BLOOD VOLUME AND CAPACITANCE VESSEL COMPLIANCE IN THE QUADRAPLEGIC PATIENT

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THE NATURE of functional changes occurring in chronic quadraplegic patients and the mechanisms responsible for the altered responses to stress situations, which occur in these patients, are not yet clearly defined and understood. Anaesthesia and surgery are examples of stress situations in which these patients respond in abnormal fashion, and instability of the circulation during surgery has been of concern to anaesthetists.[1–4]. These patients often experience precipitous falls in blood pressure as a response to exceedingly small doses of anaesthetic agents.

We have investigated the total blood volume and the compliance of the capacitance vessels of the circulation in the upper limb in a group of such patients, in an endeavour to define some of the altered responses in the chronic quadraplegic, which might account for this troublesome fall in blood pressure and which might point the way to some measures of control to improve the risk of anaesthesia and operation in these patients.[5]

METHOD AND MATERIALS

A group of 27 quadraplegic patients was chosen at random for this study.

Blood volumes were measured in all cases using I^{131} albumen (RISA) and the "Volumetron".® The calculation was based on the weight of the patient at the time of the current admission to hospital.

Again on a random selection basis, seven patients had upper limb plethysmography. Capacitance vessel compliance of the forearm was determined with a Whitney mercury-in-rubber gauge. Normal vessel compliance was first recorded. A mild stress was then applied, through the use of a Bird respirator set in the assist/control position, and triggered by the patient.[6,8] A positive pressure sufficient to cause alteration in venous return was added, and again the limb vessel compliance was recorded. No changes in compliance could be recorded in any of the patients studied.

The anaesthetist who haphazardly injects a large dose of thiopentone into this type of patient during induction might be doing him a great disservice, by dilating a resistance and capacitance system which has no means of retaliating against this aggression. We have observed many times under such conditions that blood pressures which start at normal levels may soon fall to levels at which cerebral, coronary and renal function cannot be maintained.

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Discussion

The literature contains many references to the frequency and severity of hypertension during anaesthesia in the paraplegic patient, and much stress has been placed on the role of autonomic hyper-reflexia[2-7] and the occurrence of both hypertension and hypotension resulting from this phenomenon. In 1970, one of the present authors described in some detail the problems relating to anaesthesia in the paraplegic,[1] and in that discussion it was surmized in agreement with other writers on the subject that there might be a reduction of blood volume in these patients. We have now documented this in a small group of quadraplegic patients. Now that we know this to be true in many cases, the question arises as to whether all quadraplegics should have a blood volume measurement prior to surgery.

Failure of the capacitance side of the circulation to respond in normal fashion to the application of a respiratory stress[8] is due, we suggest, to disordered control of the autonomic receptors in this system, associated with the quadraplegia, with the result that the capacitance system is abnormally dilated. This failure of compliance of the capacitance side of the circulation increases the serious implications and importance of the reduction in blood volume which we have documented.

Further reference to Table I indicates that in many of these patients the phenomenon of automatic hyper-reflexia was recorded at some stage of the surgical management and nothing was done about this. Many patients had recorded systolic blood pressures of 60 to 70 mm Hg for the major part of the operation. In reviewing the case records of these patients, it is interesting that all seemed to develop fever of 43.9° to 44.4° C on the first or second day post-operatively, despite prophylactic antibiotic therapy. Jousse[9, 10, 11] states that elevation of temperature in these patients is conducive to pressure sores and poor wound healing.

Finally we note that in many of those who had low blood volume, the red cell volume was disproportionally reduced in relation to plasma and total blood volume. The question which eventually must be faced is whether such changes disrupt wound healing and increase the morbidity in these patients. Such effects on wound healing and morbidity are suggested by the following two case reports:

Case Reports

Case 1. A 34-year-old male patient involved in a high-jump accident ten years ago, presented for surgery in December, 1971. The greater trochanter was excised and a rotation graft brought over the excised area. As there was very little blood loss, no blood was given to him during the operation. His blood pressure during operation never got above 70 mm Hg systolic, in spite of administration of three litres of lactated Ringer's solution. It remained at this level through his stay in the recovery room and during the next three weeks his condition remained unsatisfactory. His graft broke down and at this stage we did a blood volume measurement on him. It was grossly deficient, with a red cell volume of 1020 ml. His physician was immediately informed and four pints of blood were transfused. A dramatic change occurred within twenty-four hours. He has since had several uneventful anaesthetics.

TABLE I

Blood Volume in 27 Patients and Upper Limb Plethysmography in 7 Patients

				Normal Blood Volume 73 ± 5 ml/Kg			Normal Red Blood Volume 30 ± 5 ml/Kg		Normal Plasma Volume 43 ± 5 ml/Kg			
No.	Age	Wt/Kg	Level of Lesion	Total Blood Volume ml/Kg	Red Cell Volume ml/Kg	Plasma Volume ml/Kg	H'crit	Plethys-mography	Duration of Injury	Surgery	Untoward Effects	Remarks
1	20	52	C5–6	4389 83.9	2032 38.8	2357 45.1	46.3		5 yrs	1. Cervical Fusion 2. T.U.R. Bladder Neck 1971	2. B.P. 120/80 up to B.P.170/– for 50 min Pulse 90 down to 70/min	Autonomic Hyper-reflexia
2	38	50	C5	5652 113	1932 38.16	3719 74.4	33.2		Unknown	1. Cystolithopaxy	Nil	—
3	37	80	C5–6	8250 103	2822 25.3	5429 67.8	34.2		2 yrs	1. Cystolithopaxy 1971	Nil	—
4	21	62	C5–6	3929 62.9	1693 27.1	2234 36.8	43.1	Yes	1.5 yrs	1. Cystolithopaxy 1971	B.P. 100/– up to B.P. 150/–	Autonomic Hyper-reflexia
5	20	75	C5–6	5025 67	1837 24.5	3562 47.5	36.6	Yes	1 yr	1. Cervical Fusion	Nil	—
6	19	52.3	C4	4368 83.5	1586 30.3	2782 53.2	36.3	Yes	8 yrs	1. Traction 2. Cystolithopaxy 1969 3. Cystolithopaxy 1967	Nil	—
7	23	80	C5–6	4809 60	1606 20	3203 40	33.4	Yes	8 yrs	1. Traction 2. Obturator Neurectomy 1966 3. Tendon Transfer 1966	3. B.P. 120/70 fell to 80/–	Hypotension
8	49	60	C5–6	4684 78	1785 29.3	2899 48.3	38.1		0.5 yrs	1. Cervical Fusion and tracheostomy	Nil	—
9	52	74	C5–6	4607 62.1	1645 22.2	2962 39.9	35.7		17 yrs	1. Laminectomy C4–5–6 2. Decompression 1966 3. T.U.R.B.T. 1970	1. B.P. 80/– 2. B.P. 80/– 3. B.P. 140/–	1. Hypotension 2. Hypotension
10	21	58	C6	4769 81.4	1898 32.4	2871 49	39.8		6 yrs	1. 1st Stage Urethoplasty 1970	Nil	—

TABLE I—*continued*

No.	Age	Wt/Kg	Level of Lesion	Total Blood Volume ml/Kg	Red Cell Volume ml/Kg	Plasma Volume ml/Kg	H'crit	Plethys-mography	Duration of Injury	Surgery	Untoward Effects	Remarks
11	16	60	C4–5–6	4329 72.3	1909 32.3	2420 40.9	44.1		2 yrs	1. Circumcision 1970	Nil	—
12	59	69	T.6	2201 34.3	660 10.3	1541 24	30.0		?	1. Reimplant Ureters 1970 2. Closure of Bladder 1970	1. B.P. 170/– down to B.P. 90/– for 3 hr 2. B.P. 100/– down to B.P. 90/–	1. Hypotension 2. Hypotension
13	59	69	C6–7	3227 50.3	1123 17.5	2104 32.8	33.8		?	Pt. no. 12 after transfusion		Blood volume repeated after 2 units of blood
14	19	50.4	C5–6	4340 77.9	2235 44.3	2105 40	41.5		5 yrs	1. Cervical Fusion 2. Lindsberg Flaps on four occasions	No untoward effects	—
15	33	75	C5–6	3004 40.05	1484 19.8	1520 20.2	46.8		1 yr	1. Guillan Barrie Syndrome	Nil	—
16	26	69	C6–7	4736 70.4	1847 27.5	2889 45.1	38.0		2 yrs	1. Cervical Fusion 1970 2. Tendon Transfer 1972	2. B.P. 100/– up to B.P. 170/–	Autonomic Hyper-reflexia
17	28	81.8	C5–6	4092 50.8	1788 20.2	2304 29.8	43.7		10 yrs	1. Skull Traction 2. Ileal Conduit 3. Stamp Graft 4. Cordotomy 1972	3. B.P. 90/– up to B.P. 140/–	Autonomic Hyper-reflexia
18	34	63.6	C5	4430 70.0	1108 17.4	3322 52.6	25.0	Yes	10 yrs	1. Rhizotomy 2. Exc. of Gt. Trochanter	1. B.P. 70/– up to B.P. 160/– 2. B.P. 80/– down to B.P. 60/–	1. Autonomic Hyper-reflexia 2. Hypotension
19	34	42	C5	4576 109.0	2709 64.5	1867 44.5	59.0		5 yrs	1. Cervical Fusion 1966 2. Cystolithopaxy 1970	2. B.P. 140/– up to B.P. 210/– Given Rogitine	1. Autonomic Hyper-reflexia

TABLE I—*concluded*

No.	Age	Wt/Kg	Level of Lesion	Total Blood Volume ml/Kg	Red Cell Volume ml/Kg	Plasma Volume ml/Kg	H'crit	Plethys-mography	Duration of Injury	Surgery	Untoward Effects	Remarks
20	36	75	C5–6	4567 61.0	1891 25.2	2666 35.8	41.5	Yes	14 yrs	1. T.U.R.B.Neck 1963 2. Supra-Pubic Cystotomy 1968 3. Cystoscopy 1970	Nil	—
21	39	47.7	C5–6	4668 97.8	1722 36.1	2946 61.8	36.9		14 yrs	1. Traction 1958 2. Cystolithopaxy 1959 3. Skin Graft 1963 4. Skin Flap 1966	2. B.P. 140/– up to B.P. 210/– 3. B.P. 80/– down to B.P. 60/–	2. Ventricular Extrasystoles
22	37	70	C6	4463 61.5	1852 25.2	2611 36	41.5		16 yrs	1. Supra Pubic Lithotomy 2. Cystolithopaxy	1. B.P. 90/– up to B.P. 180/– in Recovery Room— down after 45 min to 120/–	Autonomic Hyper-reflexia
23	35	72	C5–6	4107 56.5	1696 23.3	2412 33.1	41.4		17 yrs	1. Traction 2. Exc. of mass from R. Buttock 1962 3. Laminectomy/Rhizotomy	3. B.P. 100/–	—
24	45	63.4	C4–5	3398 53.6	1216 19.2	2182 34.4	35.8		5 yrs	1. Cervical Laminectomy 1967 2. Lumbar Laminectomy 1971 3. Debridement	3. B.P. 90/– down to B.P. 60/– 2. B.P. 100/–up to B.P. 160/–	Hypotension. Autonomic Hyper-reflexia
25	32	60.5	C5–6	3088 50.0	1372 22.7	1716 28.3	44.2	Yes	7 yrs	1. Traction	Nil	—
26	19	61.4	C6	5321 86.6	1580 25.4	3741 61.2	29.7		1 yr	—	—	Aspiration at time of initial injury
27	30	72.7	C5–6	4507 62.0	1573 21.6	2934 40.4	34.9		3 mths	1. Cervical Laminectomy in Mexico	—	Postural Hypotension. Ephedrine 30 m.g.m. before getting up
28	18	68.2	C6–7	4036 60.0	1655 25.0	2381 35.0	41.0		3 yrs	1. Tracheostomy 1968 2. Urethral Fistula 1972	1. Massive collapse of L.Lung 2. B.P. 140/– down to 80/– for over one hour	—

Case 2. The patient became a quadraplegic following a cervical laminectomy in 1969. During 1971–72 he had several grafting and debridement procedures with poor results. Systolic blood pressures during operation were occasionally recorded at 60/mm Hg. A blood volume determination on this patient showed a low total volume and a very low red cell volume (1216 ml) (19 ml/kg). These abnormalities were corrected and the patient showed a remarkable change in his general attitude to life and his physical reaction to surgery and anaesthesia were subsequently good.

Summary

A study of 27 quadraplegic patients selected at random has demonstrated that both blood volume and vessel response to stress are unpredictable. A study of the surgical history of quadraplegic patients suggests that wound healing is impaired and that morbidity is increased in such patients unless the blood volume is replaced to near normal. Blood volume measurements should be routine in the pre-operative assessment of these patients.

Résumé

Une étude de 27 patients quadriplégiques choisis au hazard, a démontré que le volume sanguin et les vaisseaux répondent au stress de façon imprévisible. Une étude portant sur l'histoire chirurgicale des quadriplégiques, suggère que la guérison des plaies est retardée et que la morbidité est augmentée chez ces patients, à moins que le volume sanguin ne soit corrigé à des chiffres quasi-normaux. De routine, la mesure du volume sanguin devrait faire partie de l'évaluation préopératoire chez ces patients.

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