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A method for the continuous recording of peripheral vascular conductance

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A method is described for the continuous recording of the conductance of a perfused vascular bed, derived from simultaneous measurement of blood flow and perfusion pressure. For the auto-perfused hindquarters of the anaesthetized cat, it is shown that for vasoconstrictor or vasodilator drugs, injected either intravenously or into the arterial perfusion circuit, a record of changes in conductance may be of considerable aid in clarifying the responses of the vessels.

The prospect of following variations in the properties of a vascular bed by changes in its resistance to flow rather than by flow itself, offers the advantage of detecting those changes independently of changes in perfusion pressure, thus permitting the study of vascular effects of drugs in auto-perfused areas. Changes in vascular capacitance are, however, less readily reflected by changes in resistance than by its reciprocal, namely, conductance (Stark, 1968). This value is represented by flow divided by pressure and provides a more ready interpretation of the effects of drugs upon the vessels.

Methods for the continuous recording of peripheral vascular resistance have been described by Hughes (1970) and Jancsó & Galgócry (1969). The method described here records both blood flow and perfusion pressure and continuously relates these parameters by an electronic divider circuit, to give a record of vascular conductance.

METHODS

Blood flow is measured by the insertion of an electromagnetic flowmeter (Statham E-3002) into the arterial perfusion circuit using an extra-corporeal flow probe; the principle of the method would, however, apply if cuffed flow sensors were to be used. Perfusion pressure is measured with a pressure transducer attached to the distal side of the extra corporeal circuit. Signals from both the blood flow and perfusion pressure transducers are amplified and their outputs fed into a dividing module (Figs 1 and 2).

Using blood flow as the numerator and perfusion pressure as the denominator, the divider output represents conductance of the vascular bed.

In the demonstrations of the applications of the method presented in this paper, cats intraperitoneally anaesthetized with chloralose (100 mg/kg) were used. After cannulation of the trachea, a blood pressure transducer was inserted into the common carotid artery and the external jugular vein cannulated for the intravenous administration of drugs.

For the study of vascular changes in the hindquarters, the extra-corporeal circuit was inserted into the abdominal aorta just proximal to the iliac bifurcation; for the study of the splanchnic vascular bed the circuit was connected to the superior mesenteric artery. Blood was thus allowed to be propelled naturally through the extra-corporeal circuit and perfused bed without the intervention of a perfusion pump.

Records were obtained of the heart rate (HR), systemic arterial blood pressure (BP), perfusion pressure (PP), conductance (C) and regional blood flow (F). Drug solutions were injected either intravenously or intra-arterially through a side arm on the extra-corporeal circuit. Maximum dose volume administered intra-arterially was 0·3 ml.

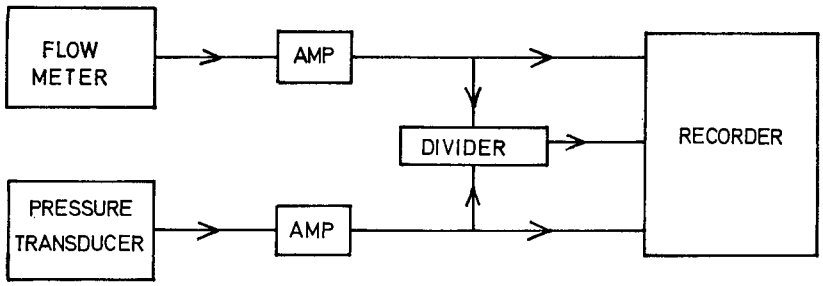


FIG. 1. Block diagram of arrangement for recording blood flow, perfusion pressure and vascular conductance. AMP = D.C. amplifier.

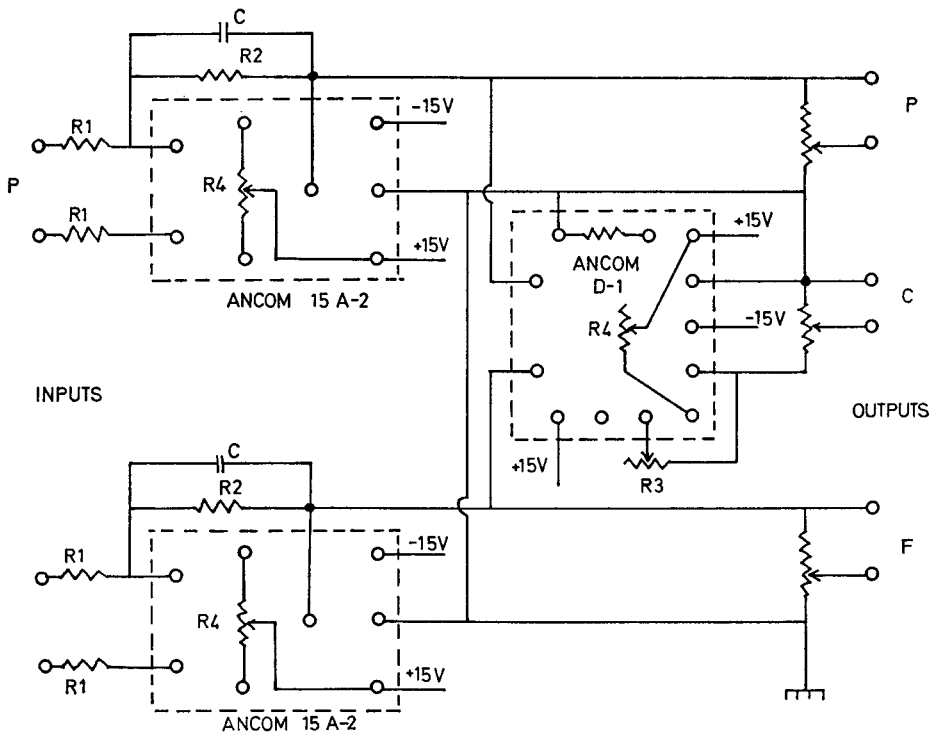
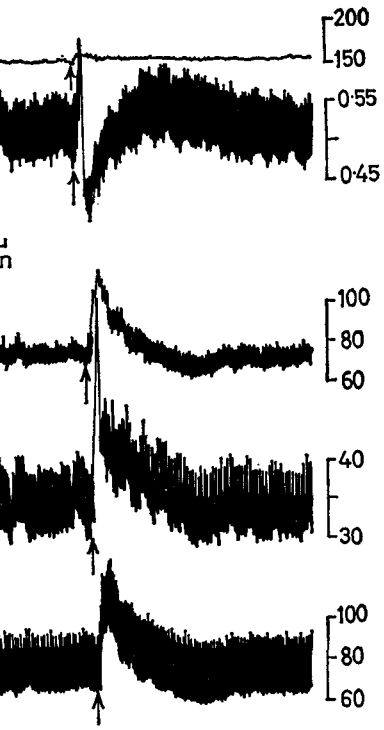


FIG. 2. Circuit diagram. C = 0·1 μF. R1 = 2·2 KΩ; R2 = 2·2 MΩ; R3 = 2KΩ. R4 = 50KΩ. P = Perfusion pressure. F = Blood flow. C = Vascular conductance = F/P.

RESULTS

In both the hindquarters and the splanchnic region, the effects of intra-arterial or intravenous injection of vasoconstrictor or vasodilator agents upon the vessels could be detected by changes in vascular conductance and distinguished from the



Part of recording of hindquarters in a chloralosed cat. Traces: Heart . Vascular conductance (C). Pressure (PP). Blood flow (F). Carotid pressure (BP) mm Hg. At the n injection of noradrenaline, 0·2 travenously: these show correspondts on the traces and indicate the he recording pens.

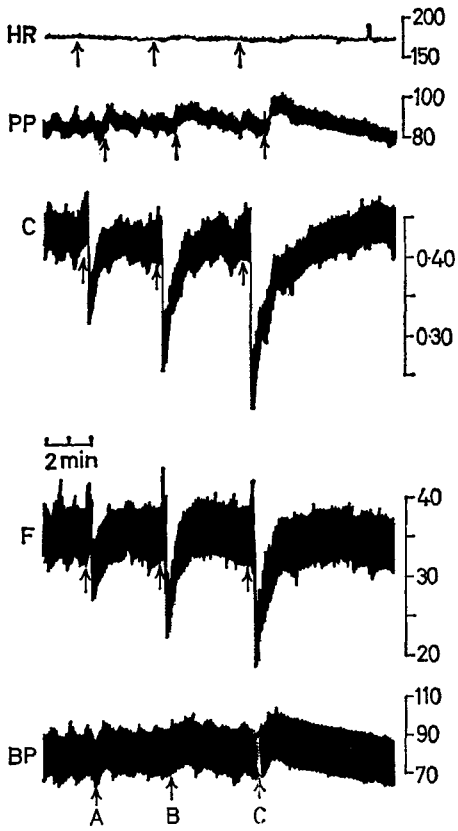


FIG. 4. Recording as Fig. 3. At each set of arrows, an injection of noradrenaline into the perfusion circuit: these show corresponding points on the traces and indicate the offset of the recording pens. The doses of noradrenaline were as follows: A—0·01 μg; B—0·02 μg; C—0·05 μg.

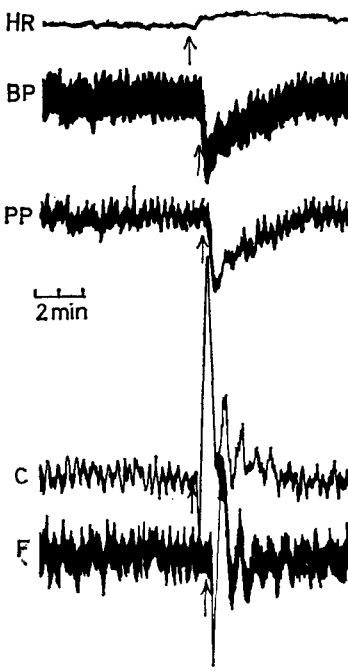


FIG. 5. Recording as Fig. 3. At t an injection of papaverine, 1 mg/kg ously: these show corresponding the traces and indicate the offset cording pens.

consequences of their effects on blood pressure. Thus, Fig. 3 shows that noradrenaline (0·2 μg/kg) injected intravenously was followed by an increase in both pressure and blood flow in the hindquarters. These increases arose from changes outside the perfused bed, within which conductance rose briefly as the vessels were distended by the increased perfusion pressure. The conductance then showed a secondary fall, similar to the effect after injection of noradrenaline into the perfusion circuit (Fig. 4); this may therefore be attributed to the direct action of the amine on the vessels of the perfused bed. The flow record in Fig. 3 shows a sharp fall at a time when the pressure is still elevated, consequent upon the reduced conductance.

These secondary effects were maximal some 24 s after intravenous injection (Fig. 3) while the corresponding direct effects reached their peak 12 s after injection into the perfusion circuit (Fig. 4). These figures indicate a circulation time of some 12 s which is similar to that reported from precise studies (Groom, Morris & Rowlands, 1957).

Similarly, as shown in Fig. 5, the intravenous injection of papaverine (1 mg/kg) caused a fall in perfusion pressure, owing to widespread vasodilatation; as a consequence, the flow in the perfused hindquarters decreased initially and the conductance record also shows an initial decrease, i.e., passive reduction in tone of the vessels. Secondarily, however, the conductance is seen to increase as the drug reached the perfused bed, with a similar further delay whereupon flow increased, despite the low perfusion pressure.

The injection of vasoconstrictor or vasodilator drugs into the arterial perfusion circuit caused the expected rise in conductance and flow, with a fall in perfusion pressure (Fig. 4), although large doses resulted in secondary changes in systemic pressure when sufficient of the drug reached the general circulation. The relations between dose of drug and effect on conductance, flow and perfusion pressure of the perfused hindquarters are illustrated in Fig. 6 for intra-arterially injected isoprenaline.

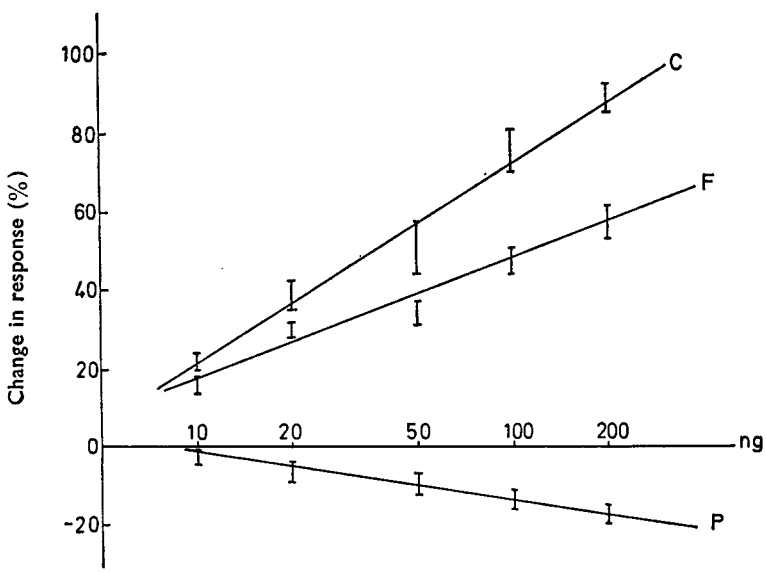


FIG. 6. Dose-response relations for the effect of isoprenaline, injected into the perfusion circuit, upon blood flow (F), perfusion pressure (P) and vascular conductance (C). The vertical bars represent the mean values ± s.e. obtained with each dose level. The lines were calculated from 60 values.

The effects are plotted as percentage change from the value recorded before injecting the dose; multiple regression analysis showed that the highest correlations were obtained by expressing results in this way.

DISCUSSION

By deriving a value for the conductance of the perfused vascular bed it is claimed that a more informative representation of the responses of the vessels to drugs is achieved than may be obtained by observing only changes in flow or perfusion pressure. The consequences of the intravenous injection of vasoconstrictors or vasodilators, illustrated by Figs 3 and 5, may be analysed into components of direct effects on the perfused vessels and indirect systemic effects.

For drugs injected into the perfusion circuit, the evidence again suggests that changes in conductance most nearly represent the effects of the drugs on the vessels. From multiple regression analysis applied to the results plotted in Fig. 6, the changes in flow with various doses of isoprenaline were more closely correlated with changes in conductance ($r_{FC} = 0{\cdot}86$) than with changes in perfusion pressure ($r_{FP} = -0{\cdot}6$); at the highest dose used, systemic changes may have affected pressure. The partial correlation of flow changes on conductance changes was somewhat less than the overall correlation ($r_{FC.DP} = 0{\cdot}72$) while, when dose and conductance were held constant, the negative correlation of flow changes with changes in perfusion pressure became positive ($r_{FP.DC} = 0{\cdot}51$).

This suggests that the increase in conductance affected flow to an extent that more than compensated for the fall in perfusion pressure, as may be seen by comparing the dose-response relations in Fig. 6.

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