

STUDIES OF ANAESTHESIA IN RELATION TO HYPERTENSION
I: CARDIOVASCULAR RESPONSES OF TREATED AND UNTREATED
PATIENTS*

BY

C. PRYS-ROBERTS, R. MELOCHE AND P. FOËX

with the technical assistance of A. RYDER

SUMMARY

The cardiovascular responses to the induction, maintenance, and recovery from anaesthesia with thiopentone, nitrous oxide and halothane, have been studied in seven elderly normotensive patients, seven untreated hypertensive patients, and fifteen patients under treatment with a variety of anti-hypertensive drugs. In five untreated and three treated hypertensive patients, all of whom had high arterial pressures before anaesthesia, severe reduction of arterial pressure occurred during anaesthesia and was associated with electrocardiographic evidence of myocardial ischaemia. Other treated hypertensive patients, whose arterial pressures were well controlled, behaved in a similar manner to the normotensive patients, and gave no ground for concern during anaesthesia. Cardiac output fell to the same extent (30 per cent) in all three groups, and where a great reduction of arterial pressure occurred it was largely due to reduction of initially high systemic vascular resistance. Baroreflex control of heart rate was significantly depressed in hypertensive patients both before and during anaesthesia. It is concluded that untreated high arterial pressure constitutes a serious risk to patients undergoing anaesthesia and surgery, and therefore anti-hypertensive therapy should not be withdrawn prior to anaesthesia without a compelling reason.

Widespread concern has been expressed that anti-hypertensive drugs disturb the maintenance of circulatory homeostasis in patients undergoing anaesthesia and surgery (Armstrong Davison, 1951; Foster and Gayle, 1955; Dundee, 1958; Smessaert and Hicks, 1961; Ziegler and Lovette, 1961; Dingle, 1966; Lawin et al, 1966; Pickering, 1968; Grogono and Lee, 1970). Studies on the effects of anaesthesia in patients pretreated with reserpine or other rauwolfia alkaloids produced conflicting findings and conclusions (Coakley, Alpert and Boling, 1956; Munson and Jenicek, 1962; Alper, Flacke and Krayner, 1963; Morrow and Morrow, 1963; Hamelberg, 1964; Katz, Weintraub and Papper, 1964; Ominsky and Wollman, 1969). The position was summarized by Papper (1965) who concluded that "no patient need be taken off reserpine because he is going to be anaesthetized or operated upon".

Since the introduction of more potent anti-hypertensive drugs, most of these having pharmacological effects that differ from those of reserpine, there has been scant information on the interactions between the newer forms of anti-hypertensive therapy and the combined influences of anaesthesia and surgery. Opinion appears to be divided, both among anaesthetists and physicians, as to whether it is either necessary or even wise to stop anti-hypertensive therapy before anaesthesia. In their admirable reviews Dingle (1966) and Hickler and Vandam (1970) have stressed the difficulties of reaching a rational conclusion to the issues, mainly due to the paucity of information on the cardiovascular responses to anaesthesia and

C. PRYS-ROBERTS, M.A., PH.D., M.B., B.S., F.F.A.R.C.S.; R. MELOCHE,† M.D., F.R.C.P.(C); P. FOËX, M.D.; The Nuffield Department of Anaesthetics, University of Oxford.

† Present address: Hôpital Notre-Dame, Montreal 133, P.Q., Canada; work performed during tenure of a McLoughlin Travelling Fellowship, 1969-70.

* Abstract published in Proceedings of VI World Congress of Cardiology, Cardiovascular Research, 1970.

surgery of treated and untreated hypertensive patients. The present study represents the first of a series of studies in which we have investigated the cardiovascular responses of hypertensive patients to the induction, maintenance and recovery from anaesthesia and surgery.

CLINICAL MATERIAL

Three groups of patients were studied under identical conditions of induction and maintenance of anaesthesia, during and after various forms of surgery, and subsequently during the early post-operative period. Anthropometric data from patients in each group are summarized in table I.

Group 1. Normotensive elderly patients.

A control group of seven elderly subjects was studied, whose resting arterial pressures were within one standard deviation of the median relation between both systolic and diastolic pressures and age derived from data of Hamilton and associates, (1954a, b).

Group 2. Untreated hypertensive elderly patients.

Seven elderly hypertensive patients not receiving treatment with anti-hypertensive drugs were studied. Four of these patients were under medi-

cal care for symptoms related to their high blood pressure, which was well above the mean values for their age predicted from the data of Hamilton and associates (1954a, b). Three patients were found on routine pre-operative examination to be markedly hypertensive, though unsymptomatic. They were included in the study in order to assess their resting haemodynamic state as well as their response to anaesthesia. One of these patients was subsequently treated with methyldopa and was studied again 4 months later; the results are included in group 3.

Group 3. Treated hypertensive patients.

Fifteen patients were studied, whose established hypertension was under treatment with a variety of anti-hypertensive drugs. Their methods of treatment are detailed in table II. They were predominantly elderly, although the mean age of the group was reduced by the inclusion of a 27-year-old woman with malignant hypertension. All the patients in this group were maintained on their anti-hypertensive therapy up to and including the day of operation. Full haemodynamic studies were performed on nine patients; in the other six, observations of direct arterial pressure, e.c.g. and

TABLE I

Summary of anthropometric and haemodynamic data in conscious unpremedicated patients before anaesthesia. The present data are compared with those from Fröhlich, Tarazi and Dustan (1969) for normotensive patients, and their pooled data for patients with essential hypertension. Mean values shown, with SD in brackets.

	Present study			Fröhlich et al.	
	Group 1 Normotensive	Group 2 Untreated hypertensive	Group 3 Treated hypertensive	Normotensive	Untreated essential hypertension
Male	6	3	4	20	45
Female	1	4	5	5	14
Total	7	7	9	25	59
Age	60.4 (5.2)	63.5 (8.0)	53.4 (12.0)	34 (15.0)	45 (17.0)
Weight (kg)	77.7 (16.9)	65.2 (10.4)	71.5 (13.1)		
Height (cm)	174.7 (4.6)	162.3 (10.3)	169.1 (12.0)		
Body surface area (m ²)	1.91 (0.20)	1.70 (0.19)	1.81 (0.22)	1.87	1.88
Mean arterial pressure (mm Hg)	89.5 (5.0)	129.5 (13.0)	129.0 (18.8)	93.0 (8.0)	134.0 (22.5)
Cardiac index (l./min/m ²)	2.80 (0.49)	2.70 (0.31)	2.99 (0.43)	3.05 (0.45)	2.83 (0.56)
Systemic vascular resistance (dyne. sec. cm ⁻⁵)	1338 (229)	2226 (378)	1879 (324)	1360 (—)	2080 (—)
Heart rate (beats/min)	72 (11)	71 (10)	74 (16)	68 (10)	75 (14)
Stroke index (ml/m ²)	39 (13)	37 (8)	40 (13)	45 (6)	38 (8)

TABLE II

Details of treated hypertensive patients (group 3). Those labelled with an asterisk were studied in full and form the basis of the summarized data in table III.

Patient	Age	Sex	Height (cm)	Weight (kg)	Blood pressure (mm Hg)	Type	Therapy (daily total dose)	Type of surgery
1*	63	F	174	82.7	150/90	E	Methyldopa 500 mg	Excision of basal cell tumour of ear
2	51	M	176	78.0	135/90	E	Methyldopa 1500 mg	Vasectomy
3*	50	M	183	97.5	160/100	E	Methyldopa 1000 mg Bethanidine 150 mg Amisulpride 75 mg Navidrex-K†	Excision of large lipoma of neck
4†	71	F	162	63.9	180/90	E	Methyldopa 750 mg	TUR bladder
5†	60	M	178	76.2	170/100	E	Methyldopa 1075 mg Navidrex-K	Cystoscopy
6	55	M	171	63.5	150/90	E	Reserpine 0.5 mg	Thoraco-abdominal nephrectomy
7	61	F	159	62.3	150/105	R	Bethanidine 20 mg Navidrex-K	Hysterectomy
8*	27	F	173	66.0	180/120	R	Methyldopa 1000 mg Bethanidine 120 mg Navidrex-K	Tubal ligation
9	67	F	161	65.2	200/100	E	Reserpine 0.5 mg Navidrex-K	TUR urethral stricture
10*	69	F	145	44.0	190/95	E	Methyldopa 250 mg	Cystoscopy
11*	68	F	145	58.1	180/100	E	Reserpine 0.5 mg	Vaginal hysterectomy
12*	46	F	160	59.3	180/100	R	Bethanidine 35 mg	Dilatation and curettage
13*	44	M	178	75.4	220/100	R	Methyldopa 1000 mg	Nephrectomy
14*	51	F	165	65.2	180/120	R	Methyldopa 1000 mg Bethanidine 40 mg	Hysterectomy
15	67	M	178	78.0	220/110	E	Guanethidine 30 mg Bendroflumazide 2.5 mg	Oesophagoscopy Celestin tube

† cyclopentiazide.

‡ previously studied as untreated hypertensive and included in group 2.

E essential hypertension.

R renal hypertension.

heart rate were made throughout anaesthesia and surgery.

PROCEDURE

Each patient was routinely examined by the house surgeon, and subsequently by one of us on the day before surgery. A detailed examination included a classification of fundal changes (Keith, Wagener and Barker, 1939), an electrocardiogram, and heart size estimated from the chest radiograph. The patient's consent to the studies was obtained after a thorough explanation of the purpose and relative benefits to themselves and others, of the investigations to be performed. The patients were brought to the anaesthetic room in their beds about 2 hours before surgery was scheduled, and throughout the studies remained in a supine level position with one pillow under the head. No premedication was given but with one exception the patients appeared calm and relaxed.

Electrocardiographic limb and chest leads were applied, together with a simple circumferential chest pneumograph. A rectal thermistor temperature probe was inserted. Under local analgesia, an 18-gauge teflon cannula (Becton-Dickinson, Longdwell) was inserted percutaneously into a brachial artery, and a similar 15-gauge teflon cannula was inserted into the basilic vein of the same or opposite arm. Through the latter, a 90-cm nylon floating catheter (1.34 mm o.d., Portex Plastics Ltd) was advanced centrally under electrocardiographic and pressure visualization, until its tip lay in either the right ventricle or the pulmonary artery. Once this procedure had been completed, the patients were encouraged to make themselves comfortable and to settle undisturbed for a period of 15–20 minutes. One patient fell asleep.

A duplicate set of control observations were then made (stage A), and consisted of a full

electrocardiographic scan and steady-state haemodynamic measurements, Riley-Cournand analysis of pulmonary function, responses to Valsalva's manoeuvre, and other assessments of baroreflex activity. These observations were repeated in full on three subsequent occasions; during established steady-state anaesthesia before surgery (stage B), during steady-state anaesthesia after surgery (stage C), and finally when full consciousness had returned in the postoperative period (stage D).

Patients were not told at what moment anaesthesia would be induced, but unknown to them, thiopentone sodium (2.5 per cent) was infused slowly through the right-heart catheter until they were asleep, the required dose varying between 50 and 200 mg. Anaesthesia was subsequently maintained throughout the study with 1 per cent halothane vaporized in 70 per cent nitrous oxide and 30 per cent oxygen and administered through a Magill attachment and mask until a steady cardiovascular state was achieved. Electrocardiograph, heart rate, and intravascular pressures were continuously recorded throughout the induction period and subsequent anaesthesia, and intermittent measurements of cardiac output were made, together with sampling of arterial and mixed venous blood.

The haemodynamic responses to the following sequence of endotracheal intubation were studied in detail. Suxamethonium (50–75 mg) was injected i.v. and the onset of fasciculations and complete paralysis marked on the record. Laryngoscopy was performed without prior lung inflation since the patient was already well oxygenated, and a 15–20 second period was allowed for the haemodynamic responses to become manifest before the endotracheal tube was inserted, its cuff inflated, and manual lung inflation commenced. When spontaneous ventilation had returned, and a steady state of ventilation and circulation was again established, a complete set of observations (stage B) was repeated. In a few patients who required neuromuscular relaxation and artificial ventilation during surgery, further measurements were repeated after this regime had been established, but the results are not reported in this paper. Observations were continued during surgery in some patients, but since no formal pattern of events could be adhered to, these observations could not be analyzed in group format.

When surgery had been completed, the patients returned to their beds in the anaesthetic room, under the same maintenance anaesthesia, and a further complete set of observations (stage C) was repeated. Anaesthesia was then abruptly withdrawn and, while continuous recording continued, the patients were allowed to recover undisturbed, breathing room air. Endotracheal extubation was performed at various stages during recovery, in order to assess the cardiovascular response to this stimulus. Cardiac output measurements and withdrawal of blood samples were performed at 5–10 minute intervals until awakening occurred. After verbal contact had been established with the patients, they were allowed to rest undisturbed for at least 1 hour before the final set of observations was made (stage D). At this stage, all patients were fully awake, conversing intelligently, and capable of remembering events occurring prior to induction of anaesthesia. The results of observations on the transient haemodynamic responses to induction and awakening from anaesthesia are presented in a separate publication (Prys-Roberts and associates, in preparation).

METHODS

A complete set of electrocardiograph leads was studied at each of the four main stages of the study, and comprised the standard and bipolar limb configurations, and chest leads VI–7. The criteria used in defining pathological changes in ventricular repolarization were S–T segment depression or accentuation of existing S–T depression, and inversion of T wave, in each case amounting to an amplitude change of more than 0.1 mV. A Neilson instantaneous ratemeter (Devices instruments) was triggered from the R wave of the e.c.g. Arterial pressure was measured with a Satham SP37 miniature strain-gauge transducer, connected by a tap directly to the arterial cannula. The amplitude/frequency of the complete arterial catheter-manometer system was measured with an electrohydraulic sine-wave pressure generator (Gersh, 1970) and consistently found to be flat (± 5 per cent) to more than 30 Hz with a resonant frequency in excess of 150 Hz. Right heart pressures were measured with a Satham PM131 TC transducer connected directly to the 90-cm catheter. The amplitude/frequency response of this catheter-manometer system was

flat (± 5 per cent) to only 4 Hz, with resonance occurring at 12-15 Hz. Thus phasic right ventricular and pulmonary arterial pressures were interpreted with caution, and used largely to indicate the position of the catheter tip, and the magnitude of the right ventricular end-diastolic pressure (RVEDP). Both catheters were continuously flushed with 5 ml heparinized saline per hour, from a butane pressure-generator/reservoir system (Stott, 1966).

Cardiac output was measured by analysis of indocyanine green indicator dilution curves, using a Waters X-302 cuvette-densitometer and amplifier (Prys-Roberts, 1969). In the pre-anaesthesia control period, measurements of cardiac output by dye dilution were compared with the results obtained by the direct Fick method using oxygen, thus establishing the accuracy with which oxygen uptake ($\dot{V}O_2$) could be derived during anaesthesia from dye-dilution measurements of cardiac output and measurements of arteriovenous oxygen content difference ($Ca_{O_2} - C\bar{V}_{O_2}$). The electrocardiograph, heart rate, intravascular pressures, the ventilatory excursion derived from the chest pneumograph, and the dye dilution curves were recorded on an Elema-Schonander EM81 recorder. Stroke volume was derived by dividing the measured cardiac output by the heart rate during the period of the dye curve, and systemic vascular resistance was derived by dividing mean arterial pressure minus right ventricular end-diastolic pressure by the cardiac output, and expressed in the standard c.g.s. units.

Estimates of baroreflex activity were obtained by two methods. Valsalva's manoeuvre was performed spontaneously by the awake patients, and by constant pressure inflation of the lung during anaesthesia. Baroreflex control of heart rate was assessed by the method described by Bristow and associates (1969b), in which the slowing of heart rate in response to the injection of phenylephrine 50-100 μ g was measured. The slope of the linear regression of the e.c.g. R-R interval on systolic arterial pressure gave an index of the sensitivity of the baroreflex arc, and the intercept of the regression an index of the degree of resetting of the baroreceptor reflex.

Details of ventilatory and pulmonary gas exchange measurements included under the general heading of Riley-Cournand analysis, are presented

together with methods for oxygen and carbon dioxide measurement in the gas and blood phases, in a separate publication (Prys-Roberts and associates, in preparation). Rectal temperature was measured with a digital thermistor thermometer.

All calculations of cardiac output and derived haemodynamic data were performed on a Wang Series 370 digital computer. Statistical analysis of the data was performed on the same computer using two-way analysis of variance and paired two-tailed *t*-tests for comparisons within groups (stages A, B, C and D), and unpaired *t*-tests for comparisons between groups.

RESULTS

Cardiovascular status of conscious patients.

Awake control haemodynamic data (stage A) for all groups are tabulated in table I and compared with data from Frohlich, Tarazi and Dustan (1969) for a larger series of normotensive and untreated essential hypertensive patients. Mean arterial pressures were significantly higher in both hypertensive groups (2 and 3) compared with the normotensive group (1). The similarity of mean arterial pressures in groups 2 and 3 reflects largely the severity of hypertension in group 3, kept under control by anti-hypertensive therapy. In group 2, the raised mean arterial pressures were the result of increased vascular resistance, since mean cardiac outputs for all three groups were not significantly different.

Cardiovascular effects of anaesthesia.

The haemodynamic data relating to steady-state conditions (stages A, B, C and D) are summarized in table III*, and figures 1 and 2. Following the induction of anaesthesia, mean arterial pressures in all three groups were significantly lower than the respective values in stage A, although differences between groups at stage B were not significant. Thus, although mean arterial pressures in both hypertensive groups were significantly above normal in the awake state, the values fell towards those of the normotensive group during anaesthesia, particularly those of the untreated hypertensive group (fig. 1).

* Details of values in individual patients may be obtained from C.P.-R.

TABLE III

Summary of haemodynamic variables at the four stages of investigation in all three groups of patients. Values shown are means with standard deviation of sample in brackets.

	Stage	Group 1 Normotensive n=7	Group 2 Untreated hypertensive n=7	Group 3 Treated hypertensive n=9
Mean arterial pressure (mm Hg)	A	90 (5)	130 (13)	129 (19)
	B	69 (13)	71 (16)	87 (16)
	C	66 (12)	59 (12)	81 (22)
	D	91 (15) A-B**, A-C*** B-D***, C-D***	121 (13) A-B***, A-C*** B-D***, C-D***	114 (16) A-B***, A-C*** B-D**, C-D***
Cardiac output (l./min/70 kg)	A	5.03 (1.08)	4.99 (0.69)	5.37 (1.09)
	B	3.61 (0.50)	3.71 (0.81)	3.74 (0.83)
	C	3.52 (0.20)	3.55 (1.15)	3.46 (0.32)
	D	4.58 (0.72) A-B***, A-C*** B-D**, C-D**	4.65 (0.93) A-B***, A-C*** B-D**, C-D***	5.15 (1.50) A-B**, A-C*** B-D**, C-D**
Systemic vascular resistance (dyne. sec. cm ⁻⁵)	A	1338 (230)	2226 (379)	1878 (324)
	B	1306 (224)	1604 (322)	1784 (418)
	C	1269 (265)	1451 (212)	1825 (640)
	D	1437 (288)	2280 (274) A-B***, A-C*** B-D***, C-D***	1822 (237)
Heart rate (beats/min)	A	72 (11)	71 (10)	74 (16)
	B	62 (15)	59 (10)	66 (15)
	C	59 (15)	53 (4)	59 (6)
	D	70 (15) A-C*, C-D*	73 (8) A-B**, A-C*** B-D***, C-D***	72 (14)
Stroke volume (ml)	A	76 (13)	66 (16)	78 (26)
	B	63 (7)	57 (15)	60 (16)
	C	66 (9)	62 (20)	60 (12)
	D	72 (14)	59 (11)	72 (19)

Significance of mean differences (paired two-tailed *t*-test) between stages A, B, C and D within groups are denoted: P<0.05*; P<0.01**; P<0.001***.

All other differences not significant.

Cardiac output was reduced to a similar degree in all three groups, and the values during anaesthesia were remarkably constrained. Thus the marked fall of mean arterial pressure in untreated hypertensive patients was related to a significant reduction of systemic vascular resistance, whereas in groups 1 and 3, no significant change in systemic vascular resistance was observed (fig. 1).

In all groups, the reduction in cardiac output at stage B was related to a fall of both heart rate and stroke volume, and although a significant change in heart rate only occurred in untreated hypertensive patients the general trends are clearly shown in figures 1 and 2. In no patient did either heart rate or stroke volume increase during steady-state anaesthesia. Although the findings are to be presented in detail in a separate publication (Prys-Roberts and associates, in preparation) the changes

in acid-base state due to inadequate spontaneous ventilation during anaesthesia are relevant to the haemodynamic findings, and are summarized in table IV. The hypercapnia associated with stage B was similar in all three groups of patients (fig. 3); thus it is unlikely that the difference in the haemodynamic responses of the untreated hypertensive patients can be attributed to the effects of hypercapnia.

Following surgery (stage C) which varied in duration between 25 and 95 minutes, there was a progressive downward trend in the values of mean arterial pressure and heart rate in all three groups, though the differences of these and other variables compared with stage B did not achieve statistical significance.

Finally, all the changes observed during anaesthesia were reversed within 30 minutes of with-

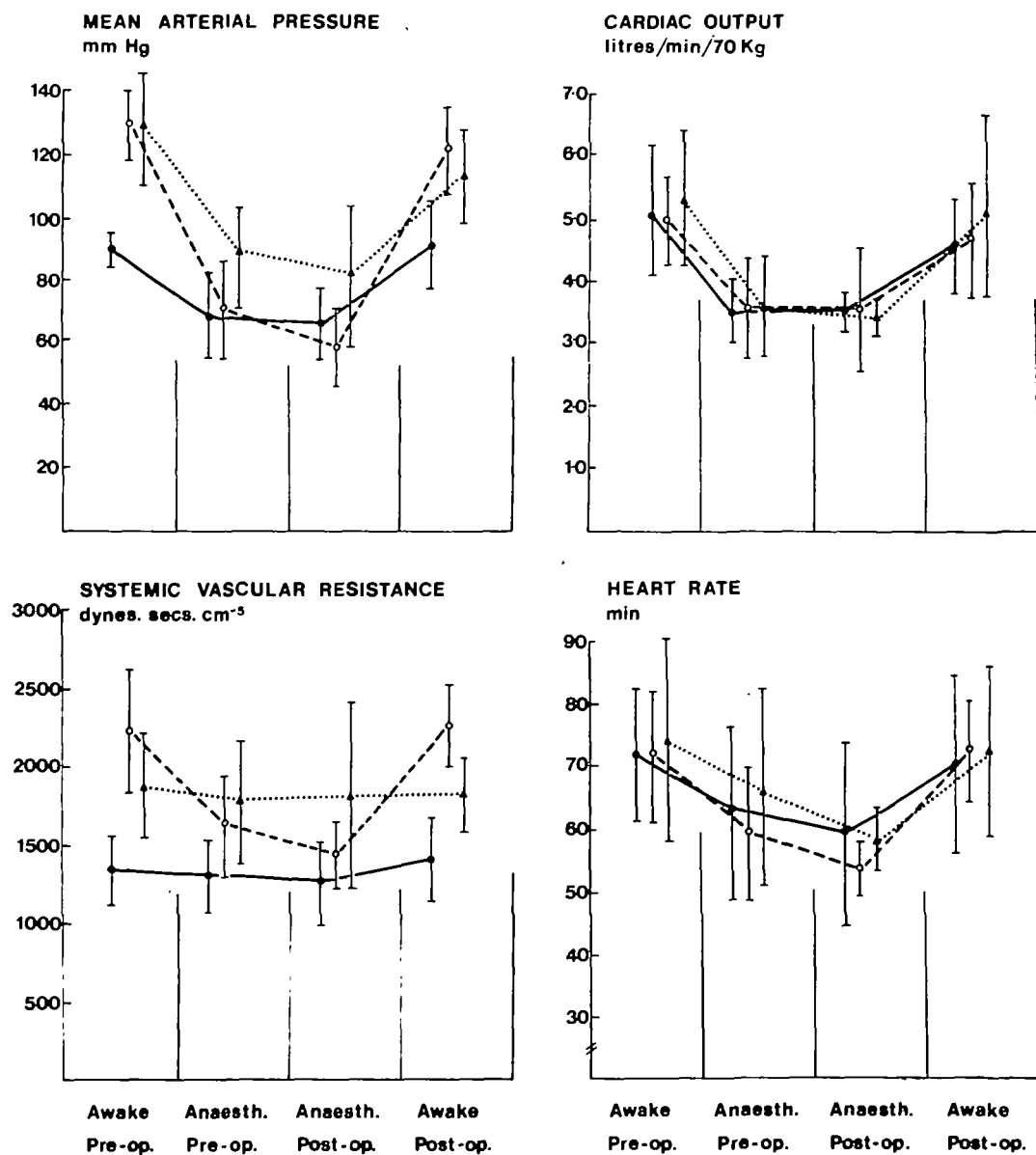


FIG. 1

Changes in mean arterial pressure, cardiac output, heart rate and systemic vascular resistance during stages 1-4 of the study in normotensive (—●—), untreated hypertensive (---○---) and treated hypertensive patients (...▲...). Based on data in table III, mean values \pm SD are shown.

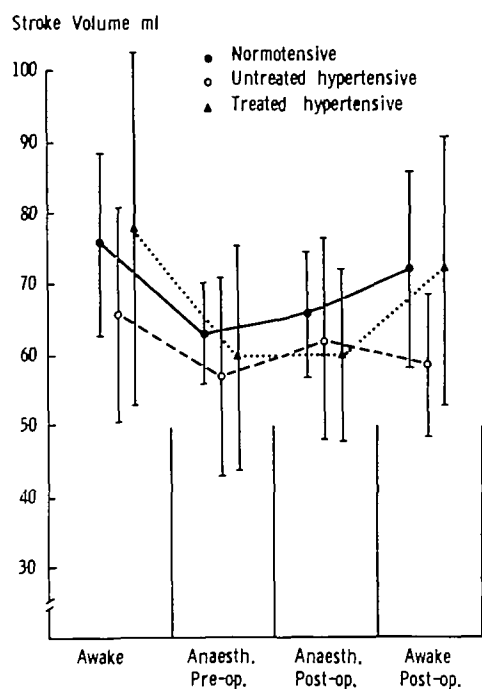


FIG. 2

Changes in stroke volume during stages 1-4 of the study in normotensive, untreated hypertensive and treated hypertensive patients.

drawal of anaesthetic agents, and the values for haemodynamic variables in all groups at stage D were not significantly different from the respective values during stage A. Thus all the cardiovascular effects of anaesthesia were reversed to the same extent in both normotensive and hypertensive patients.

Electrocardiographic changes.

No significant electrocardiographic change was detected in any of the leads examined in the normotensive patients, nor in the treated hypertensive patients with the three exceptions mentioned below. Severe and important dysrhythmia occurred in five of seven untreated hypertensive patients and in three patients treated with reserpine alone, and could be divided into two categories. Isolated atrial and ventricular extrasystoles, together with prolonged ventricular bigeminy, occurred during and after laryngoscopy and intubation, and during the immediate post-extubation period. These are considered in great-

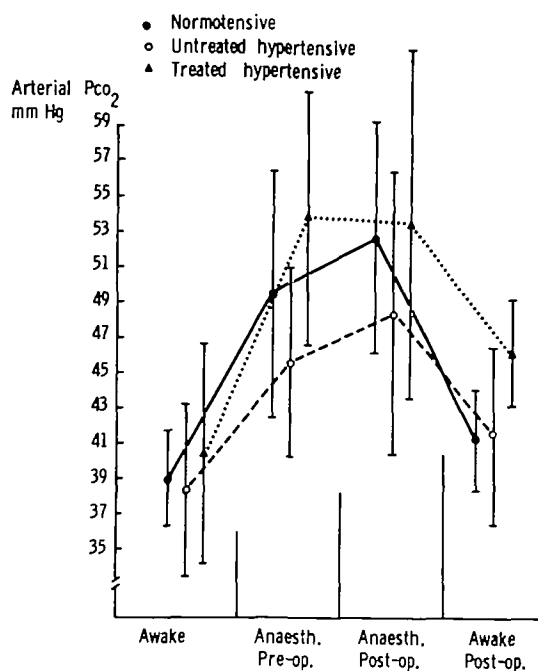


FIG. 3

Changes in arterial Pco₂ during stages 1-4 of the study in normotensive, untreated hypertensive and treated hypertensive patients. Data derived from table IV.

er detail in the relevant publication (Prys-Roberts and associates, in preparation). Evidence of myocardial ischaemia was found in five out of seven untreated hypertensive patients, as judged from the appearance of marked ST and T wave depression occurring in association with low mean arterial pressures (<50 per cent of the awake MAP). The changes observed were transient, and reverted to normal as the mean arterial pressure rose to control levels during recovery from anaesthesia.

In two patients, one untreated hypertensive patient, the other treated with reserpine alone, intermittent episodes of a-v nodal rhythm and atrioventricular dissociation occurred consistently during the administration of halothane. On withdrawal of halothane, the patients reverted to sinus rhythm (fig. 4). In the patient receiving reserpine, the cyclic intermittent episodes of a-v nodal rhythm caused a depression of more than 20 mm Hg in systolic arterial pressure associated with deepening of the T wave of the e.c.g. during the period

TABLE IV
Summary of acid-base and blood gas values during four stages of investigation in three groups of patients.

	Stage	Group 1 Normotensive	Group 2 Untreated hypertensive	Group 3 Treated hypertensive
Number		7	7	9
pH	A	7.392 (0.034)	7.397 (0.026)	7.431 (0.038)
	B	7.322 (0.039)	7.322 (0.048)	7.352 (0.025)
	C	7.307 (0.040)	7.297 (0.061)	7.340 (0.031)
	D	7.373 (0.026)	7.369 (0.030)	7.379 (0.030)
Significances		A-B**, A-C** B-D*, C-D*	A-B**, A-C*** B-D**, C-D***	A-B***, A-C*** A-D*
P _a CO ₂ (mm Hg)	A	38.9 (2.8)	38.3 (4.9)	40.5 (6.3)
	B	49.5 (7.0)	45.6 (5.5)	53.9 (7.2)
	C	52.6 (6.8)	48.2 (8.3)	53.5 (10.2)
	D	41.2 (3.0)	41.4 (5.0)	46.2 (3.0)
Significances		A-B***, A-C*** B-D**, C-D***	A-B***, A-C*** B-D*, C-D**	A-B***, A-C*** B-D*, C-D* A-D*
P _a O ₂ † (mm Hg)	A	77.6 (9.5)	77.8 (13.9)	76.4 (14.5)
	B	91.9 (13.5)	113.7 (28.3)	102.9 (24.7)
	C	89.3 (11.4)	116.4 (29.5)	94.5 (20.8)
	D	63.7 (6.7)	72.4 (15.7)	70.6 (7.6)
Significances		A-B**, A-C* A-D*, B-D*** C-D***	A-B***, A-C*** B-D***, C-D***	A-B**, A-C* B-D***, C-D*

Significances (paired two-tailed *t*-test) between mean differences: **P*<0.05; ***P*<0.01; ****P*<0.001
Other differences not significant.

† During stages A and D, FI_O₂=0.209.

During stages B and C, FI_O₂=0.300 (range 0.295–0.305).

of hypotension (fig. 5). These changes were also reversed by the withdrawal of halothane.

Baroreflex activity.

A normal baroreflex response to Valsalva's manoeuvre is difficult to define but Corbett (1969) has identified twelve characteristics, three of which were used in this study, namely an increase in heart rate during the period of falling arterial pressure as intrapulmonary pressure is raised, a sudden bradycardia as the arterial pressure increases on releasing intrapulmonary pressure, and an overshoot of arterial diastolic pressure during the recovery phase. These criteria of a normal response were found in only three of the sixteen patients, in whom the manoeuvre was assessed before anaesthesia; two of them were normotensive, the other a young hypertensive under treatment. In the other patients, there were no consistent changes of heart rate during the manoeuvre, and no diastolic overshoot. During anaesthesia, the response to sustained lung inflations (modified Valsalva manoeuvre) did not differ from those in the awake patients.

The baroreflex responses to phenylephrine-induced increase in arterial pressure are summarized in table V. The mean value for baroreflex sensitivity (slowing of heart rate in m.sec/mm Hg increase in systolic arterial pressure) in conscious normotensive elderly subjects was similar to the mean value for a group of younger normotensive patients (mean age 39) studied by Bristow and his colleagues (1969b). Conscious hypertensive patients, both treated and untreated, showed much smaller changes of heart rate in response to increasing arterial pressure (Bristow et al., 1969a). Baroreflex sensitivity was depressed by anaesthesia and the values were similar in all three groups, indicating a lack of barostatic control as the blood pressure fell during induction and maintenance of anaesthesia. Significant resetting of the barostatic reflex also occurred in all patients, allowing significantly lower heart rates to occur despite marked reduction in arterial pressure (as shown by the pulse interval at the reference pressure).

Influence of anti-hypertensive therapy.

The inhomogeneity of group 3 with regard to

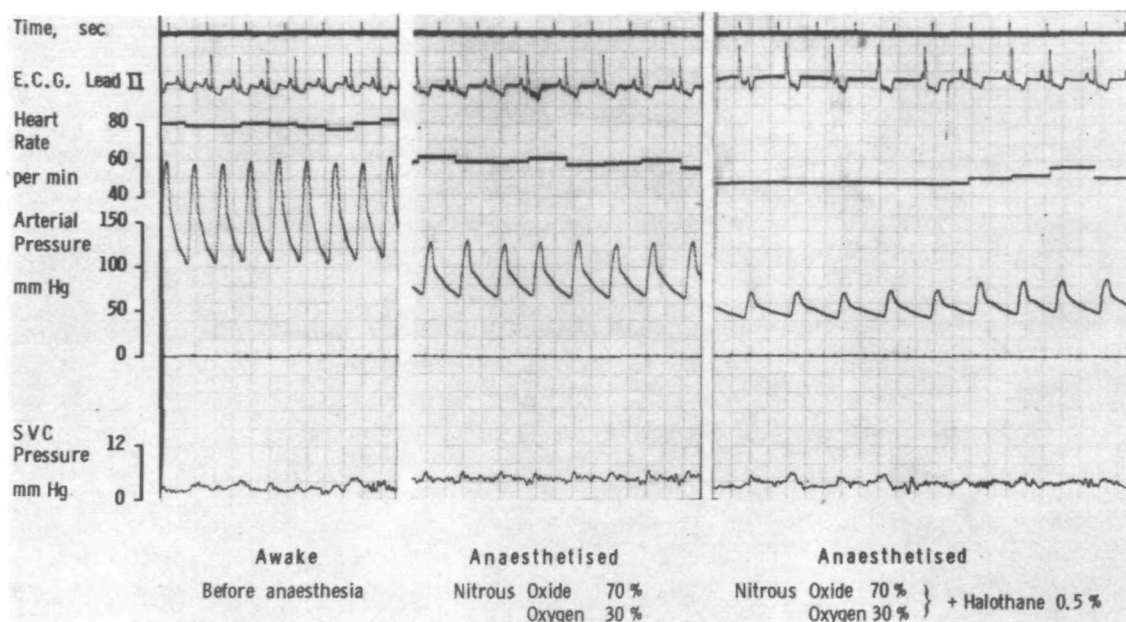


FIG. 4

Influence of halothane (0.5 per cent) on the appearance of nodal bradycardia with wandering pacemaker (righthand panel) in an untreated hypertensive patient. Note the increase in arterial pressure on resumption of sinus rhythm following a period of a-v nodal rhythm, and the progressive deepening of the S-T segment as the pressure falls. The further reduction of arterial pressure on adding halothane to the inspired gas mixture was almost entirely due to a 25 per cent reduction of cardiac output, partly due to the decrease in heart rate, but also due to a 20 per cent reduction of stroke volume.

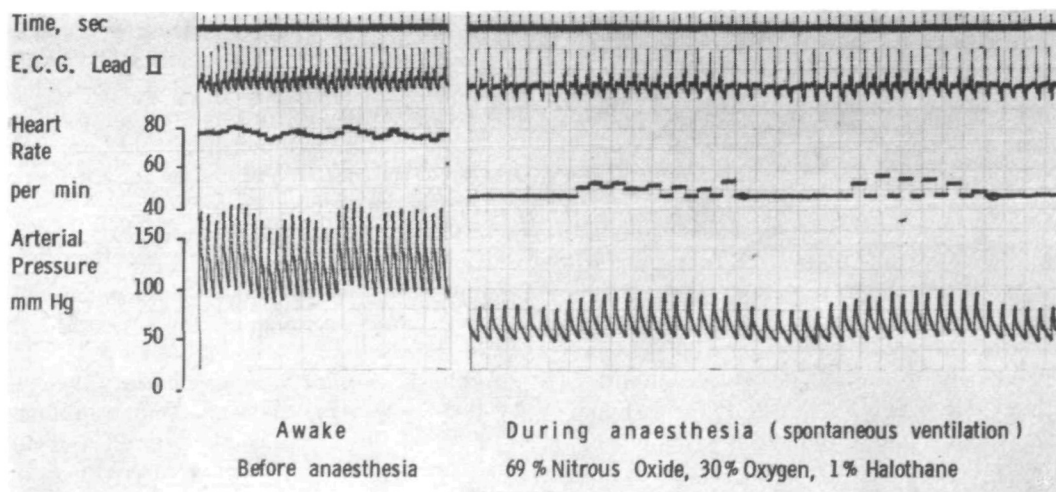


FIG. 5

Cyclical episodes of nodal bradycardia occurring in patient No. 9 (treated with reserpine) during spontaneous ventilation under anaesthesia with 1 per cent halothane in nitrous oxide/oxygen. Note the increase in systolic arterial pressure of nearly 20 mm Hg, due entirely to an increase in cardiac output, which in turn is probably due to improved synchrony of left ventricular contraction during sinus rhythm as compared with A-V nodal rhythm. Deepening of the T wave of the e.c.g. occurred during the episodes of nodal bradycardia.

TABLE V

Summary of assessments of baroreflex activity in all three groups of patients, awake before anaesthesia (stage A), and during anaesthesia but before surgery (stage B). For a detailed description of the interpretation of these assessments, the reader is referred to Bristow and associates (1969b).

		Pulse interval (m sec)*	Systolic pressure (mm Hg)*	Diastolic pressure (mm Hg)*	Baroreflex slope in sec slowing per mm Hg rise	Pulse interval at reference pressure in sec
1. Normotensive	Awake	881 (120)	130 (11)	73 (7)	10.2 (5.9)	881 (120)
(n=7)	Anaesthetized	1083 (287)	91 (20)	53 (14)	1.8 (2.0)	1136 (324)
	P	<0.02	<0.001	<0.001	<0.01	<0.02
2. Untreated	Awake	855 (93)	204 (25)	102 (5)	5.2 (3.7)	855 (93)
hypertensive	Anaesthetized	1127 (108)	106 (15)	57 (10)	2.1 (1.8)	1318 (137)
(n=7)	P	<0.001	<0.001	<0.001	<0.01	<0.001
3. Treated	Awake	856 (97)	174 (21)	89 (12)	4.1 (3.0)	856 (97)
hypertensive	Anaesthetized	1032 (146)	92 (20)	53 (14)	0.9 (1.8)	1150 (120)
(n=12)	P	<0.001	<0.001	<0.001	<0.005	<0.01

* Steady-state values before injection of phenylephrine. Means (SD in brackets) are shown with significance of mean differences (two-tailed paired *t*-test).

the drugs used, their doses, and the efficacy of treatment, is reflected in the wide range of haemodynamic values in the conscious patients, and their responses to anaesthesia. No specific cardiovascular response could be identified with any form of drug therapy but the range of responses in the treated hypertensive patients varied between those of the untreated hypertensive and those of the normotensive group, depending on the initial level of the arterial pressure. Three patients in group 3 (Nos. 9, 10, 11) under treatment with either reserpine or methyldopa, had initially high arterial pressures due to high systemic vascular resistance, and all developed marked hypotension following induction of anaesthesia, particularly patient No. 9 (fig. 5). As in group 2, the hypotension in these patients was due to a marked reduction in the systemic vascular resistance; thus in spite of their pre-existent therapy, their responses were typical of the untreated hypertensive patient. Other patients in group 3 behaved essentially like the normotensive group, in that despite the initially raised systemic vascular resistance, the reduction in mean arterial pressure was predominantly due to the fall in cardiac output.

Only in two patients (Nos. 8, 13) with hypertension of renal origin, did the arterial pressure fall slowly and only to moderate levels following induction of anaesthesia.

DISCUSSION

The choice of the anaesthetic technique used in these initial studies was based on its common

usage in the authors' department for elderly patients undergoing minor surgery. It is clear from the results that it represents somewhat less than the ideal method for either treated or untreated hypertensive patients. Premedication was avoided on two counts; first the need to establish control values prior to anaesthesia, and secondly, atropine was avoided where possible since its use would have prevented the assessment of baroreflex activity.

Despite the strange surroundings, and the stress surrounding preparations for surgery, only one of the patients studied appeared tense or apprehensive during the pre-operative stages. The others were undisturbed by the cannulation procedures, and on questioning during the postoperative period, frequently volunteered the information that they had been comfortable and unworried, and had no recollection of the moment of induction. These observations are important since in view of the marked cardiovascular responses to minimal levels of anaesthesia, the avoidance of pre-anaesthetic depression by premedication would seem wise.

Although atropine was not routinely used during this study, the intravenous administration of atropine 0.6 mg immediately prior to induction would seem wise in order to prevent sudden bradycardia occurring after the sympathetic nervous responses to induction and endotracheal intubation have settled. We administered atropine for this reason in four patients in this series, and, although heart rate increased, the stroke volume

fell and there was no significant increase in cardiac output.

The haemodynamic findings in the awake unpremedicated patients were comparable with those for a much larger sample of both normotensive and untreated hypertensive patients studied by Frohlich, Tarazi and Dustan (1969) and of normotensive elderly patients studied by Renck (1969). Although Frohlich, Tarazi and Dustan were able to distinguish a different haemodynamic pattern between patients with essential and renal hypertension, no untreated renal hypertensive patients were studied by us. Our findings in the inhomogeneous treated hypertensive group may have been influenced by the inclusion of four patients who, despite therapy, had severe hypertension of renal origin. The wide range of mean arterial pressure within group 3 was reflected in the differences in systemic vascular resistance, since cardiac output was not only similar to other groups, but there was little scatter of values within each group. Thus, regardless of the type of drug used in therapy, high arterial pressures were the result of raised systemic vascular resistance, and it was not possible to make a clear distinction between untreated and ineffectively treated hypertension. This is of clinical importance since the general conclusions of the study were that the responses to anaesthesia seemed to be dependent on the pre-existing level of arterial pressure, rather than whether the hypertension had been treated or not. Thus, broadly speaking, patients who had high arterial pressure in spite of treatment behaved essentially like those whose hypertension was untreated, whereas those whose blood pressure lay within the normal range as a result of therapy responded like normotensive patients of the same age group. There were exceptions to such a generalization, largely in patients with renal hypertension. Whereas patients with essential hypertension showed a marked reduction of arterial pressure in response to anaesthesia, in two patients with established and refractory renal hypertension, the arterial pressure fell only slowly, and not to a great extent even when the concentration of halothane was increased from 1 to 3 per cent.

Established untreated essential hypertension is characterized by raised systemic vascular resistance, with normal or slightly subnormal cardiac output (Werkö and Lagerlöf, 1949; Freis, 1960;

Page and McCubbin, 1966; Frohlich, Tarazi and Dustan, 1969). The aetiological factors involved in the causation of this increased resistance may be conveniently separated into three groups of mechanisms: neurogenic, humoral and anatomical. It is widely accepted that these mechanisms do not operate singly but that the regulation of tissue perfusion and thus vascular resistance and blood pressure, results from an equilibrium between the many mechanisms (Page and McCubbin, 1966; Page, 1967). "Labile" hypertension in young patients is predominantly due to elevated cardiac output (Eich and associates, 1962; Frohlich, Tarazi and Dustan, 1969; Sannerstedt, 1969) but there is growing evidence that essential hypertension with high vascular resistance and normal cardiac output may develop from this early hyperdynamic state (Eich et al, 1966). It is clear that in our untreated patients, and some of the treated patients, the raised systemic vascular resistance was reversible, since the values during anaesthesia were similar to those of the normotensive patients. Moreover, the reduction which occurred during anaesthesia was also rapidly reversed during the recovery phase, often within a period of a few seconds. There is little evidence to suggest that excess sympathetic activity accounts for the raised systemic vascular resistance in essential hypertension (Hickler and Vandam, 1970), though it has been suggested that hyper-reactive arteriolar smooth muscle is a fundamental defect in essential hypertension (Doyle and Fraser, 1961). In the treated hypertensive patients, although the systemic vascular resistance for the group as a whole was elevated compared with the normotensive group, the induction and maintenance of anaesthesia did not cause a significant reduction of resistance. This is partly explained by the inhomogeneity of the group, since some patients with initially high arterial pressure and systemic vascular resistance despite treatment responded in the same way as the untreated hypertensive group. Others, whose blood pressure was nearer the normal range, showed no significant change in systemic vascular resistance during anaesthesia, thus responding like the normotensive group in this study, and younger normotensive patients in other studies (Prys-Roberts et al., 1967, 1968). Although the moderate degree of hypercapnia may have contributed to the reduction

of vascular resistance in the susceptible patients, it cannot be regarded as the major cause, since the degree of hypercapnia was similar in all three groups, and the reduction of systemic vascular resistance was much greater than found during a much greater degree of hypercapnia (mean P_{CO_2} 70–80 mm Hg) in other studies (Prys-Roberts et al., 1957, 1968). Although the nature of the raised vascular resistance in untreated essential hypertension remains obscure, its reversibility by anaesthesia, and particularly the rate of change, would favour the release of arteriolar constriction as the probable mechanism.

Recent evidence has shown that the main mechanism leading to reduction of stroke volume and cardiac output during established halothane anaesthesia, lies in the depression of myocardial contractility (Gersh et al., 1970; Gersh, 1970), and that the site of depression lies within the muscle cell rather than in the autonomic postganglionic nerves or the adrenergic receptors (Prys-Roberts et al., 1970). The ejection of blood from the left ventricle is markedly influenced by the resistance and impedance characteristics of the arterial tree (Wilcken et al., 1954; Gersh, 1970) and especially the stroke volume of the depressed heart is reduced in the face of increased resistance to ejection, and increased when the resistance falls (Gersh, Prys-Roberts, Reuben and Baker, in preparation).

Although the changes in cardiac output were similar in all three groups of patients, this does not necessarily imply that myocardial contractility was depressed to a similar extent. However, since it is unlikely that depression of myocardial contractility would be greater in the normotensive patient, the reduction of systemic vascular resistance in those patients with initially high arterial pressure would seem providential. If their high systemic vascular resistance were to remain unaltered during anaesthesia the load on the ejecting but depressed ventricular muscle would be very high, and left ventricular failure with elevated end-diastolic left ventricular pressure would ensue. Such changes have been demonstrated in dogs anaesthetized with halothane where artificially high systemic vascular resistance was produced by prolonged infusion of phenylephrine (Gersh, Prys-Roberts and associates, in preparation). For this reason, peripherally acting pressor

agents should be used with caution during anaesthesia in patients with hypertension.

Influence of drug therapy.

The variety of anti-hypertensive drugs in current use makes it difficult to deal collectively with treated hypertensive patients, although no clear differences have emerged from this study. Gibb and his colleagues (1970) have shown that in a double-blind trial of reserpine, bethanidine and methyldopa, all three drugs were equally successful in maintaining a reasonable arterial pressure and reversing the symptoms, but fewer side effects were noted in patients receiving reserpine. Our experience with reserpinized patients should not be taken as evidence that the rauwolfia alkaloids are unsuitable for the management of hypertensive patients, but merely to emphasize that the response to anaesthesia appears to depend on the initial blood pressure rather than the choice of drug. While we would agree with Papper (1965) that "no patient need be taken off reserpine because he is going to be anaesthetized or operated upon", we cannot unreservedly commend his previous statement that "there is no threat to hypertensive patients from the use of reserpine", nor that of Pickering (1968) that "reserpine may make induction hazardous". We would conclude that reserpine used in the pretreatment of hypertensive patients does not of itself cause any interactions with anaesthetic agents, but that inadequate control of arterial pressure may occur in spite of treatment with reserpine or any other anti-hypertensive agent, and may constitute a significant risk in relation to induction of anaesthesia.

We have found no evidence that any anti-hypertensive drugs other than reserpine in any way predisposed to adverse circulatory changes, either in the patient's response to anaesthesia or during recovery. Although this confirms the clinical impressions of Hickler and Vandam (1970), it is contrary to the view expressed by Grogono and Lee (1970) based on the experiences of Smessaert and Hicks (1961) and Lawin and his colleagues (1966).

We find it difficult to support two other statements quoted by Pickering (1968) that "reserpine may prolong the recovery time from ether and halothane anaesthetic", or that "after an anaesthetic, the patient's blood pressure will remain low

for a variable period from a few days to many weeks”.

Examination of the postoperative blood pressure charts of these patients studied by us, revealed no evidence of prolonged hypotension relative to their pre-operative levels.

RECOMMENDATIONS

Hypertensive patients, whether treated or not, require careful individual assessment before embarking on anaesthesia and surgery. Many of our surgical and medical colleagues who have helped with this study, have set an example by referring patients to the anaesthetist, not the day before surgery is contemplated, but from the out-patient clinic. This has enabled us to make an adequate assessment of each patient, and to have a joint consultation with their physician or cardiologist before proceeding. An adequate history, detailed examination of the cardiovascular system, an electrocardiogram and a chest radiograph are essential in the pre-operative assessment of these patients, but attempts to assess vascular and baroreflex reactivity, although of academic interest, are unlikely to be of value in predicting the patient's response to anaesthesia. It is important to assess the degree of arteriosclerosis associated with hypertension in the elderly patient (Hickler and Vandam, 1970). Because autoregulation of blood flow may be seriously diminished in the arteriosclerotic patient, the possibility of myocardial, cerebral and renal ischaemia during hypotensive periods is likely to be more pronounced in this group of patients. Ophthalmoscopy provides a better objective assessment of arteriosclerosis than the electrocardiograph. Evidence of left ventricular failure, such as a gallop rhythm, or a history of orthopnoea or paroxysmal nocturnal dyspnoea (cardiac asthma) should be regarded as contraindications to immediate anaesthesia, and an indication for digitalization, antidiuretic therapy and intensified anti-hypertensive therapy.

The results of this study show that untreated high arterial pressure constitutes a serious risk to patients undergoing anaesthesia and surgery and that to withdraw anti-hypertensive therapy before anaesthesia is not only unnecessary but potentially dangerous, both during the pre-operative period and during anaesthesia. The important question would now seem to be whether one should or should not recommend an otherwise symptom-

free patient for anti-hypertensive therapy before anaesthesia and surgery. In view of the high incidence in this study of myocardial ischaemia in patients with high initial arterial pressures exposed to anaesthesia, we would consider such a course of action desirable.

Premedication of the elderly patient, whether hypertensive or not, is a matter for individual consideration. Our experience would suggest that hypnotics, sedatives or narcotic analgesics are unnecessary, and that a pre-operative visit by the anaesthetist is of much greater value. In this respect we differ from Hickler and Vandam (1970) who suggest that because “the patient with essential hypertension will be more emotionally upset than the average surgical patient”, the need for pre-operative sedation would be greater. Atropine should be administered intravenously immediately before induction of anaesthesia in sufficient dose (0.6–1.2 mg) to provide effective if not total blockade of vagal parasympathetic activity. If thiopentone is to be used for induction of anaesthesia, the lowest possible dose should be administered slowly. It has been evident that the induction period is potentially the most dangerous in terms of sudden hypotension associated with bradycardia and myocardial ischaemia. Other induction agents may be preferable, though at present we can only recommend the combination of phenoperidine and droperidol for induction of anaesthesia in hypertensive patients (Prys-Roberts, Greene, Meloche and Föex, in preparation). Further studies are necessary to establish the effects of artificial ventilation on treated and untreated hypertensive patients, and to determine their response to blood loss during anaesthesia and surgery. The ventilatory and circulatory depressant effects of halothane should be carefully weighed against any possible advantages of this agent. We cannot at present advocate an alternative agent or technique of anaesthesia.

ACKNOWLEDGEMENTS

We are grateful to Sir G. W. Pickering, F.R.S., for helpful discussions during the preparation of this paper. It is a great pleasure to thank Mr J. C. Smith under whose care most of the patients included in this study were admitted. We are also grateful to Dr L. J. Beilin, Dr B. Juel-Jensen, Mr E. Cope, and the staff of the Department of Dental Surgery for referring patients to us from their out-patients clinics. We wish to thank Mr J. B. Thomson, Miss C. Ranson, Mr P. Childs and Mr J. Aspel for technical assistance and Miss A. Kosniowska for preparing the computer programme for analysis of variance.

The study was supported by a grant from the Medical Research Council. Dr. P. Foëx was supported by a grant from the Hôpital Cantonal et Universitaire, Geneva, and by a special grant from the Holderbank Stiftung, Aargau, Switzerland.

REFERENCES

- Alper, M. H., Flacke, W., and Kraye, O. (1963). Pharmacology of reserpine and its implications for anaesthesia. *Anesthesiology*, **24**, 524.
- Armstrong Davison, M. H. (1951). Danger of methonium drugs (Correspondence). *Brit. med. J.*, **1**, 584.
- Bristow, J. D., Honour, A. J., Pickering, G. W., Sleight, P., and Smyth, H. S. (1969a). Diminished baroreflex sensitivity in high blood pressure. *Circulation*, **39**, 48.
- Prys-Roberts, C., Fisher, A., Pickering, T. G., and Sleight, P. (1969b). Effects of anaesthesia on baroreflex control of heart rate in man. *Anesthesiology*, **31**, 422.
- Coakley, C. S., Alpert, S., and Boling, J. S. (1956). Circulatory responses during anaesthesia of patients on rauwolfia therapy. *J. Amer. med. Ass.*, **161**, 1143.
- Corbett, J. L. (1969). Some aspects of the autonomic nervous system in normal and abnormal man. D. Phil. Thesis. University of Oxford.
- Dingle, H. R. (1966). Antihypertensive drugs and anaesthesia. *Anaesthesia*, **21**, 151.
- Doyle, S. E., and Fraser, J. R. E. (1961). Essential hypertension and inheritance of vascular reactivity. *Lancet*, **2**, 509.
- Dundee, J. W. (1958). Iatrogenic disease and anaesthesia. *Brit. med. J.*, **1**, 1433.
- Eich, R. H., Cuddy, R. P., Smulyan, H., and Lyons, R. H. (1966). Hemodynamics in labile hypertension: a follow-up study. *Circulation*, **34**, 299.
- Peters, R. J., Cuddy, R. P., Smulyan, H., and Lyons, R. H. (1962). The hemodynamics in labile hypertension. *Amer. Heart J.*, **63**, 188.
- Foster, M. W. jr., and Gayle, R. F. (1955). Dangers of combining reserpine (Serpasil) with electro-convulsive therapy. *J. Amer. med. Ass.*, **159**, 1520.
- Freis, E. D. (1960). Hemodynamics of hypertension. *Physiol. Rev.*, **40**, 27.
- Frolich, E. D., Tarazi, R. C., and Dustan, H. P. (1969). Re-examination of the hemodynamics of hypertension. *Amer. J. med. Sci.*, **257**, 9.
- Gersh, B. J. (1970). Ventricular function and haemodynamics in the dog during anaesthesia. D.Phil. Thesis. University of Oxford.
- Prys-Roberts, C., Reuben, S. R., and Baker, A. B. (1970). The relationship between depressed myocardial contractility and the stroke output of the canine heart during halothane anaesthesia. *Brit. J. Anaesth.*, **42**, 560.
- Gibb, W. E., Malpas, J. S., Turner, P., and White, R. J. (1970). Comparison of bethanidine, alphamethyldopa, and reserpine in essential hypertension. *Lancet*, **2**, 275.
- Grogono, A. W., and Lee, P. (1970). Danger lists for the anaesthetist: a revised version. *Anaesthesia*, **25**, 518.
- Hamelberg, W. (1964). Current concepts on antihypertensive drugs and steroids. *Anesth. Analg. Curr. Res.*, **43**, 104.
- Hamilton, M., Pickering, G. W., Roberts, J. A. F., and Sowry, G. S. C. (1954a). The aetiology of essential hypertension: the arterial pressure in the general population. *Clin. Sci.*, **13**, 11.
- Hamilton, M., Pickering, G. W., Roberts, J. A. F., and Sowry, G. S. C. (1954b). The aetiology of essential hypertension: scores for arterial blood pressure adjusted for differences in age and sex. *Clin. Sci.*, **13**, 37.
- Hickler, R. B., and Vandam, L. D. (1970). Hypertension. *Anesthesiology*, **33**, 214.
- Katz, R. L., Weintraub, H. D., and Papper, E. M. (1964). Anaesthesia surgery and rauwolfia. *Anesthesiology*, **25**, 142.
- Keith, N. M., Wagener, H. P., and Barker, N. W. (1939). Some different types of essential hypertension: their course and prognosis. *Amer. J. med. Sci.*, **197**, 332.
- Lawin, P., Herden, H., Badran, H., and Berta, J. (1966). Drei Herzstillstände bei Einleitung der Neurolept-analgesie Typ II bei vorbehandelten Patienten mit vasodilatorischen Medikamenten. *Der Anaesthetist*, **15**, 19.
- Morrow, D. H., and Morrow, A. G. (1963). The responses to anaesthesia of non-hypertensive patients pretreated with reserpine. *Brit. J. Anaesth.*, **35**, 313.
- Munson, W. M., and Jenicek, J. A. (1962). Effect of anesthetic agents on patients receiving reserpine therapy. *Anesthesiology*, **23**, 741.
- Ominsky, A. J., and Wollman, H. (1969). Hazards of general anaesthesia in the reserpinized patient. *Anesthesiology*, **30**, 443.
- Page, I. H. (1967). The mosaic theory of arterial hypertension: its interpretation. *Perspec. Biol. Med.*, **10**, 325.
- McCubbin, J. W. (1966). Physiology of arterial hypertension. *Handbook of Physiology*, Section 2: *Circulation*, Vol. 3. Washington, D.C.: American Physiol. Soc.
- Papper, E. M. (1965). Selection and management of anaesthesia in those suffering from disorders and disease of the heart. *Canad. Anaesth. Soc. J.*, **12**, 245.
- Pickering, G. W. (1968). *High Blood Pressure* (2nd ed.). London: Churchill.
- Prys-Roberts, C. (1969). The measurement of cardiac output. *Brit. J. Anaesth.*, **41**, 751.
- Gersh, B. J., Baker, A. B., and Reuben, S. R. (1970). Myocardial responses to direct and sympathetic nerve and receptor stimulation during halothane anaesthesia. *Brit. J. Anaesth.*, **42**, 560.
- Kelman, G. R., Greenbaum, R., Kain, M. L., and Bay, J. (1968). Hemodynamics and alveolar-arterial P_{O_2} differences at varying $P_{a_{CO_2}}$ in anesthetized man. *J. appl. Physiol.*, **25**, 80.
- — — Robinson, R. H. (1967). Circulatory influences of artificial ventilation during nitrous oxide anaesthesia in man. II: Results; the relative influence of mean intrathoracic pressure and arterial carbon dioxide tension. *Brit. J. Anaesth.*, **39**, 533.
- Meloche, R. (1970). Haemodynamic reactions of hypertensive patients to anaesthesia. *Cardiovasc. Res.*, **VI World Congress of Cardiology; Abstracts P**, p.254.
- Renck, H. (1969). The elderly patient after anaesthesia and surgery. *Acta anaesth. scand.*, Suppl. 34.
- Sannerstedt, R. (1969). Hemodynamic findings at rest and during exercise in mild arterial hypertension. *Amer. J. med. Sci.*, **258**, 70.
- Smessaert, A. A., and Hicks, R. G. (1961). Problems caused by rauwolfia drugs during anaesthesia and surgery. *N. Y. St. J. Med.*, **61**, 2399.

Stott, F. D. (1966). Medium term direct blood pressure measurement. *Bio-med. Engng.*, 1, 461.

Werkö, L., and Lagerlöf, H. (1949). Studies on the circulation in man. IV: Cardiac output and blood pressure in the right auricle, right ventricle and pulmonary artery in patients with hypertensive cardiovascular disease. *Acta med. scand.*, 133, 427.

Wilcken, D. E. L., Charlier, A. A., Hoffman, J. I. E., and Guz, A. (1964). Effects of alterations in aortic impedance on the performance of the ventricles. *Circulat. Res.*, 14, 283.

Ziegler, C. H., and Lovette, J. B. (1961). Operative complications after therapy with reserpine and reserpine compounds. *J. Amer. med. Ass.*, 176, 916.

BOOK REVIEW

Medical Examination Review Book. Volume 12. Edited by R. C. Brown. Published by Medical Examination Publishing Company, Inc., New York. pp. 247. Price £3.20.

The material published in this book will be tremendously helpful to all who are studying for higher qualifications in anaesthesia in this country and indeed anywhere else in the world. It will be doubly helpful to those who study on their own and require some means of checking their attainment.

One problem which arises in multiple choice examination questions is that of the exactness of the answers to individual questions. The editor of this particular volume has been extremely careful to provide a reference for each question. This reference is either to a standard textbook or to some article in a journal. It is particularly gratifying that this book, which is of American origin, contains so many references to British journals and books.

The multiple choice examination as a whole is under something of a cloud at the moment. Such hesitation, however, arises not so much from the nature of the questions as from the method of marking. There are a number of systems for this purpose. An early method was that described by Hubbard and Clemans, in which the candidate was offered five separate choices, only one of which was right. It soon became apparent that to find four convincing false answers to go with the one correct answer was beyond the wit of the vast majority of those who set the questions.

This has led to the wording of questions such as "All the following statements are true except one, which should be marked". Somehow it is much more difficult to pick out the odd man from the list of statements than it is to pick out the one correct one. Another variant of this type of question which eliminates the need for four possible or alternative answers is the question which sets down four statements and says "The answer to the following questions is A if items 1, 2 and 3 are correct, B if items 1 and 3 are correct, C if items 2 and 4 are correct, D if only 4 is correct, E if all are correct". The possibility of errors in the use of such a key is very considerable and, further, these errors may not spring from a real lack of knowledge on the part of the candidate answering the question but from the failure on his part to manipulate the rather complicated choice presented to him. Indeed it is this sort of question which has given multiple choice examinations a somewhat doubtful reputation, a reputation which implies that ability to do *The Times* crossword puzzle is an advantage to the candidate.

It was this difficulty which led to the development, mainly under the aegis of the Royal College of Physicians, of their marking system, which has also been used in the Conjoint Examining Board's final year papers in Medicine. In this the alternatives offered in a question are for purposes of marking divided into two groups: the correct answers and the wrong answers. One mark is given to every candidate who gets all the

correct answers right and leaves all the wrong answers unmarked. If to an individual question there are three right answers and two wrong answers the candidate is given one-third of a mark for each right answer which he gets and loses half a mark for each wrong answer he produces. This results in a very complicated marking system indeed and one which, in fact, involves the use of a computer if it is not to become an inordinate labour for the examiners. The other difficulty with this system is that the candidates mark only the right answers. It makes no distinction between those who simply do not know the answer to an individual question and those who have got a totally misconceived idea about the answer to a question. There is some doubt indeed as to whether this distinction is valid but many authorities, including the examiners in the Primary FFARCS, feel that it is more appropriate that a candidate should indicate whether he simply does not know or whether he has a wrong idea. With this in mind the Primary FFARCS system has been designed so that the candidate should mark each individual section of the question true or false. If he does not know the answer the candidate leaves the section blank. For every right answer he marks correctly as true, he receives one mark, for every wrong answer he marks correctly as false, he receives one mark. He loses one mark for every correct answer he indicates as wrong and vice versa for every wrong answer he indicates as correct. If he makes no marks at all on the section he gains no marks. The net result of this form of marking system ought to be that random marking should produce a score of zero, or something very close to it, depending on how many right answers and how many wrong answers in toto there are on the paper.

The candidate who turns to the book under review will not find questions of this type and anyone who uses the book as a means of checking his own knowledge might keep constantly before him the fact that when he comes to do the multiple choice examination for the Primary FFARCS the marking system will be different. Most important, the marking systems used for the "one correct answer" type of question are those where random answering will produce a score of something like 20 per cent. For this reason candidates are advised to attempt every question. If they do not know the answer they are asked to guess it. With the marking system used in the FFARCS guessing will not necessarily lead to increased marks and may actually lead to loss of marks, which would not otherwise have been lost had the candidate simply left the particular item unmarked, indicating that he did not know.

For this reason, therefore, candidates for British examinations, as opposed to American examinations, will be well advised to use this book only as a means of checking on their own attainment, and not as a means of immediate preparation for the examination. Its value, however, as a test of knowledge, particularly for the candidate working on his own, remains unquestioned. For this reason we commend it wholeheartedly.

A. R. Hunter