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THE EFFECTS OF ELECTRICAL STIMULATION OF THE DISTAL END OF THE CUT SINUS AND AORTIC NERVES ON PERIPHERAL ARTERIAL CHEMORECEPTOR ACTIVITY IN THE CAT

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SUMMARY

1. In anaesthetized cats, stimulation of efferent components of the carotid sinus or aortic nerves depressed chemoreceptor discharge from the relevant chemoreceptor afferents. The local application of 2% procaine hydrochloride to the sinus nerve trunk, peripheral to the site of the stimulating electrodes and proximal to that of the afferent nerve twig, abolished the depression of afferent chemoreceptor discharge caused by electrical stimulation; on washing the procaine away electrical stimulation once more induced depression of chemoreceptor discharge.

2. The depressant effect of efferent stimulation on carotid chemoreceptor activity was still seen during complete carotid glomeral ischaemia. Atropine given by close intra-arterial injection to the carotid body did not affect the depressant influence of efferent sinus nerve stimulation on carotid body chemoreceptor discharge.

3. Stimulation of the sinus nerve efferents usually increased carotid body blood flow. Close arterial injection of atropine abolished this effect.

4. The responses of glomeral blood flow and carotid chemoreceptor activity to efferent stimulation of the cut sinus nerve were not temporally related. It seems improbable that the depressant effect of such stimulation on chemoreceptor discharge was due to alterations of glomeral blood flow.

5. Stimulation of the peripheral end of the cervical vagus in atropinized cats reduced chemoreceptor activity recorded in the ipsilateral aortic nerve.

INTRODUCTION

Two lines of evidence indicate that the sinus nerve of the cat contains efferent as well as the better known afferent fibres. De Castro (1926) demonstrated their presence histologically. Joels (1960) and Biscoe & Sampson (1968) recorded action potentials from the central cut end of the sinus nerve. The latter workers distinguished two types of spontaneous activity; one showed a respiratory or cardiac rhythmicity and arose from post-ganglionic axons of the superior cervical ganglion, while the other was non-rhythmical and increased its discharge rate during systemic hypoxia or hypercapnia and following the intravenous administration of adrenaline.

The role, if any, of such efferent fibres in influencing chemoreceptor function has received no serious attention. We have investigated it in the present study. Our findings have already been briefly reported (Neil & O'Regan, 1969*a*).

METHODS

Thirty-two cats (1·3–3·8 kg in weight) were anaesthetized with either pentobarbitone sodium (Nembutal, Abbott 42–48 mg/kg) or by a combination of chloralose (60 mg/kg) and urethane (250 mg/kg) injected I.P. After tracheal cannulation a femoral artery and vein were cannulated.

Collection and measurement of carotid body blood flow. The technique employed closely resembles that used by Daly, Lambertsen & Schweitzer (1954). This involved the identification of the carotid body veins and the preparation of a segment of vein, which received their drainage, large enough for the introduction of a suitable collecting cannula. This venous segment was vascularly isolated from all neighbouring structures including the superior cervical and nodose ganglia, and drained only the carotid body. Portex polyethylene tubing (internal diameter 0·5–0·8 mm; external diameter 0·86–1·27 mm) was used for cannulation of the prepared venous segment. The distal end was led through the skin of the opposite side of the neck and maintained at a lower level than the vein into which the proximal end was inserted. Blood was collected in pipettes of varying bore, these being suitably adjusted with polythene tubing to fit snugly into the distal end of the collecting cannula. Flow rate was measured by timing the advancing column of blood over distances corresponding to volumes of 5, 10 or 25 μl., depending on the magnitude of carotid body flow.

That the segment of vein which was cannulated derived its drainage solely from the carotid body veins was usually self evident by direct inspection under a magnification of 16 times. When any doubt existed, a successful isolation was confirmed by the cessation of venous outflow on clamping the common and external carotid arteries. Heparin (Weddel; 500 i.u./kg) was given before dissecting the carotid body sinus area and again immediately before cannulating the isolated venous segment.

Preparation of the sinus and aortic nerves for stimulation and recording purposes. The sinus nerve was cleared and cut at its junction with the glossopharyngeal nerve so as to obtain as much nerve length as possible. The aortic nerve was cut at its junction with the superior laryngeal nerve. Lengths of 2–3 cm of the aortic nerve were dissected free from the vago-sympathetic trunk. After removing the sheath the nerve was placed on a pair of stimulating electrodes.

Use of the aortic nerve. Simultaneous efferent stimulation and afferent recording

were technically easier to perform with the lengths afforded by the aortic nerve. It was assumed that the aortic efferents were similar in function to the glossopharyngeal efferents destined for the carotid bifurcation. As similar changes of chemoreceptor afferent activity resulted to efferent stimulation of both these nerves, this assumption seems justified.

Recording procedures. Afferent activity was recorded from strands peeled off from the cut sinus and aortic nerves using saline wick electrodes. Impulse activity was led to a high-gain, low noise-level, R–C coupled amplifier and then to an oscilloscope and audiomonitor for preliminary examination. The output of the amplifier was also led to one channel of a direct-writing ink jet recorder with a frequency response flat to 500 Hz (Elema Schönander Mingograf 24B) from which permanent records were obtained. Permanent records were also obtained occasionally from a Cossor double-beam oscilloscope with motorized camera attachment. Afferent activity was adjudged to arise from chemoreceptors if its impulse frequency was increased during hypoxia and reduced by oxygen breathing. The close arterial injection of 5–30 μg sodium cyanide increased such carotid chemoreceptor discharge. A strand peeled off the cut nerve trunk was dissected to provide a single or few fibre chemo- or baroreceptor preparation. In experiments on the aortic nerve, such afferent strands were dissected from the nerve trunk 2–3 cm from the site of the stimulating electrodes. In the case of the sinus nerve the distances between the site of stimulation and afferent recording were necessarily much smaller.

Femoral arterial blood pressure was measured with an Elema Schönander electromanometer (E.M.T. 460) together with a variable inductance pressure transducer (E.M.T. 490A; 0–300 mm Hg). The output was displayed on the monitor oscilloscope and recorded on another channel of the direct-writing ink jet recorder. With needle electrodes, diaphragm electromyographic activity was suitably amplified, displayed on the monitor oscilloscope and recorded on yet another channel of the ink jet recorder.

Stimulation procedures. The main trunk of the nerve was placed across platinum bipolar stimulating electrodes and square wave pulses were delivered from a Palmer electronic stimulator through an isolator (Grass Siu 4B) unit. The stimulating electrodes were covered with warm mineral oil. Pulses, 0·5–5 m sec duration, 10–35 V intensity and 1–25 Hz frequency were used. When investigating chemoreceptor afferent activity responses to efferent stimulation, the voltage used was supramaximal unless the effect of intensity of stimulation on the recorded changes was being specifically studied. Even after prolonged bouts of such stimulation, afferent activity could still be recorded from the stimulated portion of the nerve. A Palmer 'students' stimulator together with silver stimulating electrodes were employed in some of the investigations of the effects of efferent stimulation on carotid body blood flow. Much lower intensities of stimulation (1·9–6·7 V) were sufficient with this latter stimulating set-up mainly due to the increase in the field of excitation in the absence of isolation and also because the silver electrodes had only half the impedance of their platinum counterpart. This latter stimulating arrangement was not suitable for the investigation of the effects on chemoreceptor afferent activity as it caused too much electrical interference in the electroneurogram.

The effect of blocking the conduction in efferent fibres, excited by electrical stimulation, on the impulse activity of the chemoreceptor afferent preparation was examined by placing a tiny pledget of cotton wool soaked in 2% procaine hydrochloride (B.D.H.) in 0·9% NaCl on the sinus nerve trunk, distal to the site of the stimulating electrodes and proximal to that of the afferent chemoreceptor twig.

Analysis of recorded changes. Permanent records were examined for any changes from control levels in systemic arterial blood pressure, diaphragmatic electromyo-

graphic activity and in the impulse frequency of baro- and chemoreceptor afferent discharge, both during stimulation and in the 30–60 sec immediately following stimulation. Analysis of some records was facilitated by plotting the impulse frequency every one to five sec against the time for control, stimulatory and post-stimulatory periods.

Administration of drugs. Retrograde lingual artery cannulation allowed the close arterial injection of atropine sulphate and sodium cyanide (dissolved in Ringer–Locke solution).

RESULTS

Effects of efferent stimulation on chemoreceptor afferent activity

In twenty-three experiments, efferent stimulation of the cut sinus and/or aortic nerves was carried out and the effects on chemoreceptor afferent activity recorded from a slip of the stimulated nerve examined. The upper part of Fig. 1 shows a diagram of the experimental procedure. The main trunks of either the sinus or aortic nerves were efferently stimulated by repetitive electrical pulses. Strands, containing active chemoreceptor units, were peeled off peripheral to the stimulating electrodes and the recorded activity analysed for changes in response to this experimental procedure.

Changes in afferent activity were observed in twenty-one experiments. In nineteen experiments efferent stimulation quickly depressed chemoreceptor activity and this depression was well sustained throughout the period of stimulation. In the post-stimulatory period, impulse activity was variable, either remaining depressed for several minutes or recovering rapidly to control levels of activity or even showing a marked increase for 1 min or so. Post-stimulatory increase of the activity was also observed in chemoreceptor recordings which had shown no changes during efferent stimulation. Neither systemic arterial blood pressure nor respiratory activity was affected by efferent stimulation. In two experiments, depression in activity was confined to the initial 10–20 sec of stimulation and was then replaced by an increase in the impulse activity relative to control values; this increase was maintained in the immediate post-stimulatory period. Fig. 1 (lower part) displays the usual effect of efferent stimulation on chemoreceptor discharge, in this case recorded from the aortic nerve. Fig. 2 shows a similar response recorded from the sinus nerve.

These two examples were recorded from chemoreceptor tissue with a normal local circulation, but the depression of chemoreceptor activity caused by efferent stimulation still occurred in conditions in which the blood flow through the carotid or aortic bodies was cut off. Thus, Fig. 3 shows carotid chemoreceptor discharge during carotid body ischaemia effected by occluding both the common and external carotid arteries which were the only sources of arterial supply to the glomus in this preparation;

efferent stimulation depressed this afferent activity. Fig. 4 similarly shows that aortic efferent stimulation reduces chemoreceptor discharge even when the animal is recently dead.

Although 10 V shocks sometimes depressed chemoreceptor discharge, usually some 20–35 V were required. Fig. 5 shows that an intensity of

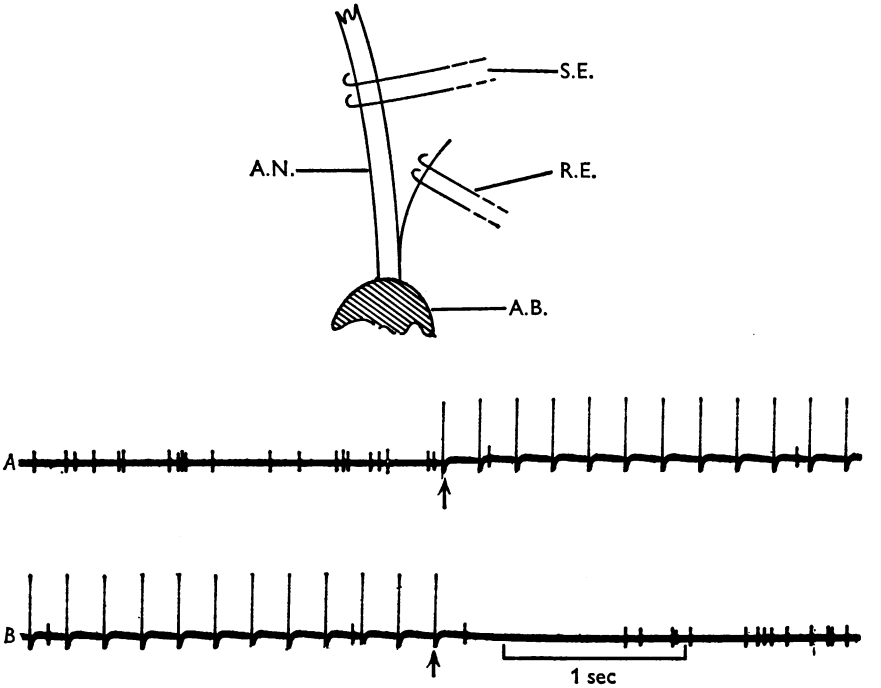

Fig. 1. Cat. Chemoreceptor afferent activity recorded from a slip of the cut aortic nerve. Efferent electrical stimulation of the main trunk of the same nerve. The arrangement of the preparation is shown in the upper section: A.B. = aortic body; A.N. = aortic nerve; R.E. = recording electrodes; S.E. = stimulating electrodes. Lower section: *A* = control and early period of a stimulation (25 V, 5 Hz, 1 msec) which lasted for a total of 30 sec. *B* = end of stimulatory and early recovery periods. Large deflexions = stimulus artifacts; ↑ = onset and cessation of stimulation.

15 V (5 Hz) was relatively ineffective, but that an increased voltage of 25 then depressed discharge. Efferent stimulation at 1 Hz caused a detectable depression of discharge which was more marked at 2 Hz and pronounced at 5 Hz (Fig. 6). Alteration of the pulse duration from 0·5 to 5 msec did not modify the depression caused by stimulation.

The effect of local anaesthetization of the intermediate part of the sinus nerve trunk on the response of chemoreceptor discharge to electrical stimulation of the sinus nerve trunk

It was necessary to ensure that the depression of chemoreceptor activity induced by electrical stimulation of the trunk was due to the stimulation of its efferent components and not simply to a spread of electric current. Therefore, the afferent response to electrical stimulation was recorded before, during and after the local application of procaine hydrochloride to the sinus nerve trunk between the site of stimulation and that of recording. Fig. 7*A* shows the usual depressant effect of sinus nerve stimulation

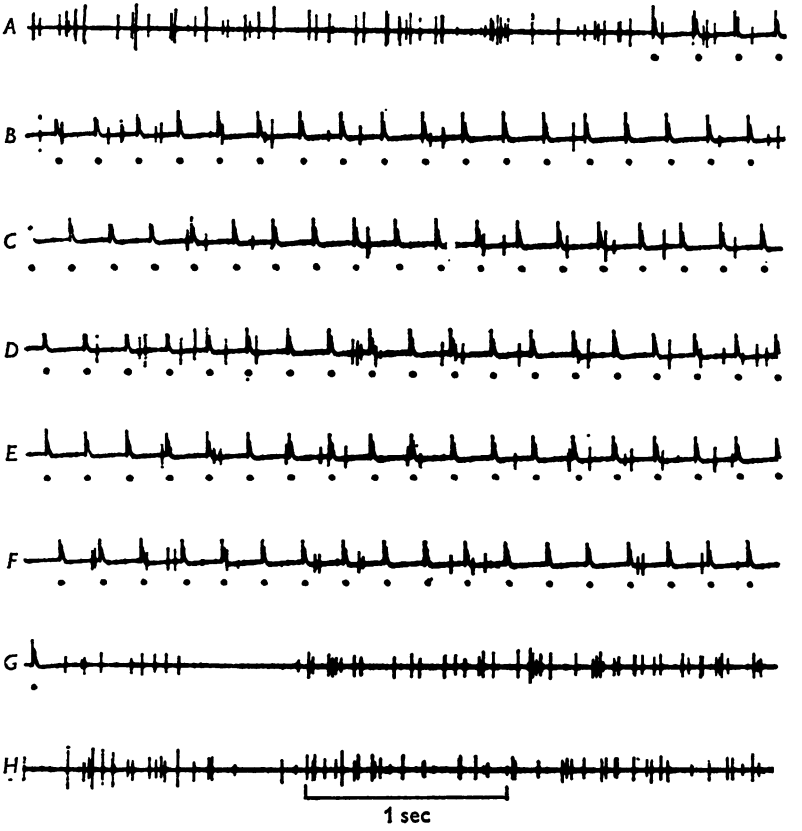

Fig. 2. Cat. Chemoreceptor afferent activity recorded from a slip of the cut sinus nerve. Efferent electrical stimulation of the main trunk of the same nerve. *A* to *D* = continuous recording showing control and early periods of a stimulation (30 V, 5 Hz, 1 msec) which lasted for a total of 40 sec. *E* to *H* = continuous recording showing end of stimulatory and early recovery periods. Periods of stimulation indicated by the dots placed directly underneath each stimulus artifact.

on chemoreceptor impulse activity. Between Fig. 7*A* and *B*, a pledget of cotton wool soaked in 2% procaine hydrochloride was applied for 2 min to the nerve, distal to the stimulating and proximal to the recording electrodes. 5 min later, electrical stimulation at a higher intensity now caused little effect on the afferent discharge from the same chemoreceptor

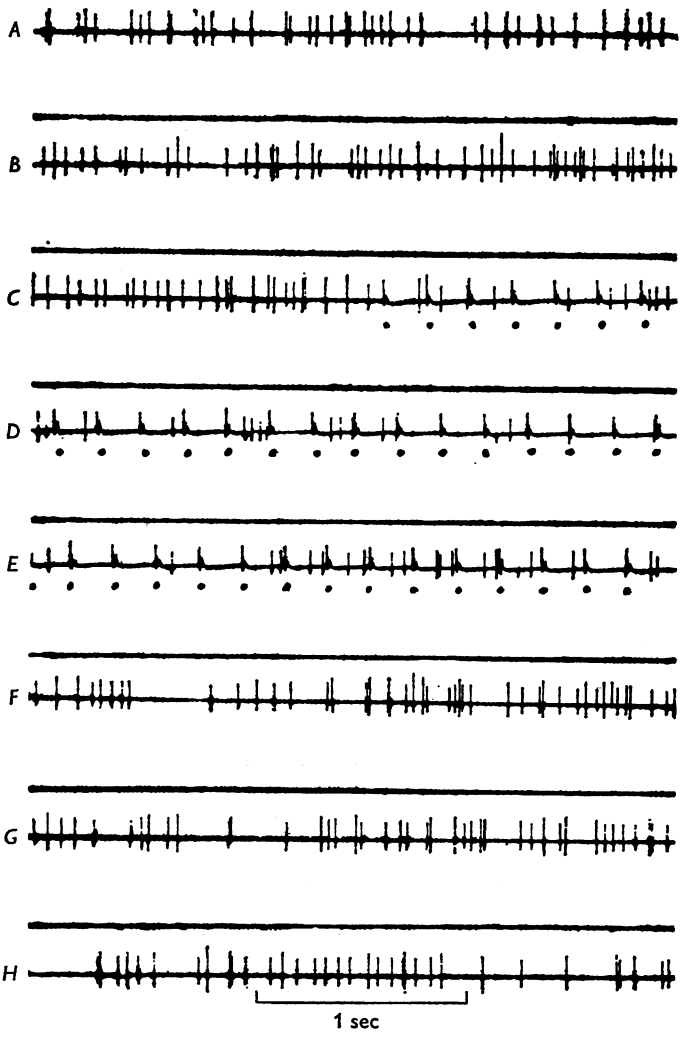

Fig. 3. Cat. Chemoreceptor afferent activity recorded from a slip of the cut sinus nerve. Efferent electrical stimulation (25 V, 5 Hz, 1 msec) of the main trunk of the same nerve. Carotid body was ischaemic throughout the recording period. *A* to *H* = continuous recording. Stimulation periods indicated by the dots placed directly underneath each stimulus artifact (tracks *C*, *D*, *E*).

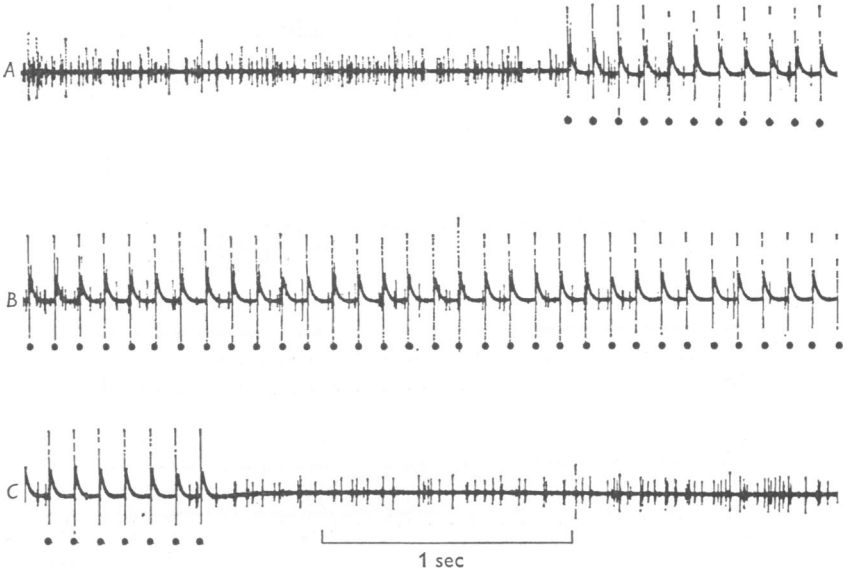

Fig. 4. Cat (shortly after death). Chemoreceptor afferent activity recorded from a slip of the cut aortic nerve. Efferent electrical stimulation (25 V, 10 Hz, 5 msec) of the main trunk of the same nerve. *A* to *C* = continuous recording. Periods of stimulation indicated by the dots placed directly underneath each stimulus artifact.

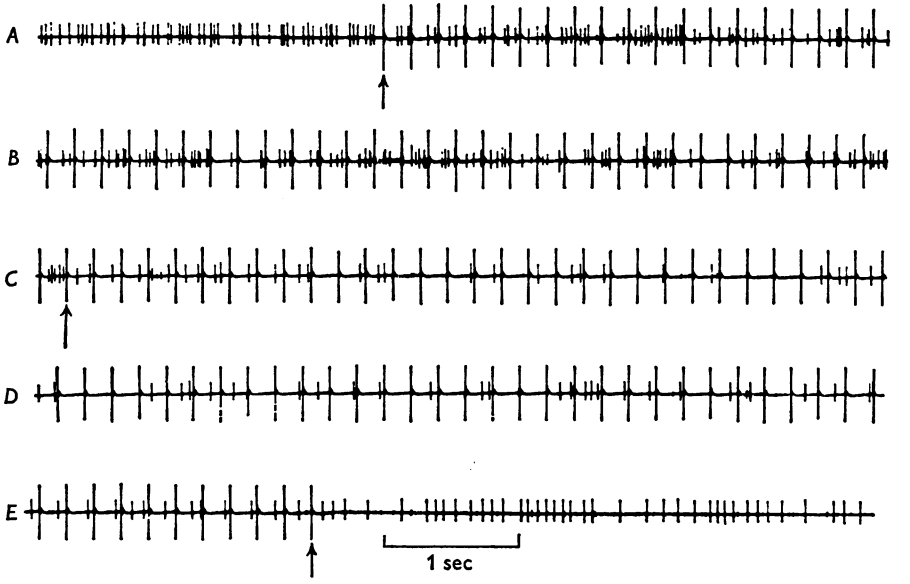

Fig. 5. Cat. Chemoreceptor afferent activity from a slip of the cut aortic nerve. Efferent electrical stimulation of the main trunk of the same nerve. *A* to *E* = continuous recording. Onset of stimulation (15 V, 5 Hz, 1 msec) at first arrow. Voltage increased to 25 at second arrow. End of stimulation signalled by third arrow. Large deflexions = stimulus artifacts.

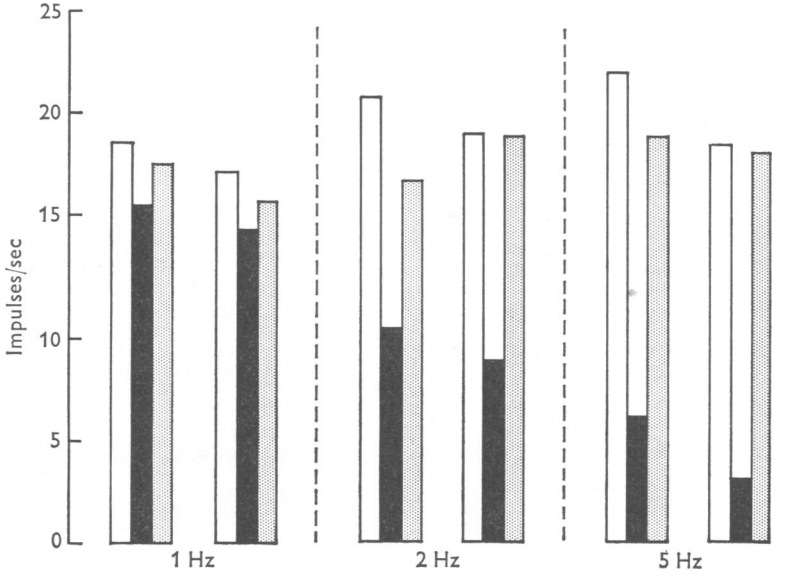

Fig. 6. The effects of altering the frequency of efferent electrical stimulation (25 V, 1 msec) of the cut sinus nerve (cat) on the reduction of chemoreceptor afferent activity which occurs to such stimulation. □ = impulse frequency during the 20 sec immediately preceding stimulation. ■ = impulse frequency during a 10 sec stimulation. ▦ = impulse frequency in the 20 sec immediately following stimulation. - - - - = separation of trials at different frequencies.

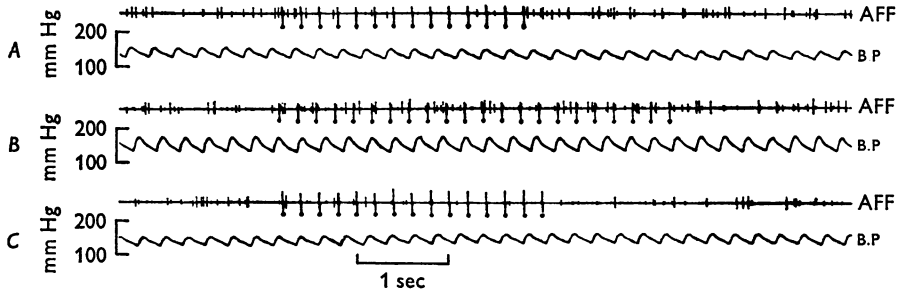

Fig. 7. Cat. Chemoreceptor afferent activity (AFF) recorded from a slip of the cut sinus nerve. Electrical stimulation of the main trunk of the same nerve. *A* = stimulation (10 V, 5 Hz, 1 msec) carried out before applying 2% procaine hydrochloride to the sinus nerve trunk between the stimulating and recording electrodes (see text). *B* = stimulation (10 V, 5 Hz, 1 msec) carried out 5 min after procainization. *C* = stimulation (10 V, 5 Hz, 1 msec) carried out after washing away the procaine (see text). Periods of stimulation indicated by the dots placed directly underneath each stimulus artifact. B.P. = systemic arterial blood pressure recorded from the descending aorta.

twig (Fig. 7*B*). The nerve trunk was then irrigated freely with Ringer solution for 5 min to remove the procaine. Fig. 7*C*, obtained 10 min after Fig. 7*B*, shows that electrical stimulation once more depressed chemoreceptor afferent discharge as in Fig. 7*A*.

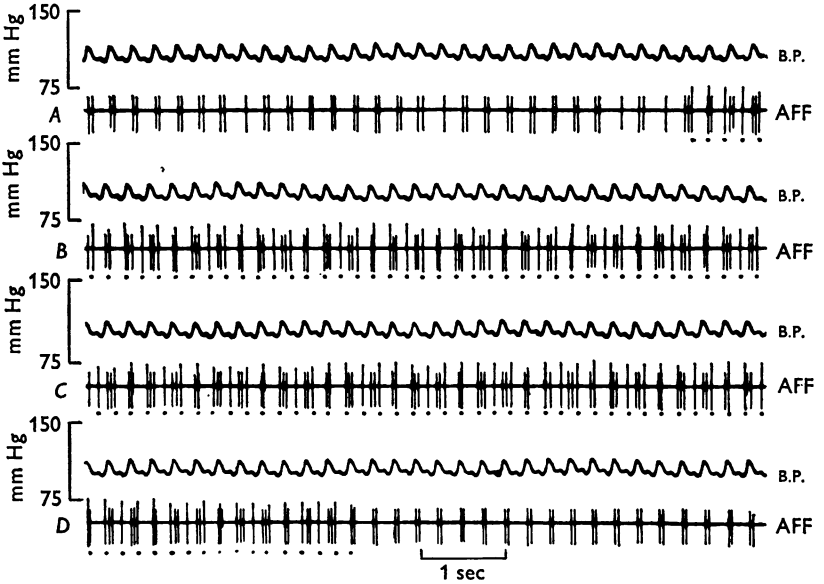

Fig. 8. Cat. Baroreceptor afferent activity (AFF) recorded from a slip of the cut sinus nerve and systemic arterial blood pressure (B.P.) recorded from a femoral artery. Efferent electrical stimulation of the main trunk of the same sinus nerve. *A* and *B* = continuous recording showing control and early periods of a stimulation (30 V, 5 Hz, 1 msec) which lasted for a total of 40 sec. *C* and *D* = continuous recording showing the end of the stimulatory and early post-stimulatory periods. Periods of stimulation indicated by the dots placed directly underneath each stimulus artifact.

Effects of efferent stimulation on baroreceptor afferent activity

Efferent stimulation of the sinus or aortic nerves employing the same voltage frequency and pulse duration as depressed chemoreceptor discharge had no effect whatever on baroreceptor impulse activity (Fig. 8).

Effects of efferent stimulation on carotid body blood flow

In ninety trials in the course of experiments on fourteen cats, efferent stimulation of the cut sinus nerve caused alterations of carotid body blood flow. Resting carotid body blood flow in these animals ranged from 20 to 65 μl./min. When stimulation without isolation was employed, glomus blood flow always increased, although the temporal pattern of this hyperaemia varied. Fig. 9 shows two types of response of which that

graphed in filled circles, showing a more prompt response which was well sustained, was the more common.

When stimulus isolation was used the responses were more protean. Again hyperaemia predominated, once more with varying patterns (Fig. 10*a*). Temporal patterns similar to the responses observed when isolation was not used were also noted (see Fig. 9). However, in two cats (entailing five trials) flow decreased during stimulation (Fig. 10*b*).

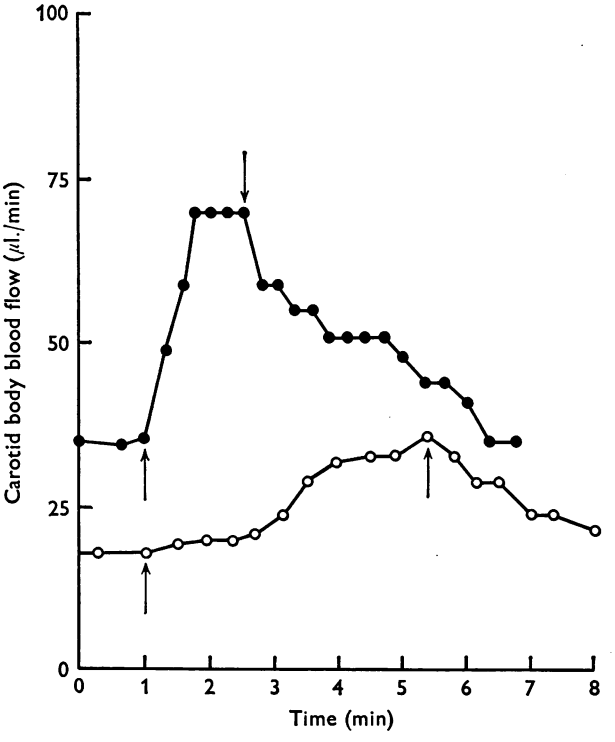

Fig. 9. Temporal patterns of hyperaemic responses of carotid body blood flow in two different cats, during efferent electrical stimulation (without stimulus isolation) of the cut sinus nerve. Each symbol represents the flow rate in μl./min. Stimulation carried out between the arrows (● = 4·7 V, 20 Hz, 1 msec; ○ = 6·7 V, 15 Hz, 1 msec).

Chemoreceptor impulse discharge in response to electrical stimulation of efferent units cannot profitably be examined unless stimulus isolation is employed. In view of the variable effects of such stimulation on glomus blood flow it is essential therefore that flow and chemoreceptor activity are both measured in order to offset a criticism that a depression of impulse activity is referable to changes of blood flow alone. Although it would be preferable to record the afferent electroneurogram simultaneously with

the carotid body blood flow during electrical stimulation of the sinus nerve, technical difficulties precluded this. The technique adopted was to measure the blood flow responses to a succession of bouts of electrical stimulation, then to record the changes of chemoreceptor activity produced by successive stimulations using the same stimulus parameters and finally to re-examine the blood flow responses to a further series of electrical stimulations. Such a regimen was carried out successfully in four cats, in all of

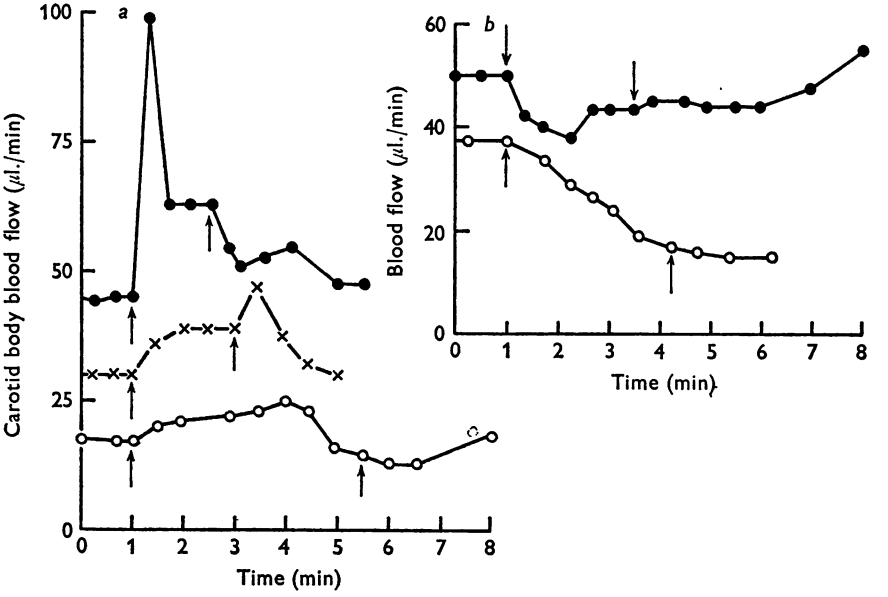

Fig. 10. Temporal patterns of responses of carotid body blood flow in five different animals during efferent stimulation (with stimulus isolation of the cut sinus nerve). Each symbol represents the flow rate (μl./min) and the arrows show the beginning and end of stimulation. *a* = patterns of increased blood flow to efferent stimulation (● = 20 V, 20 Hz, 1 msec; ○ = 30 V, 10 Hz, 1 msec; × = 10 V, 10 Hz, 1 msec). *b* = patterns of reduced blood flow to efferent stimulation (● = 25 V, 10 Hz, 1 msec; ○ = 10 V, 10 Hz, 1 msec).

which the blood flow responses to electrical stimulation were virtually identical before and after the electroneurographic responses to stimulation were recorded. Fig. 11 shows typical results of these four experiments. Fig. 11 *a–d* all show the reduction of chemoreceptor afferent activity caused by electrical stimulation and all show some hyperaemia although that in Fig. 11*c* is only scarcely evident. The time course of the hyperaemia, however, bears little relation to that of the reduction of impulse discharge. Particularly in the post-stimulatory period there is an obvious divergence between the behaviour of the impulse traffic and the glomeral blood flow.

Atropine and the responses to efferent stimulation. Intravenous doses of atropine (0·6 mg/kg body wt.) which abolished any cardiac responses to peripheral vagal stimulation did not modify the depression of chemoreceptor impulse discharge caused by efferent sinus nerve stimulation. Likewise the effects of such stimulation on carotid body blood flow were unchanged by the intravenous administration of atropine.

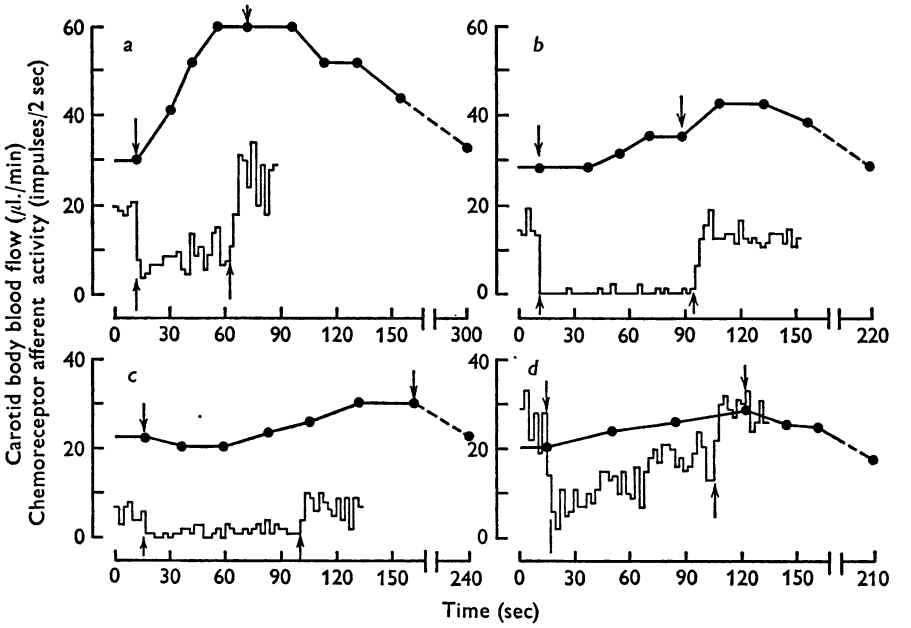

Fig. 11. Comparison between the changes in carotid body blood flow and chemoreceptor afferent activity during and following efferent electrical stimulation of the cut sinus nerve. ● = flow rate (μl./min). - - - - - = impulse frequency counted every 2 sec. *a*, *b*, *c* and *d* refer to separate cats. ↓ – ↓ onset and cessation of stimulation while measuring flow rates. ↓ – ↓ onset and cessation of stimulation while recording afferent activity (*a* = 20 V, 5 Hz, 1 msec; *b* = 30 V, 5 Hz, 1 msec; *c* = 30 V, 5 Hz, 1 msec; *d* = 25 V, 5 Hz, 1 msec).

However, although the close arterial injection of atropine in doses of up to 1 mg did not change the responses of the chemoreceptor afferents to efferent stimulation, the hyperaemic effects of such stimulation were virtually abolished (Fig. 12). In two cats, indeed, atropine converted the response to electrical stimulation to one of vasoconstriction. Presumably such vasoconstriction can be ascribed to the stimulation of sympathetic, noradrenergic vasoconstrictor fibres which are known to course in the sinus nerve to the carotid body (Biscoe & Sampson, 1968). Such large intra-arterial doses of atropine did not affect the chemoreceptor response

to the close arterial injection of 20 μg of sodium cyanide (Fig. 13). A local anaesthetic effect of atropine is unlikely therefore to be of much consequence.

Vagal efferent stimulation. Stimulation of the peripheral cervical vagus in the atropinized cat strikingly reduced (Fig. 14) the impulse traffic recorded from the ipsilateral aortic nerve.

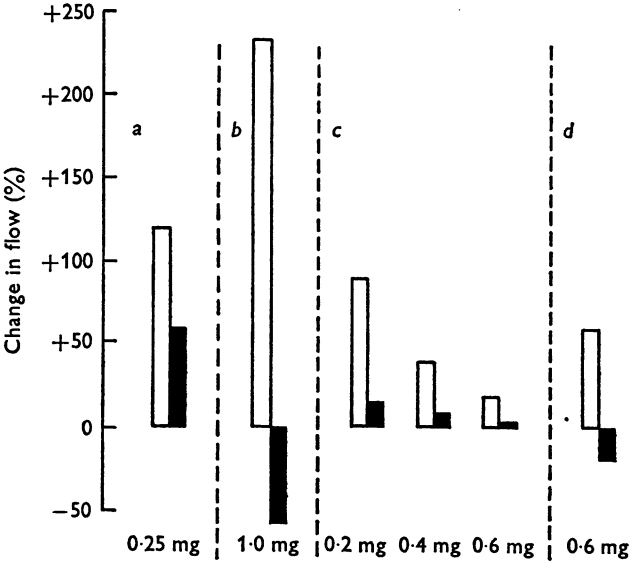

Fig. 12. Effects of close arterial atropine on the responses of carotid body flow to efferent electrical stimulation of the cut sinus nerve. *a*, *b*, *c* and *d* refer to separate experiments. □ = % changes of flow rate on stimulation before administration of atropine. ■ = % changes of flow rate on stimulation following administration of atropine. Dose of atropine administered is given under pairs of columns. In *c* separate doses of atropine, as indicated, were injected at 30 min intervals.

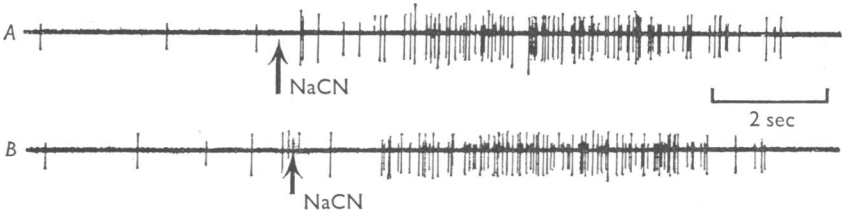

Fig. 13. Cat. Chemoreceptor afferent activity recorded from a slip of the cut sinus nerve. *A* = effect of sodium cyanide (20 μg) injected at the arrow (pre-atropine). *B* = effect of sodium cyanide (20 μg) injected at the arrow (following the administration of 0·6 mg atropine).

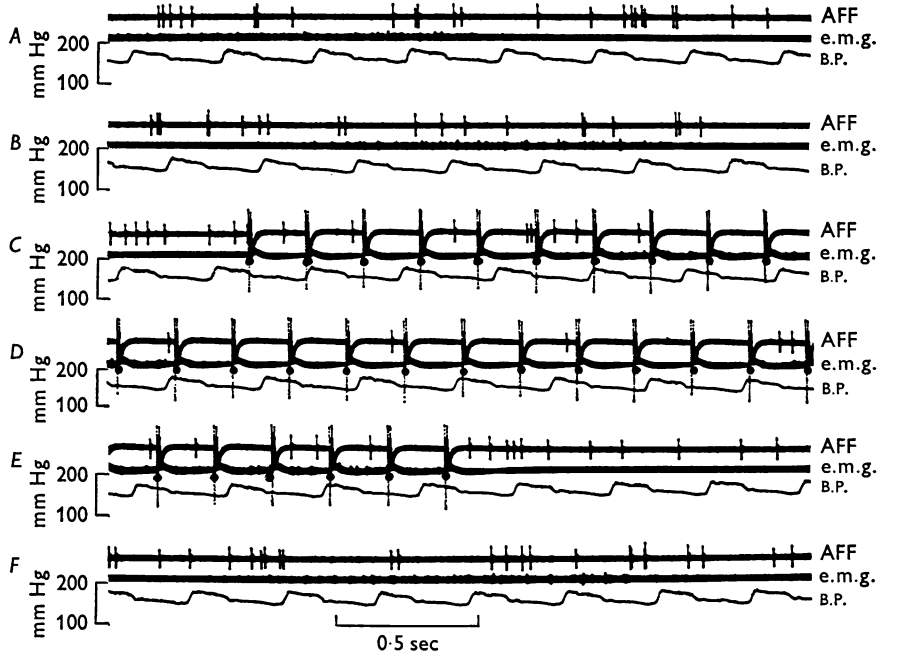

Fig. 14. Cat (atropinized). Chemoreceptor afferent activity (AFF) recorded from a slip of the cut aortic nerve, systemic arterial blood pressure (B.P.) recorded from the descending aorta and electromyographic activity (e.m.g.) recorded from the diaphragm. Peripheral electrical stimulation of the cut ipsilateral vagus nerve (right side). *A* to *F* = continuous recordings. Periods of stimulation (9·5 V, 5 Hz, 5 msec) indicated by the dots placed underneath each stimulus artifact.

DISCUSSION

Eyzaguirre & Koyano (1965) carried out electrical stimulation, placing their electrodes one on each side of the superperfused carotid body, and noted that chemoreceptor afferent activity was reduced during the stimulation and increased markedly in the post-stimulatory period. When the sinus nerve was 'efferently' stimulated reduction of discharge during stimulation still occurred, but not the post-stimulatory accentuation. Their technique, however, differed from ours for they recorded chemoreceptor activity from the same nerve trunk as was stimulated and not from a strand peeled off distal to the stimulating electrodes. They interpreted the stimulatory depression as being due to antidromic invasion of the sensory nerve endings by the propagated action potentials elicited in the nerve. On the other hand, the post-stimulatory increase in activity was considered to have resulted from the release of substances of cholinergic nature from the

carotid body cells which in turn excited the sensory terminals. The unresponsiveness of the afferent endings during direct stimulation of the carotid body rendered this excitatory influence ineffective until the electrical stimulation ceased.

Our results are similar in many respects to those noted by Eyzaguirre & Koyano. It is important to determine, therefore, whether these changes of chemoreceptor discharge are caused by the spread of the stimulating current so as to involve the glomus cells themselves or the sensory endings or both. Indeed, even in the method employed in the present investigation, stimulating current may have spread from the fibres excited directly to block conduction in the afferent fibres, thereby giving an erroneous impression of true efferent effects. Such effects of non-specific current spread are not responsible for the present results as indicated by the following observations.

1. Blockade of conduction in the efferent components of the sinus nerve trunk by procaine prevents the depression of impulse activity in the chemoreceptor twig, induced as a response to electrical stimulation of the nerve trunk (Fig. 7*B*). This effect is reversible after washing away the procaine solution.

2. Depressant effects were observed in aortic nerve chemoreceptor fibres when the aortic nerve trunk was efferently stimulated in the neck at a site remote from the aortic bodies themselves and some 2–3 cm from the filament recording the chemoreceptor afferent activity.

3. Baroreceptor impulses, recorded from slips of the stimulated sinus or aortic nerves, which were prepared in the same manner as were chemoreceptor fibres, were unaffected either during or after efferent stimulation. This indicates that their sensory endings and axons suffered little change in responsiveness as the result of the stimulation procedure carried out in the present investigation.

4. Neil & O'Regan (1969*b*) have shown that the natural effect of an increased sinus nerve efferent activity (provoked by systemic hypoxia) is to decrease glomeral chemoreceptor discharge. This too is powerful evidence, for no artificial current was employed and the spread of current is impossible.

Thus, it is probable that chemoreceptor responses to sinus and aortic nerve stimulation represent true efferent effects within the carotid body.

The release of a chemical substance from the efferent terminals might influence chemoreceptor activity either by a more direct mechanism or by altering glomeral blood flow. However, depression of chemoreceptor afferent discharge still occurred in conditions in which there was temporarily no blood flow through the carotid and aortic bodies. Furthermore, the temporal patterns of changes of chemoreceptor afferent activity recorded from the sinus nerve and carotid body blood flow are not closely

related. Additionally, atropine given locally abolishes flow changes to stimulation without affecting the responses of chemoreceptor activity.

These effects of efferent stimulation may be exerted either on the glomus cells themselves or on the chemoreceptor afferent terminals. De Castro & Rubio (1968) found that whereas section of the glossopharyngeal nerve below the petrosal ganglion caused degeneration of the nerve endings abutting the Type 1 cells of the carotid glomus, suprapetrosal section did not. Such results substantiated De Castro's original observations (1928) that the glossopharyngeal supply of the glomus cells was of afferent nature. However, Biscoe, Lall & Sampson (1969, 1970) refute these findings, reporting that a section above the petrosal ganglion caused degeneration of most of the endings in contact with the Type 1 cells. Chemoreceptor activity could still be recorded from the sinus nerve. Biscoe *et al.* concluded that the endings in contact with the Type 1 cells were efferent in nature with their cells of origin within the brain stem.

If these endings are indeed efferent then the effects observed during efferent stimulation of the sinus and aortic nerves in the present investigation are readily explained by a direct action on the Type 1 cells independent of such changes as may be secondary to changes of blood flow.

It seems that efferent fibres destined for the glomus tissue of the aortic area are also present in the vagi, an observation which is not surprising as chemoreceptor afferent fibres from these areas have been shown to be present in the vagal trunks (Neil, Redwood & Schweitzer, 1949).

The sinus nerve also contains sympathetic components (Biscoe & Sampson, 1968) and it is known that sympathetic stimulation reduces glomus blood flow (Daly *et al.* 1954) and increases the chemoreceptor impulse traffic of the sinus nerve (Floyd & Neil, 1952; Eyzaguirre & Lewin, 1961; Biscoe & Purves, 1967). The presence of such sympathetic fibres in the sinus nerve might explain our findings that electrical stimulation of the sinus nerve trunk occasionally decreased the blood flow through the carotid body and may also in part account for the wide variation in the patterns of hyperaemic responses observed during such stimulation. These variations may represent a balance between dilator (possibly parasympathetic) and sympathetic constrictor effects on the carotid body vasculature. The occasional accentuation of chemoreceptor afferent discharge, both during stimulation and in the post-stimulatory periods, may also be a consequence of such sympathetic innervation. After atropinization, glomeral hyperaemia (which usually characterizes the results of sinus nerve stimulation in the non-atropinized animal) is abolished and the blood flow response indicates the effect of stimulating vasoconstrictor fibres, presumably of such sympathetic origin.

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