

BLOOD VOLUME DETERMINATIONS IN THE OPERATIVE PERIOD

A Convenient, Simplified Procedure

CARL E. WASMUTH, M.D.,

Department of Anesthesiology

OTTO GLASSER, Ph.D.,

Department of Biophysics

WALTER E. H. LAUDE, M.D.*

and

RANSON L. SMITH, M.D.**

THE function of anesthesiology has been extended beyond the time of operation to involve preoperative evaluation and immediate postoperative management. The increasing magnitude of modern surgical procedures and the trend toward accepting for operation patients who are poor surgical risks place larger demands on the anesthesiologist's capacity to assess and to support the vital systems of the body. Blood volume is a major, determinable factor in this evaluation. Among the methods for its determination, those that use radio-active iodinated human serum albumin (I^{131})† are rapid and accurate and can be frequently repeated.

The normal average blood volume by this procedure is about 85 ml. per kilogram of body weight, of which blood cells make up some 40 ml. and plasma the remaining 45 ml. There is variation around this mean. Total blood volume is proportioned to the mass of metabolically active tissue. A lean, muscular person has a greater blood volume per unit of body weight than does an obese person. The aged tend to have smaller total blood volumes than the young. Determinations of hemoglobin content, red cell count, hematocrit ratio or plasma protein levels are made from a unit of the total volume. They give quantitative expressions of these components in relation to that volume, but they do not indicate what that volume may be. Hence, they do not substitute for direct determinations of total circulating volume (Table 1).

TABLE 1
Comparison of Findings on Three Blood Determinations in Various Conditions

Condition	Blood Volume	Hemoglobin	Hematocrit
Burns	Decreased	Normal to increased	Normal to increased
Shock	Decreased	Normal to increased	Normal to increased
Vomiting and diarrhea	Decreased	Normal to increased	Normal to increased
Acute bleeding	Decreased	Normal	Normal
Overtransfusion	Increased	Normal	Normal
Chronic bleeding	Decreased	Decreased	Decreased

* Fellow in Department of Anesthesiology.

** Former Fellow in Division of Surgery.

† The radio-iodinated serum albumin (RISA) used in this investigation was supplied by the Abbott Laboratories on authorization from the Isotopes Division, U. S. Atomic Energy Commission.

This report presents observations made with a simplified, isotopic technic that enables blood volume determinations to be made in anesthesiologic practice.

TECHNIC

Five milliliters of a reference solution containing about five microcuries of radioactive iodinated (I^{131}) human serum albumin is injected into an accessible vein. Care is exercised that no radioactive material is lost before injection and that the tip of the needle rests within the lumen of the vein. The syringe that contained the radioactive iodinated human serum albumin is rinsed twice with the patient's blood before the needle is withdrawn. Ten minutes is allowed for complete mixing of the isotope in the circulating blood of the patient. A longer period is required for patients who are hypotensive, cachectic, or seriously ill.

From another vein, 10 ml. of blood is withdrawn into a clean heparinized syringe. A portion of this blood is used to determine the hematocrit reading, and the remainder is sent to the isotope laboratory for determination of radioactivity. Five milliliters of the heparinized blood is accurately transferred into a test tube and placed in the well counter, where its radioactivity is measured on the scaler (Fig. 1). The total blood volume is determined using the formula:

$$\text{Total blood volume} = \frac{\text{Counts per minute of standard} \times \text{ml. injected} \times \text{dilution factor}}{\text{Counts per minute of patient's blood}}$$



Fig. 1. Test tube being placed in the well counter where its radioactivity will be measured on the scaler.

The standard is prepared by dilution of the reference solution and its radioactivity estimated at the time of blood assay. The calculated total blood volume divided by the patient's usual body weight in kilograms gives the number of milliliters of blood per kilogram. Loss of weight during illness is disregarded. The total cell mass is calculated by multiplying the total blood volume by the hematocrit ratio as measured from the same sample of blood.

Validation of the Procedure

The accuracy of this method was tested in two ways. In one series of tests, 24 simultaneous measurements of blood volume were made using radioactive iodinated (I^{131}) human serum albumin and Evans blue. The mean difference in estimates between the two methods was 3.7 per cent. In the second series, blood volume determinations were made by the above procedure before and after blood donations. The amount of blood lost from the circulation was measured directly and also estimated from the differences in blood volume determinations. The mean difference between observed and estimated losses was 7.8 per cent. The greatest difference was 72 ml., the estimate being 572 ml. and the loss 500 ml.

APPLICATION

Preoperative. The method has particular value in the chronically ill¹ and the aged. These patients frequently are debilitated, have sustained great losses of weight and manifest contractions of blood volume and of the mass of circulating proteins. Patients with contracted blood volumes are subject to serious hypotension and circulatory collapse when anesthesia is induced,² when the plane of anesthesia is deepened, or when blood losses occur which do not seem of themselves remarkable. With the increasing amount of surgery performed on the older age group of patients, who are very often victims of chronic infection, malignancy, or prolonged drainage, this problem looms very large.

As noted above, routine laboratory procedures are of little help. An existing anemia may be masked by contraction of the plasma volume, so that hemoglobin content and hematocrit determination appear within normal limits. Similarly, contraction of plasma volume obscures a deficit in circulating protein mass, so that plasma protein determinations may also be within normal limits. The aim of preoperative care in such patients is to restore the specific deficit in total blood volume by appropriate means, so as to make them better able to withstand the stresses of anesthesia and surgery. This can be done with some precision by basing the treatment given on a determination of total blood volume and its fractions. Further, with advancing years there develops circulatory inadequacy such that overtransfusion is a serious risk, which a determination of blood volume would avoid.



Fig. 2. The syringes containing a calculated amount of isotope always are available in the recovery room refrigerator.

Operative. The need for an accurate estimate of blood loss during operation has been for years a challenge to surgeons and to anesthesiologists.³ The techniques used include estimating the hemoglobin content of washed sponges, and weighing the sponges used at the operating table. Both methods and their modifications have many sources of gross error. As indices of the desired post-operative replacement, they all depend on the assumption that the blood volume was normal preoperatively. All that they indicate is a crude estimate of the amount of blood lost during surgery, while they give no estimate of the amount of blood that may be needed to restore blood volume to normal. The intrinsic errors of these procedures preclude obtaining a good estimate of blood loss or blood requirements in specific operations; the variables include the skill of the surgeon, the duration of the operation and the complications that may be encountered. For these reasons, the only accurate method of estimating blood loss or determining blood requirement is to measure circulating

blood volume preoperatively and at intervals thereafter. The procedure described above, as was shown, can yield adequate estimates of comparatively small blood losses. It has the further advantage that the determinations can be repeated at frequent intervals.

Postoperative. Since it is possible to make repeated determinations, the method is useful also in the critical postoperative period. The only accurate basis on which to manage a blood replacement program is the periodic determinations of the total blood volume. Any rough estimates that are made during or after the surgical procedure can be accurately checked with a blood volume determination, the importance of which becomes even greater when repeated, comparative determinations can be made.

In many surgical procedures (e.g. transurethral prostatectomies, intracranial operations, and extensive dissections⁴) there is an appreciable blood loss postoperatively that may be almost as great as the blood loss during operation. Without help from the laboratory, the replacement of this loss is left to the judgment of the clinician and again overtransfusion remains just as great a hazard as undertransfusion.

DISCUSSION

The safe administration of anesthesia extends beyond provision of an adequate oxygen and carbon dioxide transporting mechanism. All too frequently deficiencies in total circulating volume are masked in spite of the laboratory procedures that evaluate the hemoglobin concentration, the cell mass, and the red cell count (Table 2). The preoperative use of blood volume determinations permits accurate evaluation of the circulatory volume and the necessary preoperative treatment of any deficiencies. In the chronically ill and aged patients, contracted blood volumes many times are not recognized (Table 2, Case 2) unless blood volume determinations are made. If such states were properly diagnosed and then the patients were transfused with whole blood, the circulatory instability during the operative procedure would be greatly reduced.⁵

The two more common methods of determining circulating⁶ blood volume are the Evans blue method (T-1824) and that using radioactive iodinated serum albumin. There are other methods involving the use of other isotopes, but each has practically insurmountable obstacles to its use.⁷ In this study, each patient was tested both by the Evans blue and by the radioactive iodinated serum albumin method simultaneously. There was no clinically significant difference in the results. In contrast with the dye method, the isotope method using I^{131} has several advantages: it can be repeated; it does not interfere with the use of other colorimetric laboratory procedures; the preparation for administration of the isotope is minimal. The syringes containing a calculated amount of isotope are always available in the recovery room refrigerator (Fig. 2). After injecting the contents of one syringe, allowing 10 to 15 minutes for mixing in the blood stream, the blood sample for counting is withdrawn and

sent to the isotope laboratory. As many determinations as are necessary can be made for the individual patient. The calculated blood volume and the plasma volume, as previously described, disclose deficiencies of specific blood components which can be treated by specific replacement therapy. Such a program is well appreciated in the case of polycythemia.⁸

TABLE 2
Hemoglobin and Hematocrit Determinations Compared with Blood Volume in Various Conditions and Stages of Surgical Procedure

Case No.	Status		Age (yr.)	Hemoglobin Gm./100 ml.	Hematocrit %	Blood Volume ml./Kg.
1	Preoperative	Bleeding gastric ulcer	41	13.5	47	47
2	Preoperative	Carcinoma of colon	82	13.2	44	58
3	Preoperative	Embolus, femoral artery	—	14.2	54	80.5
	Postoperative	Arterial embol-ectomy	—	13.5	49	74
4	Preoperative	Diabetes and gangrenous leg	—	15	48	47
5	Postoperative	Retroperitoneal leiomyosarcoma	—	9.5	27	80.5

The use of blood volume determinations during surgical procedures does not relieve the anesthesiologist and surgeon of the responsibility of blood replacement. In many instances, the operative team can estimate blood loss with considerable accuracy. However, in the longer operative procedures and especially in those in which the blood loss is considerable, clinical estimation of the hemorrhage many times is inaccurate. In those instances, the determination of the circulating blood volume would replace supposition with fact.

References

1. Clark, J. H. and others: Problem of reduced blood volume in the chronically ill patient; concept of chronic shock; hemoglobin and red blood cell deficits in chronic shock; quantitative aspects of anemia associated with malignant tumors. *Ann. Surg.* **125**: 618-646 (May) 1947.

2. Barbour, C. M., Jr. and Tennant, R.: Clinical application of blood volume studies in major surgery. *J. Urol.* **71**: 497-501 (April) 1954.
3. Gatch, W. D. and Little, W. D.: Amount of blood lost during some of the more common operations. *J. A. M. A.* **83**: 1075-1076 (Oct. 4) 1924.
4. Saltzstein, H. C. and Linkner, L. M.: Blood loss during operations. *J. A. M. A.* **149**: 722-725 (June 21) 1952.
5. Royster, H. P., Pendergrass, H. P., Walker, J. M. and Barnes, M.: 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 (June) 1951.
6. Schultz, A. L., Hammarsten, J. F., Heller, B. I. and Ebert, R. V.: Critical comparison of the T-1824 dye and iodinated albumin methods for plasma volume measurement. *J. Clin. Investigation* **32**: 107-112 (Feb.) 1953.
7. Sterling, K. and Gray, S. J.: Determination of circulating red cell volume in man by radioactive chromium. *J. Clin. Investigation* **29**: 1614-1619 (Dec.) 1950.
8. Barbour, C. M., Jr.: Polycythemia in relation to anesthesia and surgery. *Anesthesiology* **11**: 155-163 (March) 1950.