BLOOD VOLUME STUDIES UTILIZING THE RADIOCHROMIUM 51 METHOD AND ITS APPLICATION TO ANESTHESIOLOGY* † ‡ §

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As one reviews the methods for measuring blood volume, plasma volume and red cell volume (1, 2), one cannot help but be impressed by the considerable contradiction and differences in the reported results. This is particularly true of the methods for determining plasma volume which depend on substances such as T1824. Such substances, having a strong affinity for combining with plasma proteins, are therefore assumed to have a comparable distribution volume. The mere multiplicity of the suggested methods and modifications, coupled with the subsequent controversy about them, has sown seeds of doubt in the minds of many regarding the accuracy and utility of this particular technique for measuring blood volume. This is especially true when one considers the data on red cell distribution obtained by Gibson (3) and his group, indicating marked differences in hematocrit readings of blood samples withdrawn from various organs. Studies on lymph from the various organs, showing different protein concentrations reflecting interstitial fluid composition from different parts of the body, adds further doubt (4).

It is therefore apparent that the perfect material has not yet been found and, in almost all plasma techniques, one observes progressive disappearance of the tagged elements by various routes, particularly movements across the limiting membrane bounding tissue interspaces. After the initial mixing period, T1824 dye time-concentration curves show a characteristic slope, usually with a decrease of from 3 to 13 per cent per hour. This is ascribed to the passage of T1824 bound to albumin, through capillary membranes into lymph (1). LeVeen and Fishman (5) observed binding of the dye by globulin in vitro and stated that the bond appeared to be easily dissociable, thereby theoretically making the material unsuited as a metabolic tracer. Estimation of a large body of data derived from routine preoperative calcula-
tions of plasma estimations volume on an actual surgical service indicates that approximately 5 per cent of the patients with an apparently adequate and stable circulation will have dye losses as great as from 25 to 30 per cent per hour for no known reason (6). Further evidence for the lack of a definitive membrane boundary is shown by the study of injections of iodine 131-albumin. Radioactivity was first detected in the thoracic duct lymph in about ten to twenty minutes, and for a period of some forty minutes increased rapidly (7). These disappearance curves are, however, suspected by us and others to vary considerably under conditions such as hypoxia and other stress, these being the particular conditions under which the determinations are most valuable and most desired.

Because the red cell respects its boundary membrane more readily than the other substances, together with the fact that there is definite evidence of a firm union of radiochromium 51 with the red cell and a very low leakage in vivo, as demonstrated by Gray, Sterling, Read and others (8, 9), our group adopted this approach to the particular problem. We modified the Read direct method for more rapid adaptability to our clinical anesthesia routine, so that in addition to the preoperative determination of red cell mass, we can very easily and promptly obtain a postoperative determination as a guide to replacement therapy. Our modification of the Read method is as follows.

**Method**

To a plastic bag, or 50 cc. syringe, is added 2 cc. of sodium chromate-51 solution containing approximately 100 microcuries and 0.5 cc. of heparin solution. From 40 to 50 cc. of blood is then with-

![Fig. 1.](image-url)
reduced and unable to react with the red cells whereas the bound chromate remains unchanged. A 4 cc. syringe is then filled from the bag or syringe and is reserved for later counting. The container is then weighed, about half the contents is injected into the patient’s veins, and the container is then weighed again. After a period of fifteen minutes to allow mixing with the patient’s blood, 4 cc. of blood are withdrawn from the patient into a 4 cc. syringe. Both 4 cc. syringes are then capped with rubber caps and placed in special centrifuge shields of our own design, the syringe tips being pointed centrally. These are centrifuged for thirty minutes (figs. 1, 2, 3). The volume of packed red cells is then read directly on the syringes and the hematocrit of each is calculated. The plasma is expressed from each syringe, and the syringe, with only packed red cells remaining, is placed in the well of the scintillation detector for counting (fig. 4).

The red cell and whole blood volumes are then calculated by the formula shown in figure 5. C, is the total counts per minute of the
tagged sample minus the background counts per minute. $V_1$ is the volume of red cells of the tagged sample injected and $h_1$ is the hematocrit of the tagged sample. $W$ is the weight of blood injected and SG its specific gravity. $C_2$ is the counts per minute of the patient’s blood minus the background count. $V_2$ is the volume of red cells in the patient’s sample and $h_2$ the hematocrit of the patient’s sample.

Checks of accuracy by repeated determinations and also by the addition of known quantities of blood to a patient’s circulation, have shown us that the method’s error has not exceeded 4 to 6 per cent in which for our purpose is made than adequate.

**ILLUSTRATIVE CASE**

A patient, a woman aged 76, was to undergo a radical neck dissection. She had been entirely well, except for a small melanoma of the skin of the neck, and had been doing her housework regularly. There was no history of weight loss. Routine laboratory reports showed the hemoglobin and red cell counts within normal limits. To our surprise, however, the patient’s preoperative

$$\text{Total Counts Injected} = \frac{C_1}{V_1} (h_1) \left( \frac{W}{SG} \right)$$

$$\text{RBC Volume} = \frac{C_1}{V_1} h_1 \left( \frac{W}{SG} \right)$$

$$\text{WBV} = \frac{C_1 h_1 W V_2}{V_1 c_2 SG h_2}$$

**Fig. 5.**
blood volume, as determined from the red cell mass and hematocrit reading, was approximately 2,710 cc., or about 50 per cent of the calculated normal, based on age, weight and surface area. This determination was again checked, with the same result—or more exactly, 2,760 cc. The patient was given a transfusion of 1,000 cc. of whole blood, bringing the blood volume to 3,680 cc. During four and a half hours of surgery during which she bled a lot, a rough measurement of the amount of blood lost was approximately 3,300 cc. The patient received during this period a total of 4,000 cc. of whole blood and, on the day after operation, the measured blood volume was found to be 4,150 cc., thus checking closely with the calculated end volume of 4,380 cc. The patient's course throughout was uneventful, and at no time were there periods of hypotension so characteristic of the patient with a markedly contracted blood volume.

**SUMMARY**

The importance of blood volume determinations in anesthesiology has been stressed. On comparison of the various methods, we feel that the ease and accuracy of the Read method, with our modification, recommends it to the anesthesiologist as a new tool for better control of his patient, especially in major cancer surgery in which contracted blood volumes are frequently a problem. At present these determinations are being made by our resident staff. In the future they will be an available laboratory service.

**REFERENCES**