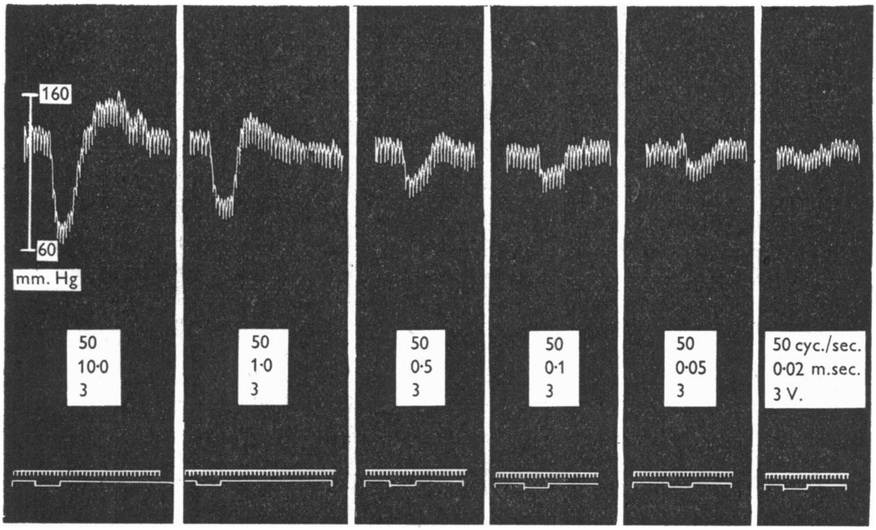

Fig. 1. Rabbit, chloralose anaesthesia. Records from above downwards: blood pressure, time in 5 sec., signal. Stimulation of right aortic nerve with 50 cyc./sec., 3 V., and decreasing pulse durations (10·0–0·02 msec.).

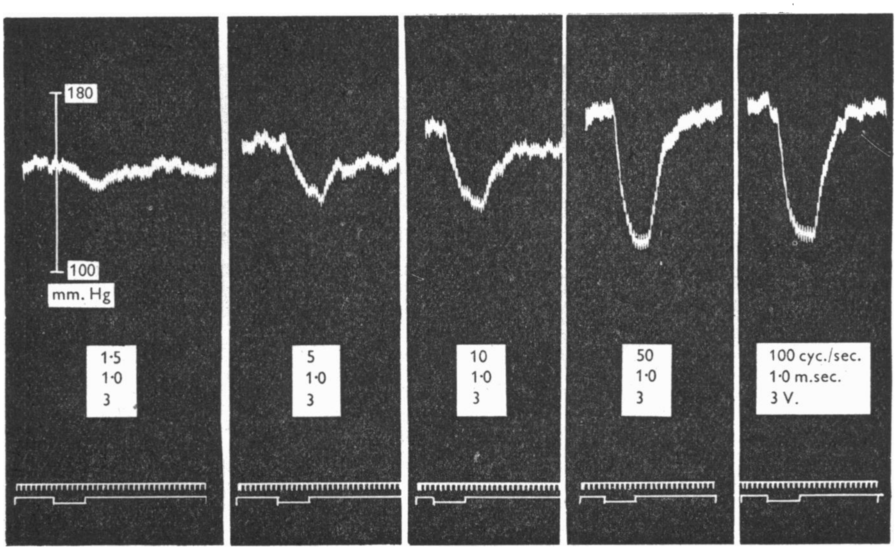

Fig. 2. Rabbit, nembutal anaesthesia. Records as in Fig. 1. Stimulation of left aortic nerve with 1·0 msec., 3 V., and increasing frequencies of stimulation (1·5–100 cyc./sec.).

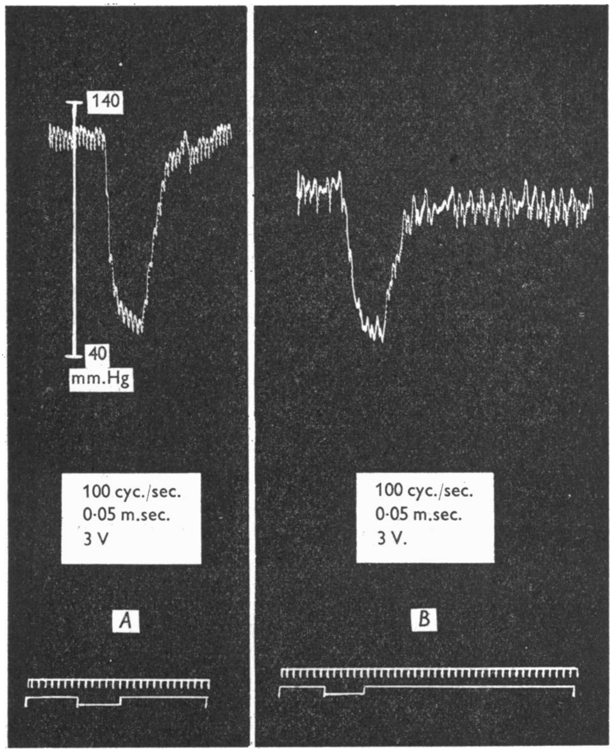

Fig. 3. Rabbit, nembutal anaesthesia, followed by chloralose. Records as in Fig. 1. Stimulation of left aortic nerve with 100 cyc./sec., 0·05 msec., 3 V. *A*, before; *B*, 15 min. after, intravenous injection of chloralose (0·07 g./kg.).

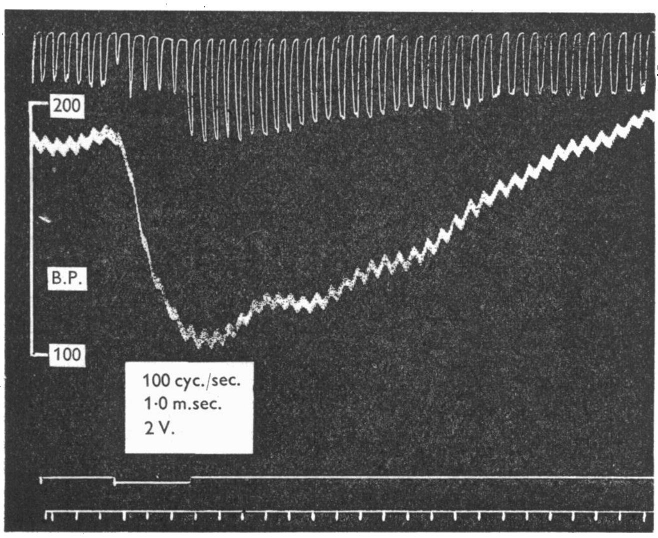

Fig. 4. Cat, nembutal anaesthesia. Records from above downwards: respiration, blood pressure, signal, time in 5 sec. Stimulation of left aortic nerve (2 V., 100 cyc./sec., 1 msec.).

Chloralose anaesthesia. Stimulation of the left aortic nerve in cats produced effects on the arterial blood pressure which were dependent on the pulse duration of the stimuli used. Pulses of 0·1–1·0 msec. duration caused a rise in blood pressure, usually attended by hyperpnoea, whereas pulses of 10·0 msec. duration caused a fall in blood pressure, accompanied by variable effects on respiration (Fig. 5). These results are similar to those obtained by stimulation of the carotid sinus nerve in cats under comparable experimental conditions (Neil *et al.* 1948, 1949*c*). It must be added, however, that the actual range of pulse durations of the stimuli producing these effects was different for the two on nerves. Thus, whereas pulses of 0·02–0·1 msec. duration caused pressor effects, stimulation of the carotid sinus nerves, pulses of 0·5–1·0 msec. duration, were sufficient to produce a fall in arterial blood pressure. In each case the stimulation intensity lay in the range of 1–3 V. Stimulation of the right aortic nerve in cats under chloralose anaesthesia usually produced a marked rise in arterial blood pressure, irrespective of the pulse duration or of the initial level of blood pressure (Fig. 6).

Decerebrate cats. Stimulation of the left aortic nerve in decerebrate cats produced a marked fall in arterial blood pressure, using stimuli of 100 cyc./sec. and 1·0 msec. duration. Intravenous injection of 0·1 g./kg. body weight of chloralose converted this depressor effect into a marked rise within 10–20 min. (Fig. 7). This finding again is similar to our previous observations on the effects of chloralose on the blood-pressure response to carotid sinus nerve stimulation in decerebrate cats (Neil *et al.* 1948, 1949*c*).

Chloralose following nembutal anaesthesia. Fig. 8 shows a typical experiment on a cat. Fig. 8*A* shows the response of the arterial blood pressure to stimulation of the left aortic nerve. Fig. 8*B* was obtained 30 min. after intravenous injection of 0·05 g. of chloralose. Stimulation of the aortic nerve now causes a pressor response. Again the results are similar to those obtained with the carotid sinus nerve. In this latter case, the present authors suggested that pressor effects caused by stimulation of the sinus nerve trunk were due to excitation of the chemoceptor fibre component. The following experiments were performed to show whether the aortic nerves contain fibres from the aortic chemoceptors.

Stimulation of aortic chemoceptors by intraventricular injection of nicotine or lobeline

Comroe (1939) showed in the cat that intra-aortic injection of small doses of nicotine or of lobeline did not produce stimulation of the aortic chemoceptors, but that intraventricular administration of these substances did. He concluded that the arterial supply of the aortic body was derived from the coronary arteries. These findings were confirmed by Gernandt (1946), and our experiments have led to similar conclusions. Hence, in this series of experiments, drug

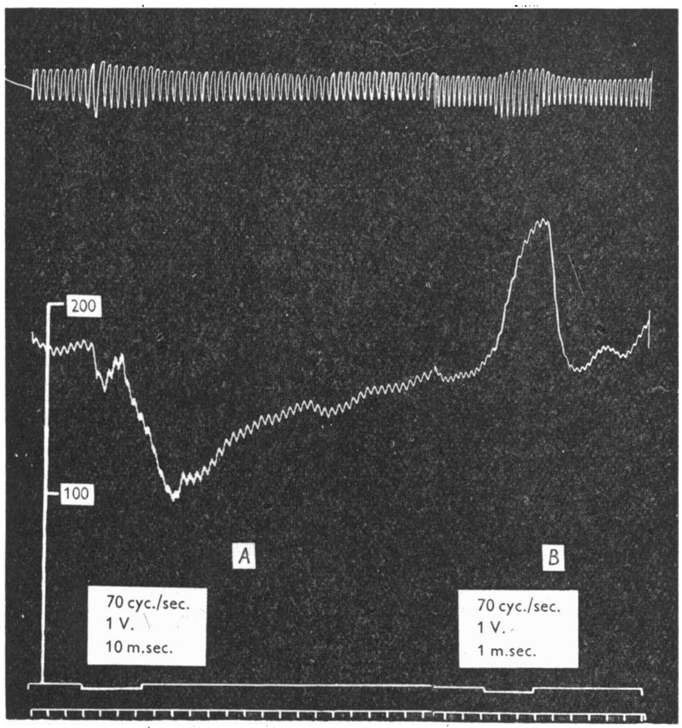

Fig. 5. Cat, chloralose anaesthesia. Records as in Fig. 4. Stimulation of left aortic nerve. Stimulation of 1 V., 70 cyc./sec. *A*, with pulse duration of 10 msec.; *B*, pulse duration of 1 msec.

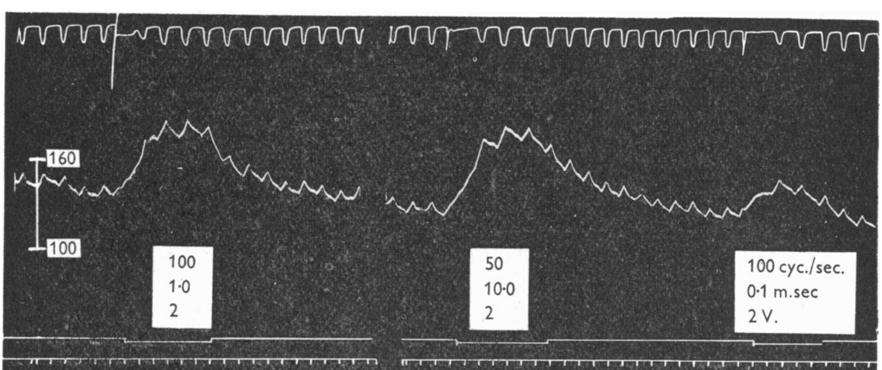

Fig. 6. Cat, chloralose anesthesia. Records as in Fig. 4. Stimulation of right aortic nerve, 2 V. 100 cyc./sec. 1 msec.; 50 cyc./sec., 10 msec.; 100 cyc./sec., 0·1 msec.

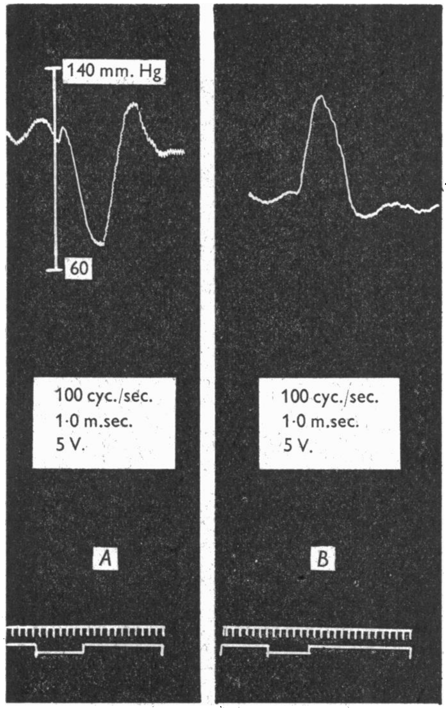

Fig. 7. Decerebrate cat before (A) and 20 min. after intravenous injection of chloralose (0·1 g./kg.). (B) Stimulation of left aortic nerve with 100 cyc./sec., 1·0 msec., 5 V.

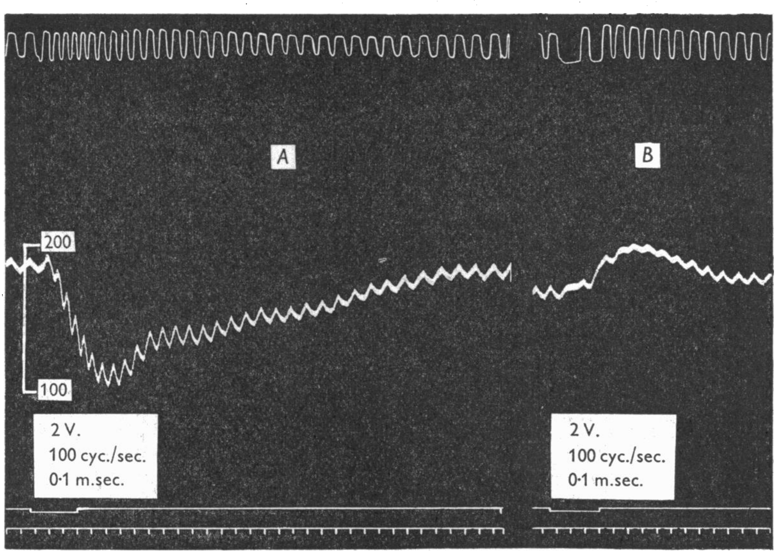

Fig. 8. Cat, nembutal anaesthesia followed by intravenous chloralose. Records from above downwards: respiration, blood pressure, signal, time in 5 sec. Stimulation of left aortic nerve (2 V., 100 cyc./sec., 0·1 msec.) Between *A* and *B*, 0·05 g. chloralose was injected. Record *B* was taken 30 min. after injection.

injections were made into the left ventricle through a cannula inserted via the common carotid artery, the tip of the cannula being pushed through the aortic valve. These experiments were performed in cats with intact and spontaneous respiration. Prior to introduction of the cannula both carotid sinuses were denervated and the aortic nerves were isolated from the vago-sympathetic trunk in the neck.

Section of both vagi, leaving the aortic nerves intact, reduced, but did not abolish, the respiratory response to intraventricular injection of nicotine or lobeline (Neil, Redwood & Schweitzer, 1949*b*) (Fig. 9). In such animals,

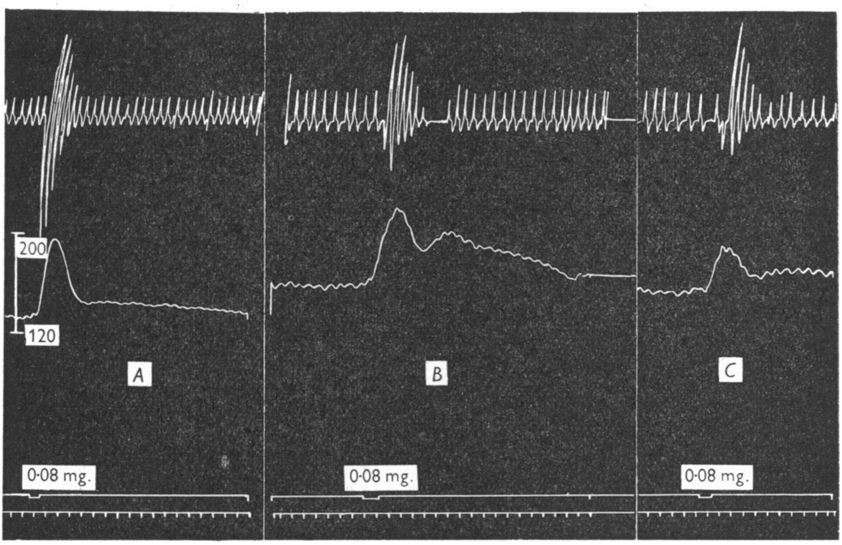

Fig. 9. Cat, chloralose anaesthesia. Records as in preceding figures. At signal 0·08 mg. nicotine was injected intraventricularly. *A*, vagi and aortic nerves intact; *B* vagi cut; *C*, left aortic nerve cut, leaving right aortic nerve intact.

separate division of the aortic nerves showed that section of the left nerve caused but little further diminution of the response to the drug injection; division of the remaining right aortic nerve, however, completely abolished the hyperpnoeic response to the injection (Fig. 10).

These experiments show that chemoceptor fibres are contained in the trunks of the aortic nerves in the cat. It appears that the right aortic nerve contains a greater number of fibres arising from the aortic body than the left nerve. This difference in the distribution of chemoceptor fibres between the right and left aortic nerves possibly explains the differences in the effects of left and right aortic nerve stimulation in the cat. These experiments have been repeated in the rabbit but, so far, no evidence has been obtained that chemoceptor fibres pass in the aortic nerves. Section of the vagi in the rabbit, after denervation of both carotid sinuses with the aortic nerves remaining intact, abolished the respiratory response to intraventricular injection of lobeline or nicotine.

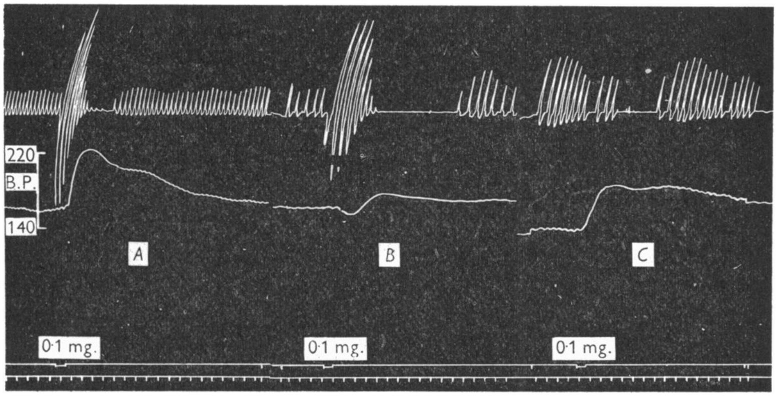

Fig. 10. Cat under chloralose anaesthesia. Records from above downwards: respiration (intratracheal pressure) blood pressure, signal, time in 5 sec. Signal marks the intraventricular injection of 0·1 mg. nicotine. *A*, vagi and aortic nerves intact; *B*, vagi cut; *C*, aortic nerves cut.

DISCUSSION

These results show that the effects on arterial blood pressure of electrical stimulation of the aortic nerves in the cat are dependent upon the type of anaesthesia employed. Under nembutal, given in usual anaesthetic doses, aortic nerve stimulation caused a fall in blood pressure. This response also invariably occurred in decerebrate cats. Subsequent injection of chloralose into cats under nembutal anaesthesia, or decerebrated, usually converted the fall in blood pressure following aortic nerve stimulation into a rise.

Furthermore, in cats under chloralose anaesthesia alone, pressor responses were obtained using stimuli of short pulse duration (1·0 msec., or less). When stimuli of longer pulse duration (10·0 msec.) were employed, the response to stimulation of the left aortic nerve changed to a fall in arterial blood pressure, although stimulation of the right aortic nerve under these experimental conditions produced a rise in pressure.

These differences in the response to stimulation of the left and right aortic nerves of cats are explained by the greater number of chemoceptor fibres running in the right aortic nerve, suggested by the results of intraventricular injection of nicotine or lobeline.

It has been impossible to obtain pressor responses to stimulation of the aortic nerves in the rabbit under experimental conditions which would result in pressor responses in the cat. These negative findings may be related to the absence of chemoceptor fibres in the aortic nerves of the rabbit, as also suggested by the observations of Schmidt (1932) and Gernandt (1946).

The experiments reported in this paper suggest that pressor responses to stimulation of the aortic nerves are due to excitation of chemoceptor fibres. The results of these experiments, and the conclusions drawn from them, are essentially similar to those obtained from experiments on the carotid sinus nerve.

SUMMARY

1. Rectangular wave stimulation of the left or right aortic nerve in rabbits under nembutal or chloralose anaesthesia caused a fall of arterial blood pressure irrespective of the pulse duration of the stimuli employed.

2. Stimulation of either aortic nerve in decerebrate cats or in cats under nembutal anaesthesia caused a fall of arterial blood pressure irrespective of the pulse duration of the stimuli used.

3. Stimulation of the right aortic nerve in cats under chloralose anaesthesia produced a rise in arterial blood pressure irrespective of the pulse duration of the impulses employed.

4. Stimulation of the left aortic nerve in cats under chloralose anaesthesia produced a fall in arterial blood pressure, using pulse durations of 10·0 msec., and a rise in pressure with pulses of 0·1–1·0 msec. duration.

5. Injection of 0·1 g./kg. body weight of chloralose in decerebrate cats or 0·05 or more of chloralose in cats under nembutal anaesthesia converted the depressor response to stimulation of the right aortic nerve into a rise of arterial blood pressure.

6. Evidence is presented by intraventricular injection of nicotine or of lobeline that the aortic nerves of the cat, especially the right, contain chemoceptor fibres from the aortic body. No evidence was obtained that such fibres are present in the aortic nerves in the rabbit.

A. S. gratefully acknowledges assistance given by the Parliamentary Grant in Aid of Scientific Investigations, administered by the Royal Society.

REFERENCES

Comroe, J. H. (1939). *Amer. J. Physiol.* **127**, 176.

Douglas, W. W., Innes, I. R. & Kosterlitz, H. W. (1948). *J. Physiol.* **107**, 48*P*.

Gernandt, B. E. (1946). *Acta physiol. Scand.* **11**, Suppl. 35.

Neil, E., Redwood, C. R. M. & Schweitzer, A. (1948). *J. Physiol.* **107**, 8*P*.

Neil, E., Redwood, C. R. M. & Schweitzer, A. (1949*a*). *J. Physiol.* **108**, 8 *P*.

Neil, E., Redwood, C. R. M. & Schweitzer, A. (1949*b*). *J. Physiol.* **108**, 26 *P*.

Neil, E., Redwood, C. R. M. & Schweitzer, A. (1949*c*). *J. Physiol.* **109**, 259.

Neil, E., Redwood, C. R. M. & Schweitzer, A. (1949*d*). *J. Physiol.* **109**, 281

Schmidt, C. F. (1932). *Amer. J. Physiol.* **102**, 94.