

## NORMAL BLOOD VOLUMES IN MEN AND WOMEN OVER SIXTY YEARS OF AGE AS DETERMINED BY A MODIFIED $\text{Cr}^{51}$ METHOD

ROBERT HUDSON SMITH, M.D.

IN THE COURSE of a study of hypovolemic subjects and their reaction to anesthetic agents, it became apparent that "normal blood volumes" for both men and women over 60 years of age had not been established and would be desirable. Reports are available on blood volumes of old men, young men, and young women, ascertained by various methods, including Evans blue,  $\text{P}^{32}$ ,  $\text{Cr}^{51}$ , and iodinated albumin. Blood volume studies comparing men and women over 60 by the  $\text{Cr}^{51}$  method were unavailable. To obtain this information, about one hundred subjects over age sixty were selected from the Northern State Hospital for the Insane, Sedro Wooley, Washington. The 52 men and 45 women were healthy, active, and eating well.

### METHOD

The method of blood volume determination was a modification of the method of Gray and Sterling (1).

Specifically, 20 cc. of the patient's blood was drawn into a heparinized syringe and injected through a vented rubber cap into a 50 cc. culture tube containing 5 cc. of sterile ACD solution, and the contents mixed well. This mixture was centrifuged at 3,000 r.p.m. for fifteen minutes. Then, using a long 18 gauge needle for aspiration, a short 18 gauge needle for airway, and a moderate vacuum, aspiration of the supernatant fluid was effected, leaving the packed red cell mass intact. The long needle was pulled well up to act as an airway, and sterile saline run in through the short needle (which was still clean) to a volume of 25 cc. Then 40 to 60 microcuries of  $\text{Cr}^{51}$  (as sodium chromate) were added through the short needle. All of the chemical was pulled into the mixture by aspirating through the long needle airway. After this, the needles were removed, the contents mixed well by shaking, and the tubes put into a water bath of 37 C. for thirty minutes.

After incubation, the tube of mixture was centrifuged eight minutes at 3,000 r.p.m., and again the supernatant liquid was aspirated and replaced with sterile normal saline. This washing of red blood cells was repeated three times. A thorough mixing by shaking is essential

Received from Division of Anesthesiology, School of Medicine, University of Washington, Seattle, Washington (where Dr. Smith was a United States Public Health Service Research Fellow), and accepted for publication July 16, 1958. Dr. Smith is now Assistant Professor of Anesthesiology, Medical College of Georgia, Augusta, Georgia.

before centrifugation. This washing of the red blood cells removes, by dilution, the sodium chromate which has not adhered to the red cells. After the fourth centrifuging, reconstituting to exactly 20 cc. was done and the material well mixed by shaking, then the short airway needle was again removed. The long needle was pushed in until the point was near the bottom of the tube. A Luer 20 cc. syringe was attached to a 20 gauge needle, and the needle tip pushed just through the rubber cap on the tube. The tube was inverted and 16 cc. of the red blood cells suspension were drawn into the syringe without air bubbles. The syringe and its contents, the needle, and a test tube type needle cover were weighed. Accuracy to 10 mg. was essential.

One cubic centimeter of the red blood cell suspension was measured from the syringe into a volumetric 100 ml. flask of cold water. (One cubic centimeter is about 30 drops from a 20 gauge needle, and will weigh about 1 Gm.) After this, the syringe and contents, needle, and needle cover were weighed again.

The 15 cc. remaining were injected into the patient's vein. Every care was taken to avoid extravasation during the injection and after the needle was withdrawn. The syringe, needle, and needle cover were then reweighed. Thus the weight of 1 cc. and the weight of the material injected into the patient were determined.

After one hour, and up to two hours, after injection of the  $\text{Cr}^{51}$ —red blood cell mixture, 8 cc. of blood were drawn into a heparinized syringe from the side opposite site of injection. A tourniquet was used to facilitate vein entry, but was removed before aspiration was begun.

Next, 4 cc. of the patient's blood were delivered by a volumetric 4 cc. pipet (calibrated to deliver 4 cc. of blood), into a standard 4 cc. glass vial with screw cap, and the cap labeled. Then 4 cc. of the 1:100 solution "standard" in the 100 cc. volumetric flask were delivered by a pipet (calibrated to deliver 4 cc.) into a standard 4 cc. glass vial with screw cap, and the cap labeled. A standard hematocrit determination was made on the patient's blood.

The gamma emanations from each vial were counted in a scintillation well counter and recorded on a decimal scaler. The background count per second was determined. The "count" was calculated as number per second, and the background count per second subtracted.

Several counts were taken that agreed within a small margin before the following computation formula was used.

Blood Volume =

$$\frac{\text{Number Counts/Second in 4 cc. of "Standard"} \times 100 \times \left( \frac{\text{Grams Injected into Patient}}{\text{Grams Diluted 1:100}} \right)}{\text{Number Counts/Second in 4 cc. of Patient's Blood}}$$

Blood volume determinations by this method are not accurate unless the glassware and needles are free from contamination by  $\text{Cr}^{51}$ . Prop-

TABLE 1  
MEAN BLOOD VOLUMES BASED ON ACTUAL AND IDEAL WEIGHTS \* FOR 52 MEN  
AND 45 WOMEN OVER 60 AS DETERMINED BY MODIFIED CR<sup>11</sup> METHOD

	Men	Women
Cc./kg. based on actual weight	65.3	56.0
Cc./kg. based on ideal weight	66.3	59.3
Cc./m. <sup>2</sup> body surface, actual	2,427	2,081
Cc./m. <sup>2</sup> body surface, ideal	2,477	2,139
Standard deviation from mean	7.8 cc./kg.	9.07 cc./kg.
Standard deviation from mean	262 cc./m. <sup>2</sup>	261 cc./m. <sup>2</sup>

\* The figures on ideal weight were derived by the Medical Statistics Division of the Metropolitan Insurance Company, New York, from the Medico-Actuarial Mortality Investigation published in 1912. The figures were verified in 1929 in the Medical Impairment Study.

erly cleaned glassware and needles, checked in the counting chamber, show no higher count than the background count. To achieve this, as soon as an article was used it was placed in running cold water. It was washed in a detergent solution as soon as practical, rinsed, and placed in reasonably strong hydrochloric acid solution for at least one hour. Rinsing in running water and sterilizing in an autoclave were the final steps.

## RESULTS

The hematocrit determination, weight, and height were recorded for each patient, and the body surface area and weight in kilograms (ideal and actual) were calculated. Mean blood volumes and standard deviation from the means were computed based on actual and ideal weight and are shown in table 1. Further data showing total blood volumes, plasma and red blood cell volumes appear in table 2.

## DISCUSSION

Determinations of blood volume have been on an orderly basis since 1915 when a study using vital red dye was reported by Kieth, Rountree, and Geraghty (3). Then Gregersen (4) in 1935 described the Evans

TABLE 2  
AVERAGE TOTAL BLOOD, PLASMA AND RED BLOOD CELL VOLUME \*  
FOR 52 MEN AND 45 WOMEN OVER 60

	Men	Women
Total cc. red cells	1,920	1,424
Total cc. plasma	2,485	2,095
Cc. RBC/kg.—actual	28.4	22.4
Cc. plasma/kg.—actual	37.1	33.2
Cc. RBC/m. <sup>2</sup> —actual	1,067	853
Cc. plasma/m. <sup>2</sup> —actual	1,385	1,247
Cc. RBC/kg.—ideal	28.9	24.2
Cc. plasma/kg.—ideal	37.7	35.7
Cc. RBC/m. <sup>2</sup> —ideal	1,078	882
Cc. plasma/m. <sup>2</sup> —ideal	1,396	1,285

\* Based on actual and ideal weight—see table 1.

blue technique, and Gibson (5, 6) in 1937 reported work which set the standards of "normality" for several years. Recent studies have utilized radioisotopes—the technique which was modified for this study.

These techniques have been used in many studies and interesting and varied reports have been made. Best and Taylor (7) quote blood volume as a percentage of body weight, and give a figure of 78 cc. of whole blood per kilogram of body weight. Using Evans blue in 49 men (average age 35.5), Gibson (8) reports 77.7 cc./kg. with a spread of 62.7 to 97.7 cc./kg. He also found that blood volume was 66.1 cc./kg. in 41 women (average age 38.9), with a spread of 46.3 to 85.4 cc./kg. Berlin (9), using  $P^{32}$  (10), found a blood volume of 64.4 cc./kg. in 60 women averaging 31.3 years. This worker also reports 12 men as having a blood volume of 64.2 cc./kg. Reilly (11), using  $Cr^{51}$ , reported blood volumes of 88 men that averaged 65.5 cc./kg.

Perara's (12) and Price's (13) statements that blood volume should be corrected to "ideal weight" appear to be based on the work of Gibson in 1937 who learned that fat people have large blood volumes, but that the volume per unit of body weight was below average. It may be that fat increases the weight and body surface area, but not the need for as much more blood as would be required if the additional mass were muscle and actively functioning tissue. In the work here presented, both the actual and "adjusted to ideal weight" figures were calculated for blood volumes in centimeters per body weight and surface area.

Gibson also believed blood volume decreased with age, roughly paralleling basal metabolic rate and vital capacity. Our findings, compared with Reilly's from a younger age group, confirm the impressions of Cohn and Shoek (14) that blood volume does not significantly change as age increases.

#### SUMMARY

Blood volumes were determined for 52 men and 45 women over the age of 60. All subjects were healthy and normal. Radiochromate-tagged red cells were used to determine the blood volume. Findings indicate that blood volume relation to body weight or surface area does not change with age.

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