USE OF BLOOD VOLUME ESTIMATIONS IN A GENERAL MEDICAL UNIT

By P. H. Feng, P. S. Cheah, B. Singh, M. H. L. Yap and Y. K. Lee

SYNOPSIS

The workings of a semi-automated equipment for measuring blood volume is described and the methodology elucidated. Illustrative cases where this investigation has helped in the clinical management are briefly outlined.

Measurement of blood volume has obvious important clinical applications both in health and disease. Until 1961 when Williams and Fine first described the measurement of blood volume with a new semi-automated apparatus, the prevailing methods have failed to find widespread clinical application for various reasons. Accurate, fast and often repeated blood volume measurements therefore provide not only important information to both the surgeon and physician but the further identification of plasma volume and red cell mass enhances the utility of such data. Since the last decade a large volume of literature has appeared regarding its uses in shock (Friedman *et al*, 1966; Little, 1966; Prout, 1968), surgery (Gardner, 1969; Gollub *et al*, 1966; Underwood and Howland, 1966), cardiology (Berger *et al*, 1964; Gazzaniga *et al*, 1966; Schechter *et al*, 1968) and other disciplines (Straub *et al*, 1969).

We describe briefly below the workings of such a machine and our early experience in its usage in a general medical unit accompanied by case illustrations.

INSTRUMENTATION

The instrument known as the Volemetron is a self-contained, mobile diagnostic facility ready for instant use and easily operated by personnel of ordinary technical competence. In essence it is a gamma-ray counter with a small programmed computer for measuring blood volume, plasma volume and red cell mass. It involves automatic measurements and automatic calculations based on the dilution of gamma-ray emitting material injected into the circulating blood.

The test material injected is human serum albumen tagged with either I^{131} or I^{125} (RIHSA). Each of these isotopes of iodine is a gamma-ray emitter. Iodine-131 has a half-life of 8 days and emits hard gamma-rays and Beta-rays. Iodine-125 has a half-life of approximately 60 days and emits only very soft gamma-rays. Unitized commercial doses of I-125 RIHSA containing 1·5 ml. in a glass syringe with 2·5 uc. of radioactivity are commercially available. This syringe together with blood sample tubes are of the "disposable" variety.

The radiation hazard by this technique for both personnel and patients is negligible. Since the average dose injected is about 3 microcuries, one single injection is equivalent to one-twentieth the amount of radiation received from a single X-ray of the chest. Thus the total radiation delivered to the patient after as many as 8 to 10 separate determinations is well within safe limits.

METHODOLOGY

Details of methodology and its pitfalls have been well described by Albert (Albert, S. A., 1966; Albert, S. N., 1963; Albert *et al*, 1965) and Free (Free, A. H., 1970).

In essence it consists of a three-step process. In the first step, the activity of the dose of material to be injected is measured. This value is recorded in a scaler "memory" incorporated in the machine. 8 cc. of blood are then removed from the patient (the premix sample) and the test dose is then injected intravenously into the patient. The small amount of "residue" remaining in the syringe is counted in the second step. 2 further blood samples are taken 10 and 20 minutes after injection of the test dose (the postmix samples). In the third and final step, the premix and postmix

Medical Unit, Thomson Road General Hospital, Toa Payoh Rise, Singapore.

P. H. FENG, M.B., B.S., M.R.C.P.G., A.M., Consultant Physician.

P. S. CHEAH, M.B., B.S., Medical Officer.

B. SINGH, M.B., B.S., Medical Officer.

M. H. L. YAP, M.R.A.C.P., M.Med. (Int. Med.), Senior Registrar.

Y. K. LEE, M.D., F.R.C.P.E., M.R.C.P., LL.B., A.M., Consultant Physician and Head.

samples are placed in the counting wells and the diluent volumes are automatically computed. These two values are plotted on a semi-logarithmic graph and extrapolated to time "0". Haematocrits are then obtained and corrected for trapped plasma using the F cell ratio (Albert, S. N. *et al*, 1965).

Calculations are done as follows:

Plasma Volume = Diluent Volume × (1 − Hct_v)

$$\text{Total Blood Volume} = \frac{P.V.}{1 - (Hct_v \times F\ cell)}$$

Red Cell Volume = Total Blood Volume − Plasma Volume

The whole process takes under 30 minutes. The values so obtained are then compared with the predicted blood volumes based on height and weight (Nadler *et al*, 1962).

CLINICAL APPLICATIONS

Illustrative examples from our early studies are presented below. Since we are a medical unit, the cases presented are necessarily medically biased.

Case 1

N.S.C. a 21-year old female with end-stage kidney disease (creatinine clearance 5 ml./min.) was admitted on 22.9.71 with hiccoughs and vomiting. Physical examination revealed a sallow complexion and dehydration. Blood pressure was 120/80. Investigations were as follows: Hb. 6·7 gm., blood urea 222 mgm. %, serum potassium 2·5 mEq./L., sodium 128 mEq./L. and chloride 90 mEq./L. 24-hour urinary electrolyte excretion were potassium 13·5 mEq./day, sodium 47·5 mEq./day and chloride 41·2 mEq./day. Fluid and electrolyte replacement were instituted and patient's symptoms improved. On 29.9.71 she was noticed to "behave queerly" and rather disorientated and drowsy. A clinical diagnosis of uraemic coma was made. Investigations showed a blood urea of 219 mgm.%, alkali reserve of 23 volumes % and serum potassium 4·1 mEq./L., sodium 117 mEq./L. and chloride 86 mEq./L. This indicated a low-salt syndrome but there was a question of dilutional hyponatraemia. A blood volume done revealed normovolaemia. 200 cc. of 5% saline, 100 cc. of 8·4% sodium bicarbonate, 500 cc. of normal saline and 1,000 cc. of 5% dextrose were infused within the next 24 hours. Patient's mental state improved dramatically the next day and electrolytes were normal with continuing oral salt supplement.

COMMENT

Blood volume measurement helped us to differentiate between dilutional hyponatraemia, in which case the volume would be high and absolute salt deficit. This is crucial as treatment is different in these two conditions.

Case 2

O.C. a 71-year old Chinese man was admitted on 22.10.71 with salicylate poisoning. Physical examination revealed a red and congested face, blood pressure of 160/100 and evidence of right hemiparesis. There was also a past history of peptic ulcer. He improved with forced diuresis and investigations revealed the following: Hb. 20·5 gm., TW 19,300, platelets 130,000, P.C.V. 70%, total red cell count 7·7 million, blood gases were normal and oxygen saturation 93%. There was no clinical or laboratory evidence to suggest renal, liver or respiratory illness. Blood volume studies showed the following results: Total Blood Volume 4,300 ml. (expected obtained from normogram 3,800), plasma volume 1,710 ml. or 37 ml./kg. (normal 38-48 ml./kg.) and total RBC mass 55 ml./kg. (Normal 25-35 ml./kg.).

COMMENT

This case illustrates the use of the Volemetron not only for estimation of blood volume but also its component parts namely plasma volume and RBC mass.

Case 3

W.B.N. a 57-year old housewife was admitted to the medical unit on 1.10.71 with history of malaena and giddiness. She was a known case of mitral stenosis, atrial fibrillation and was admitted three times previously for congestive heart failure. Physical examination revealed severe pallor (Hb. 5·5 gm.) and blood pressure of 70/40. She was resuscitated with blood transfusions but her malaena persisted. In view of her poor cardiac status it was decided to treat her conservatively. For the next two weeks a total of 7 pints of blood were administered but she remained hypotensive (Bp. 90/60) although her Hb. rose to 11 gm.%. Fearing that further transfusions could compromise her cardiac status a blood volume was estimated. This revealed an intravascular deficit of 600 cc. The deficit was then corrected with blood and saline. The next day her blood pressure rose to 120/80 and she remained fairly well until 29.10.71 when she suddenly had a massive bleed. An emergency gastrectomy was done and about 5 pints of blood were administered. Post-operatively the measured blood volume was normal and subsequent fluid replacement was guided by careful intake and output charting. Her cardiac status remained satisfactory although she eventually succumbed to over-whelming chest infection.

COMMENTS

Repeated blood volume measurements were of considerable help in guiding fluid replacement in this case. Overtransfusions with resultant cardiac decompensation could have occurred easily.

Case 4

M.O. a 34-year old Malay housewife was admitted on 1.10.71 for septic abortion and shock. Patient was treated with massive blood transfusions, intravenous fluids, large doses of hydrocortisone and ampicillin. The next morning she was found to be extremely dyspnoeic with signs of acute heart failure. A blood volume done showed 3,600 ml. (her expected blood volume was 2,700 ml.), an excess of about 1 litre. Despite intravenous diuretics and digoxin, patient failed to respond and passed away the same morning.

Case 5

N.S. a 69-year old left hemiplegic Indian male was brought to the hospital on 10.10.71 because of giddiness, fainting attacks and vomiting. Physical examination revealed severe dehydration, crepitations in lung bases and signs of old left hemiplegia and right hemiparesis of recent onset. Routine investigations revealed Hb. 14·8 gm., blood urea 248 mgm. %, serum potassium 5·4 mEq./L., serum sodium 132 mEq./L. and chloride 101 mEq./L. Urine microscopy showed WBC 10-15. He was rapidly rehydrated and received 7 litres of fluid within the next 48 hours. Blood urea done on 13.10.71 fell to 115 mgm. %. However in view of his old age and persistent basal crepitations, there was a reluctance to give him further fluids. A blood volume done at this time revealed an intravascular deficit of 700 ml. Further fluids were then administered and within 48 hours his urea fell to 50 mgm. %. He was discharged well after a further week's stay in hospital.

Case 6

A 50-year old Malay male was admitted on 2.11.71 with a 2 day history of acute anuria which was subsequently confirmed in the hospital (urine output less than 20 ml./day). He gave a history of passing small stones for a few years. Unfortunately he persistently refused any form of treatment or investigations and discharged himself two days later. In a week's time he returned in acute pulmonary oedema. Meanwhile the anuria had persisted. Physical examination confirmed the presence of pulmonary oedema and also revealed a blood pressure of 190/110. A cystoscopy and retrograde pyelography revealed "a blockage of the left ureter at 2 cm. and non-visibility of the right ureteric opening". Laboratory results were as follows: Hb. 9 gm., blood urea 426 mg. %, alkali reserve 14 ml. %, serum potassium >7 mEq./L., serum sodium 125 mEq./L. and chlorides 83 mEq./L. Peritoneal dialysis utilizing hypertonic solution was immediately instituted. A total of 8 litres of fluid was removed in 48 hours. At conclusion of dialysis he was noticed to be "sunken and dehydrated". Blood pressure had also fallen to 110/80. A blood volume done revealed a deficit of 1,500 ml. which were replaced. 24 hours later spontaneous diuresis occurred and within the next 48 hours a total of 8 litres of urine was passed. Although this was "balanced" with intravenous fluids a repeat blood volume revealed a deficit of 1,000 ml. This was subsequently replaced. His progress since then has been satisfactory and at the time of writing, he is up and about although his urea is still raised at 108 mgm. %. Further tests are contemplated to elucidate the cause of the obstruction.

COMMENTS

The exact cause of the obstruction and his spontaneous improvement is unknown at this moment. Nevertheless repeated blood volume measurements have assisted us considerably in the management of this patient.

DISCUSSION

The concept of measuring blood volume as an aid to clinical practice is not new. As early as 1915 Keith using the dye dilution method measured blood volumes in dogs with experimentally induced shock. In 1937 Gibson and Evans reported on the use of the dye Evan's blue to measure plasma volume.

The modern tracer method of radioisotope labelling began with the use of radioactive phosphorus to label the red blood cell and determine blood volume by Hahn and Hevesy in 1940. In 1943 Fine and Seligman first labelled serum proteins with an isotope and introduced the modern use of iodinated I-131 serum albumen. This method proved more accurate than the others but was time consuming and tedious. With the advent of this automated machine, results can be obtained rapidly and therapy instituted within half an hour. The accuracy that can be achieved with Volemetron for measuring blood volume is within $\pm 3\%$ of absolute values (Free, A. H., 1970). We feel that our initial experience have demonstrated the usefulness of this equipment in a general medical unit. It appears therefore that this instrument should form part of the armamentarium in any unit that deals with trauma, shock, burns, complicated electrolyte and water problems and intensive care.

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