Acta orthop. scand. *50*, 433–441, 1979

CONTROLLED HYPOTENSION IN HIP JOINT SURGERY

An Assessment of Surgical Haemorrhage During Sodium Nitroprusside Infusion

A. K. VAZEERY & O. LUNDE

Department of Anaesthesiology and Department of Orthopaedic Surgery, Central Hospital of Rogaland, Stavanger, Norway

Controlled hypotension, combined with light balanced anaesthesia, was employed during total hip replacement operations on 25 patients. Sodium nitroprusside (Nipride, Roche), in the form of a 0.01 per cent (100 μg/ml) infusion, was used as a hypotensive agent. The mean arterial blood pressure (MABP) was lowered from 108 to 64 mmHg (range 60–70) ($P<0.001$). The average blood loss during the operations was 212 ml and none of the patients required homologous blood transfusion. In comparison with 25 normotensive patients undergoing similar surgery, the difference in the mean volume of haemorrhage between the two groups was 826 ml ($P<0.001$). The difference in the total haemorrhage, however, between the same two groups was 518 ml (mean) ($P<0.01$). The results were compared with those of another investigation in which epidural anaesthesia was used to diminish bleeding during surgery on the hip.

Key words: controlled hypotension; sodium nitroprusside; transfusion during surgery

Accepted 20.viii.78

Induced hypotension in major surgical operations has been in vogue for several years yet its application has been hampered by occasional unpleasant side effects caused by either a lack of knowledge of the hypotensive agent or of the technique used to accomplish the diminished bleeding. The earlier hypotensive techniques of arteriotomy (Bilsland 1951) were abandoned in favour of more beneficial methods when the autonomic ganglion blocking agents were introduced, providing a relatively avascular field for surgical procedures (Royester et al. 1951, Steven & Tovell 1954, Holms 1956, Nayman 1960). Deliberate hypotension has been employed in thoracic surgery (Lewis 1951), prostatic surgery (Bruce 1960) and in large blood vessel surgery (Glenn et al. 1954) in order to diminish the blood loss. It has also been used to attain ischaemia of the surgical wound in orthopaedic surgery (Holms 1956), in gynaecological surgery (Linacre 1961) and in reconstructive plastic surgery (Enderby 1961). Deviations from the normal clinical state, such as hypovolaemic anaemia and polycythaemia, have been clear-cut contraindications in the same way as cardiovascular or cerebrovascular, renal or hepatic pathological involvement. In spite of the fact that there has been considerable criticism of hypotensive anaesthesia, the promising results after surgical ischaemia cannot be denied (Gillies 1950, Safar 1955, Enderby 1961, Learmonth 1976). Nevertheless, deliberate hypotension cannot be regarded as a routine procedure and it is

0001–6470/79/040433–09$02.50/0

employed only when specifically indicated (Eckenhoff 1955, Adams 1975). After the initial introduction of methonium compounds in induced hypotension, trimetaphan (arfonad) became very popular due to its evanascent action (Nicholson et al. 1953). Later clinical experience, however, showed that its application was not all that straightforward (Payne 1956) because of the histamine release. Moreover, it often created problems due to tachyphylaxis. Halothane has been used as an adjuvant to hypotensive drugs (Smith et al. 1960, Neill & Nixon 1965, Taylor et al. 1970) but its application in elderly people cannot be entirely justified as it has a potent myocardial depressive action. The introduction of sodium nitroprusside (SNP) has eliminated many of the hazards of ganglion blocking agents although its administration by experienced anaesthesiologists is absolutely essential due to its highly potent action. Its use has been declared safe by Vesey et al. (1976) (with appropriate authenticity) provided the dose does not exceed a maximum of 1.5 mg/kg body wt. This investigation was conducted to assess the volume of haemorrhage during as well as after surgery on the hip using SNP in the dose recommended by the abovementioned authors (Vesey et al. 1976).

PATIENTS AND METHODS

A comparative study was conducted of 50 patients with coxarthrosis who were operated on and fitted with a Charnley prosthesis. The patients comprising this group showed no signs of cardiovascular or other systemic diseases. (Deliberate hypotension has been employed in just over 300 orthopaedic patients and the same clinical criteria have been observed in each case.) The standard Charnley operative technique was used. Postoperatively the patients were treated routinely with Warfarin sodium (marevan). Twenty-five patients were operated upon under normotension (NTN) and in the remaining 25 patients controlled hypotension (CHN) was induced prior to operation. There were nine patients who were operated on bilaterally, i.e. on one side under NTN and on the other side under CHN. The average age of the patients, 36 women and 14 men, in both the groups was 70.4 years. The ranges, however, varied slightly, being 57–86 years in the normotensive group and 55–80 years in the hypotensive group (Table 1).

The surgical haemorrhage was measured by weighing the wet swabs and the towels. Postoperative blood loss was determined by measuring the volume of blood in the vacuum drain, which was usually removed 1–3 days after the operation. A meticulous watch was kept on the postoperative diuresis and a comparison was made with the normotensive group. At the time of insertion of the acrylic material, the clinical changes in the patient, if any, were closely observed. The patients were not given prophylactic treatment with antibiotics or hydrocortisone.

The number of blood transfusions was determined and compared with the normotensive group. In the event of blood loss exceeding 500 ml, homologous blood was used for replacement. The hypotensive group included a patient who refused blood transfusion on religious grounds and her wishes were complied with. Her haemoglobin level dropped from 13.6 g on the day of operation to 11.4 on the following day. It returned to normal during the subsequent days.

The results of this investigation were compared with a study conducted at the Academic Hospital,

Table 1. Patients treated for coxarthrosis with Charnley's prosthesis under normotension (NTN) or controlled hypotension (CHN) and light balanced anaesthesia. (Data given as mean and range.)

No. of patients	Normotension 25	Controlled hypotension 25
Age (years)	70.4 (57–86)	70.4 (55–80)
Weight (kg)	68.6 (52–85)	69 (54–90)
Hb (g%)	13.8 (11.7–16.8)	13.9 (12.2–16.9)
Duration of operation (min)	109.4 (95–120)	94 (82–105)

Uppsala, Sweden (Jakobson & Wigren 1972). The 21 patients in this study underwent 27 operations using Muller's prosthesis on the hip. Twelve patients in this group received epidural anaesthesia and 15 were operated under general anaesthesia.

ANAESTHETIC TECHNIQUE

After a standard premedication with atropine 0.6 mg, pethidine 50–100 mg and promethazine 25–50 mg (Hopkins et al. 1957) 1 hour before the operation, anaesthesia was induced using methohexitone 70–100 mg, followed by suxamethonium 50 mg. All the patients were artificially ventilated (IPPV & Hyperventilation) with a mixture of 50–50 per cent oxygen and nitrous oxide. Analgesia was provided using fentanyl and further muscular relaxation was obtained with d-tubocurarine (Albertson et al. 1956, Neill & Nixon 1965). All the patients received 1.0 l Ringer's acetate and 1.0 l fructose on the day of the surgery.

Prior to the commencement of sodium nitroprusside infusion (0.01 per cent solution in 5.5 per cent glucose), an intra-arterial cannula was inserted into the radial artery for the continuous monitoring of the mean arterial blood pressure (MABP). Five minutes before the skin incision the MABP was lowered to 60–65 mmHg Törr and this was maintained throughout the surgery. Halothane was added only when absolutely necessary. The SNP infusion was discontinued just before the closure of the surgical wound in order to restore the blood pressure to the pre-SNP levels. The surgeon was then asked to check the bleeding points if any. The recording of the MABP was as in Table 2. Arterial blood specimens were collected before, during and after the administration of SNP, in order to keep an eye on any possible changes in the blood chemistry of the patient. All the patients were lying in the supine position during surgery.

RESULTS

Haemorrhage during surgery. The average blood loss during controlled hypotension was 212 ml (range 160–350 ml). In the normotensive group the mean surgical

Table 2. Mean arterial blood pressure (MABP) in mmHg (range in parentheses)

Normotension		Controlled hypotension	
At admission	126.1 (87–180) [a]	At admission	125.2 (85–183)
Before induction of anaesthesia	114 (80–107) [b]	Before induction of anaesthesia	108.2 (90–130) [c]
During operation	93.7 (80–107)	After induction of anaesthesia	91.8 (73–117) [d]
		During SNP infusion	64.4 (60–70) [e]
		10 mins after discontinuation of SNP	92.6 (78–120)
After extubation	98.8 (75–133)	After extubation	104.1 (85–127)
At recovery from anaesthesia	116.2 (80–140)	At recovery from anaesthesia	119 (83–143)

Difference a–b=20.3 (N.S.)
Difference c–d=16.4 ($P<0.05$)
Difference c–e=43.8 ($P<0.001$)

Table 3. Mean haemorrhage in ml (range in parentheses)

	Normotension	Controlled hypotension
Haemorrhage during operation	1038 (500–1750) [a]	212 (160–350) [b]
Postoperative haemorrhage	808 (590–1205)	877 (695–1130)
Total haemorrhage	1846 (1090–2725) [c]	1328 (905–1335) [d]

Difference a–b=826 ($P<0.001$)
Difference c–d=518 ($P<0.01$)

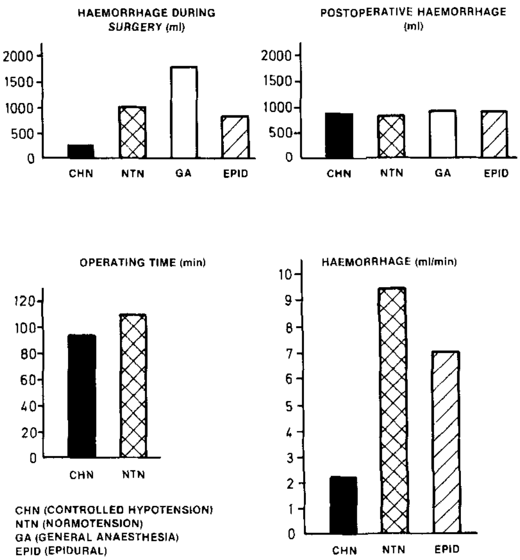

Figure 1. Haemorrhage and operating time during surgery for total hip replacement with different anaesthetic techniques

haemorrhage was 1038 (range 500–1750 ml). The difference between the two groups was highly significant, i.e. 826 ml ($P<0.001$) (Table 3). In the Swedish investigation, the average blood loss was 1775 ml using general anaesthesia but it was reduced to 820 ml using epidural anaesthesia (Figure 1). The difference between the epidural and the hypotensive groups was also highly significant ($P<0.001$).

Postoperative haemorrhage. It was noted that the blood loss after CHN was slightly more (mean 877, range 695–1130 ml) as compared with NTN (mean 808, range 590–1205 ml). The difference, however, was clinically insignificant (Table 3). In the work done at Uppsala the postoperative blood loss was 900 ml with both epidural and general anaesthesia (Figure 1).

Total haemorrhage. The total blood loss under controlled hypotension was on average 1328 ml (range 905–1335 ml) as compared with the normotensive group where the mean haemorrhage was 1846 ml (range 1090–2725). The difference between the two groups was significant ($P<0.01$) (Table 3).

Operating time. The operating time was reduced to a certain extent, i.e. from a mean of 109.4 min (range 95–120) with normotension to a mean of 94 min (range 82–105) with hypotension ($P<0.05$) (Table 1).

Bilateral total hip replacement. In the nine bilaterally operated patients the difference in the blood loss during the operations was on average 820 ml. The operating time was reduced by 15 per cent.

Blood transfusions. A blood loss of more than 500 ml was replaced by homologous blood during the operation or immediately afterwards. With CHN the patients required an average of 1.6 units of blood. Under NTN the unilateral and the bilateral hip replacements needed 3.3 and 3.16 units of blood, respectively. Under hypotension not a single patient required transfusion during surgery. The difference in blood transfusions between the normotensive and hypotensive groups was highly significant ($P<0.001$).

Clinical evaluation of the patients

The following unusual complications were observed,

	Normotension	Controlled hypotension
Moderate haematoma	1	–
Thrombophlebitis	2	1
Myocardial insufficiency (moderate, total haemorrhage 2725 ml)	1	–
Supraventricular tachycardia during SNP infusion (treated with practolol)	–	1
Moderate reduction in Po_2	–	6
Accidental fracture	–	1

Under SNP-induced hypotension one patient developed a tachycardia of 150/min. She was treated with practolol and the pulse stabilized and no further complications ensued. One patient needed 0.5–1 per cent halothane in order to maintain the MABP at the desired low level. During SNP administration there was an arterial reduction of Po_2 in six patients (mean reduction 13.2 per cent) as compared with pre-SNP levels. However all patients acquired their normal Po_2 levels after the discontinuation of sodium nitroprusside. Postoperatively, there was one incident of thrombophlebitis in the hypotensive group 30 days after surgery. It was not related to SNP and the patient was treated successfully. A moderate haematoma occurred in the normotensive group. There were no such complications after SNP administration. One of the hypotensive patients sustained a fracture of the femur, on the day before discharge. She was reoperated upon and had to stay in the hospital for several months. This patient had been doing very well before this accident happened and it could not be attributed in any way to the hypotension. The postoperative diuresis was delayed in patients in the hypotensive group but when compared to the normotensive group there was no significant difference clinically. There was no incidence of oligurea or anurea in patients given controlled hypotension. At the time of the insertion of the acrylic material there was no change in any of the parameters being monitored continuously. However, there was a slight reduction in systolic blood pressure in two of the normotensive patients (a mean reduction of 11 per cent). The postoperative clinical evaluation was conducted with the assistance of the medical department of the clinic. In the 25 patients investigated, there was no evidence of cardiovascular, cerebrovascular, renal or hepatic complications immediately after surgery or during the ensuing days. All the patients were discharged after an average hospital stay of 31 days (range 29–41) with the exception of the patient who sustained a fracture of the femur.

DISCUSSION

Systematic hypotension without compensatory oxygenation of the central nervous system leads to neuropathological consequences derogatory to cerebral function due to reduction in the cerebral blood flow. However, the circulatory insufficiency responsible for the diffuse changes in the brain of the Rhesus monkey, in the study by Brierley & Excell (1966), has not been attributed entirely to the systemic hypotension but to a combination of hypotension and the head-up position of the subject (Adam et al. 1966). This combination results in a markedly reduced oxygenation of the brain tissue and thus a deleterious effect on brain metabolism (Brierley & Excell 1966). The effects of deliberate hypotension on cerebral haemodynamics are dependent largely on the compensatory mechanisms present in an individual. There appears to be little danger of cerebral anoxia in the supine position when the mean arterial blood pressure is reduced to a level as low as 55 mmHg (Morris et al. 1953) with ganglion blockade. There is no evidence of cerebral dysfunction in induced hypotension as long as the blood flow in the brain is not interrupted significantly (Slack & Walter 1963). Deliberate hypotension is regarded as safe, as long as the systolic blood pressure is not reduced below 50 mmHg (Slack & Walter 1964). In actual practice, levels of mean arterial blood pressure lower than 60–65 mmHg are not necessary and no undesirable effects have been reported with a combination of careful monitoring and correct positioning of the patient subjected to induced hypotension (Royester et al. 1951, Eckenhoff 1955, Tough 1960, Enderby 1961, Linacre 1961, Lindop 1975). Continuous arterial monitoring is a simple procedure and without ill-effects on the patients (Brown et al. 1969, Zorab 1969). This was achieved in all 25 patients in the present investigation and did not inconvenience the patients in any way. There were no psychological disturbances, assessed on the same principles as suggested by Eckenhoff et al. (1964).

Respiratory function has not been found to be reduced after exposure to deliberate hypotensive anaesthesia. On the contrary it has been proposed that hypotension can increase the vital capacity of the patient (Bromage 1956). There was no evidence of any significant changes in the pattern of diuresis as compared to normotensive anaesthesia. Measurement of diuresis in relatively short-term surgery (mean operating time, 94 min) was considered unjustifiable due to the possible risk of infection. Previous studies have shown that induced hypotension does not significantly change the renal blood flow, due to the presence of compensatory mechanisms resulting in renal vasodilatation and increased renal plasma flow offering protection from significant anoxic effects (Shipley & Study 1951, Miles et al. 1952, Evans & Enderby 1952).

After these comprehensive studies on the capability of the vascular system to withstand a low systolic blood pressure of 50 mmHg and attain recovery by compensatory methods (Kohlstaedt & Page 1943), patients were submitted to a brief period of simulated shock, with simultaneous continuous monitoring, with beneficial results. In addition to trials with arteriotomy (Bilsland 1951), high spinal anaesthesia has been employed concomitantly to facilitate surgery (Sarnoff & Arrowood 1946, Lynn et al. 1952). Thus surgery on the hip which was considered a serious undertaking has been rendered more beneficial and without grave after effects (Kern 1952, Welch et al. 1975, Donaldson 1975). Nevertheless the fact remains that, in the performance of arthroplasty, both trauma and profuse haemorrhage remain a challenge to the surgeon and the anaesthesiologist. The prevention of shock can be accomplished by efficient surgical techniques and prompt blood transfusion (Keith 1977) but it is a disturbing fact that one has to submit these often old and frail patients to massive blood transfusions.

For several years methonium compounds as well as trimetaphan (arfonad) have been employed to avoid cumbersome blood transfusions or in the majority of the cases diminish them. Recent clinical application of a peripheral vasodilator, sodium nitroprusside, which was recommended as early as 1929 by Johnson, has solved many problems for those engaged in hypotensive anaesthesia. However, its high potency and the use of inadvertently large doses have led, in a few cases, to highly disappointing results (MacRae & Owen 1974 and others) which cannot be overlooked. After its initial clinical trials (Page et al. 1955, Moraca et al. 1962, Taylor et al. 1970, Siegal et al. 1971), its metabolic effects have been extensively investigated (Vesey et al. 1974, 1976) and it has been found not to cause any significant changes in cerebral haemodynamics (Griffiths et al. 1974). It is thus considered superior to other hypotensive agents (Styles et al. 1973, Landauer 1976). It can, however, cause tachycardia as well as moderate reduction in the arterial P_{O_2} levels, but these return to normal levels after its discontinuation (Wildsmith et al. 1975). The maximum dose which earlier was considered to be 3.5 mg/kg body wt. (McDowall et al. 1974) has been reduced to 1.5 mg/kg body wt. after comprehensive investigations (Vesey et al. 1976). In the study reported herein an average dose of 0.54 mg/kg body wt. was employed (Table 4), which is well below the recommended maximum dose. In a further investigation it has been demonstrated that the dosage of SNP can be successfully lowered by using larger doses of neuroleptic drugs in patients undergoing a variety of different types of surgery (Vazeery et

Table 4. Sodium nitroprusside (SNP) infusion

Duration of SNP infusion (mean and range)	80 (66–100) min
Amount of SNP (mean and range)	37.4 (13–50) mg

al.). Its use over longer periods is not recommended (Nourok et al. 1964). Controlled hypotension accomplished by a combination of sodium nitroprusside, curare (Thomas 1957, Neill & Nixon 1965), and moderate hyperventilation (Schieve & Wilson 1953, Harp & Wollman 1973) can be extremely beneficial to a patient undergoing total replacement of the hip, provided the clinical state of the patient is monitored continuously by experienced anaesthesiologists. It has its value in major orthopaedic surgery when it is mandatory to avoid large blood transfusions.

REFERENCES

Adams, A. P. (1975) Techniques for vascular control for deliberate hypotension during anaesthesia. *Brit. J. Anaesth.* **47,** 777–792.

Adams, J. H., Brierley, J. B., Connor, P. C. R. & Treip, C. S. (1966) The effects of systemic hypotension upon the human brain: Clinical and neuropathological observations in 11 cases. *Brain* **89,** 235–267.

Albertson, H. A., Trout, H. H. & Morfin, E. (1956) The safety of curare in anaesthesia. *Ann. Surg.* **143,** 833–837.

Bilsland, W. L. (1951) Controlled hypotension by arteriotomy in intracranial surgery. *Anaesthesia* **6,** 20–25.

Brierley, J. B. & Excell, B. J. (1966) The effects of profound systemic hypotension upon the brain of M. Rhesus. Physiological and pathological observations. *Brain* **89,** 269–297.

Bromage, P. R. (1956) Hypotension and vital capacity. *Anaesthesia* **11,** 139–148.

Brown, A. E., Sweeny, D. B. & Lumley, J. (1969) Percutaneous radial artery cannulation. *Anaesthesia* **24,** 532–536.

Bruce, A. W. (1960) Blood loss in prostatic surgery. *Brit. J. Surg.* **32,** 422–426.

Donaldson, W. F. (1975) Orthopaedic surgery. *Surg. Gynec. Obstet.* **140,** 204–205.

Eckenhoff, J. E. (1955) The use of controlled hypotension for surgical procedures. *Surg. Clin. N. Amer.* **35,** 1579–1584.

Eckenhoff, J. E., Compton, J. R., Larson, A. & Davies, R. M. (1964) Assessment of cerebral effects of deliberate hypotension by psychological measurements. *Lancet* **ii,** 711–714.

Enderby, G. E. H. (1961) Hypotensive anaesthesia in plastic surgery. *Brit. J. plast. Surg.* **14,** 41–46.

Evans, B. & Enderby, G. E. H. (1952) Controlled hypotension and its effect on renal function. *Lancet* **i,** 1015–1016.

Gillies, J. (1950) Anaesthetic factors in the causation and prevention of excessive bleeding during surgical operations. *Ann. roy. Coll. Surg. Engl.* **7,** 204–221.

Glenn, W. W. L., Hampton, L. J. & Goodyer, A. V. N. (1954) Use of controlled hypotension in large blood vessel surgery. *Arch. Surg.* **68,** 1–6.

Griffiths, D. P. J., Cummins, B. H., Greenbaum, R., Griffith, H. B., Staddon, G. E., Wilkins, D. G. & Zorab, J. S. M. (1974) Cerebral blood flow and metabolism during induced hypotension with sodium nitroprusside. *Brit. J. Anaesth.* **46,** 671–679.

Harp, J. R. & Wollman, H. (1973) Cerebral metabolic effects of hyperventilation and deliberate hypotension. *Brit. J. Anaesth.* **45,** 256–262.

Holms, F. (1956) Induced hypotension in orthopaedic surgery: Hexamethonium bromide (C6) in 407 orthopaedic operations. *J. Bone Jt Surg.* **38-B,** 846–854.

Hopkins, D. A. B., Hurter, D. & Jones, C. M. (1957) Promethazine and pethidine in anaesthesia: a new approach to pre-anaesthetic medication. *Anaesthesia* **12,** 276–281.

Jakobson, S. & Wigren, A. (1972) Epiduralanestesi och blödning vid stor höftkirurgi. *Svenska. Lak.-Tidn.* **69,** 267–270.

Johnson, C. C. (1929) The action and toxicity of sodium nitroprusside. *Arch. int. Pharmacodyn.* **35,** 480–496.

Keith, I. (1977) Anaesthesia and blood loss in total hip replacement. *Anaesthesia* **32,** 444–450.

Kern, E. R. (1952) Problems of anaesthesia and transfusion in major surgery on the hip-joint. *Anesth. Analg. Curr. Res.* **31,** 350–357.

Kohlstaedt, K. G. & Page, I. H. (1943) Haemorrhagic hypotension and its treatment by intraarterial and intravenous infusions of blood. *Arch. Surg.* **47,** 178–191.

Landauer, B. (1976) Die kontrollierte hypotension mit nitroprussidnitrium. *Anaesthesist* **25,** 266–273.

Learmonth, J. (1976) The surgeon and ischaemia. *Brit. med. J.* **1,** 743–748.

Lewis, J. (1951) Value of hypotensive drugs in minimising blood loss in thoracic surgery. *Lancet* **ii,** 150–151.

Linacre, J. L. (1961) Induced hypotension in gynaecological surgery: A review of 1000 major cases. *Brit. J. Anaesth.* **33,** 45–50.

Lindop, M. J. (1975) Complications and morbidity of controlled hypotension. *Brit. J. Anaesth.* **47,** 799–803.

Lynn, R. B., Sancetta, S. M., Simeone, F. A. & Scott, R. W. (1952) Observations on the circulation in high spinal anaesthesia. *Surgery* **32,** 195–213.

MacRae, W. R. & Owen, M. (1974) Severe metabolic acidosis following hypotension induced with sodium nitroprusside. *Brit. J. Anaesth.* **46,** 795–797.

McDowall, D. J., Keany, N. P., Turner, J. M., Lane, J. R. & Okuda, Y. (1974) The toxicity of sodium nitroprusside. *Brit. J. Anaesth.* **46,** 327–332.

Miles, B. E., Wardener, H. E., Churchill-Davidson, H. C. & Wylie, W. D. (1952) The effect on the renal circulation of pentamethonium iodide during anaesthesia. *Clin. Sci.* **11,** 73–79.

Moraca, P. P., Bitte, E. M., Hale, D. E., Wasmuth, C. E. & Poutasse, E. F. (1962) Clinical evaluation of sodium nitroprusside as a hypotensive agent. *Anesthesiology* **23,** 193–199.

Morris, G. C., Jr., Moyer, J. H., Synder, H. B. & Haynes, B. W., Jr. (1953) Cerebral haemodynamics in controlled hypotension. *Surg. Forum* **4,** 140–143.

Nayman, J. (1960) Treatment of haemorrhage with ganglion blocking agents: A preliminary report. *S. Afr. med. J.* **34,** 26–31.

Neill, R. S. & Nixon, B. A. (1965) Halothane and tubocurarine. A study of changes in blood pressure. *Anaesthesia* **20,** 250–257.

Nicholson, M. J., Sarnoff, S. J. & Crehan, J. P. (1953) The intravenous use of a thiophanium derivative (Arfonad-RO2-2222) for the production of flexible and rapidly reversible hypotension during surgery. *Anesthesiology* **14,** 215–225.

Nourok, D. S., Glossock, R. J., Solomon, D. H. & Maxwell, M. H. (1964) Hypothyroidism following prolonged sodium nitroprusside therapy. *Amer. J. Med. Sci.* **248,** 129–138.

Page, I. H., Cocoran, A. C., Dustan, H. P. & Koppanyi, T. (1955) Cardiovascular actions of sodium nitroprusside in animals and hypertensive patients. *Circulation* **11,** 188–198.

Payne, J. P. (1956) Histamine release during controlled hypotension with arfonad. Proceedings World Congress of Anaesthesiologists, Scheveningen, The Netherlands, September, 1955, pp. 180–181. Burgess Publ. Co., Minneapolis.

Royester, H. P., Pendergrass, H. P., Walker, J. M. & Barnes, M. R. N. (1951) The value of blood volume determinations in radical operations for cancer of the head and neck, including measurements of operative blood loss. *Ann. Surg.* **133,** 830–836.

Safar, P. (1955) A study of deliberate hypotension in anaesthesia with special consideration of surgical blood loss in comparable groups of normotensive and hypotensive anaesthesia. *Surgery* **37,** 1002–1018.

Sarnoff, S. J. & Arrowood, J. G. (1946) Differential spinal block: a preliminary report. *Surgery* **20,** 150–159.

Schieve, J. F. & Wilson, W. P. (1953) The changes in cerebral vascular resistance of man in experimental alkalosis and acidosis. *J. clin. Invest.* **32,** 33–38.

Shipley, R. E. & Study, R. S. (1951) Changes in renal blood flow, extraction of insulin, glomerular filtration rate, tissue pressure and urine flow with acute alterations of renal artery blood pressure. *Amer. J. Path.* **167,** 676–688.

Siegal, P., Moraca, P. P. & Green, J. R. (1971) Sodium nitroprusside in the surgical treatment of cerebral aneurisms and arteriovenous malformations. *Brit. J. Anaesth.* **43,** 790–795.

Slack, W. K. & Walter, W. W. (1963) Cerebral circulation studies during hypotensive anaesthesia using radioactive Xenon 133. *Lancet* **i,** 1082–1083.

Slack, W. K. & Walter, W. W. (1964) Cerebral circulation in induced hypotension. Measurement using radioactive Xenon 133. *Anaesthesia* **19,** 494–500.

Smith, D. L., Didier, E. P. & Clagett, O. T. (1960) Controlled hypotension in radical mastectomy. Second 5-year review. *Ann. Surg.* **163,** 263–266.

Steven, R. J. M. & Tovell, R. M. (1954) Hexamethonium salts as an aid to the orthopedic surgeon. *J. Amer. med. Ass.* **154,** 402–404.

Styles, M., Coleman, A. J. & Leary, W. P. (1973) Some hemodynamic effects of sodium nitroprusside. *Anesthesiology* **38,** 173–176.

Taylor, T. H., Styles, M. & Lamming, A. J. (1970) Sodium nitroprusside as a hypotensive agent in anaesthesia. *Brit. J. Anaesth.* **43,** 859–864.

Thomas, E. T. (1957) The effect of d-Tubocurarine chloride on the blood pressure of the anaesthetised patient. *Lancet* **i,** 772–773.

Tough, I. C. K. (1960) Induced hypotension and postoperative bleeding. *Anaesthesia* **15,** 154–157.

Vazeery, A. K., Skeie, S., Aspelund, K., Sydnes, S. & Halvorsen, S. Sodium nitroprusside as a hypotensive agent in surgery: Determination of its minimum requirement in combination with larger doses of neuroleptic drugs. *Brit. J. Anaesth.* (Submitted for publication).

Vesey, C. J., Cole, P. V., Linnell, J. C. & Wilson, J. (1974) Some metabolic effects of sodium nitroprusside in man. *Brit. med. J.* **2,** 140–142.

Vesey, C. J., Cole, P. V. & Simpson, P. J. (1976) Cyanide and thiocyanate concentrations following sodium nitroprusside infusion in man. *Brit. J. Anaesth.* **48,** 651–660.

Welch, R. B., Taylor, L. W. & Wynn, G. (1975) Total hip replacement as a salvage in traumatic lesions about the hip. *Surg. Gynec. Obstet.* **140,** 708–714.

Wildsmith, J. A. W., Drummond, G. B. & MacRae, W. R. (1975) Blood-gas changes during induced hypotension with sodium nitroprusside. *Brit. J. Anaesth.* **47,** 1205–1211.

Yashon, D., Locke, G. E., Bingham, W. G., Wiederholt, W. C. & Hunt, W. E. (1971) Cerebral function during profound oligemic hypotension in the dog. *J. Neurosurg.* **34,** 494–499.

Zorab, S. M. (1969) Continuous display of the arterial pressure. A simple manometric technique. *Anaesthesia* **24,** 431–437.

Correspondence to: Afzal K. Vazeery, Department of Anaesthesiology, Central Hospital of Rogaland, Stavanger, Norway.