argument. Clinical experience of the blood bank in 9000 cases was uniformly favourable. The way is open to replace citrate, at least partially, by lactate. This could be done either maintaining the dilution as we personally prefer, or preparing a more concentrated formula, if dilution is not considered an advantage. A specific action of lactate was not found, but lactate is a good preservative for whole blood and might supersede citrate in the future.

References


The Immediate Collection Damage to Red Cells*

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The damage sustained by red cells during the process of collection and storage of blood results from two orders of lesions: the first is the sudden and complex physico-chemical change in the environment, which is followed by a slower biological deterioration, resulting from continuance of metabolic activity in vitro. This activity progressively exhausts components essential to the maintenance of the dynamic requirements of the red cells.

In a series of 35 autotransfusions of blood collected with ACD solution (NIH formula A) as anticoagulant and transfused within one hour of collection the average loss of radioactivity of red cells tagged with Cr51 during the first day after transfusion is 6.4%. From the second to the tenth posttransfusion day this apparent loss is constant and averages 2.2%/diem, resulting in a linear disappearance curve (fig. 1). Mollison et al.1 found a similar excessive loss of radioactivity of Cr81 tagged transfused cells in the first day post transfusion. These authors favor the hypothesis that the loss is only apparent, and is due to loss of Cr51 and not destruction of cells. Since a similar phenomenon is noted when red cell survival is determined with the

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differential agglutination method we consider justified attributing the loss of radioactivity to actual loss of red cells from circulation. This phenomenon is readily understood when the cells transfused are altered because of prolonged storage or because of a pathological condition affecting the red cells, i.e. congenital hemolytic diseases, acquired hemolytic humoral factors, etc. It is less readily explained when it occurs following autotransfusion of fresh normal cells.

We may consider the excess loss of red cells transfused immediately after collection as possibly due to at least three causes. Firstly, to removal of blood samples for determination of the blood volume and the immediate posttransfusion survival of red cells. This loss varies with the technical procedure employed for the determination of the blood volume, and in the experimental work here presented it varied from 0.4 to 2%.

Secondly, a number of cells reach daily the limit of their life span, and are removed from circulation. This expected normal loss is conventionally estimated at 0.83%.

Thirdly, the damage which some cells receive during the process of removal, chromation and transfusion predisposes them for rapid removal from circulation. Correcting for sampling losses (av. 1.2%); normal expected loss (0.83%) and for elution (estimated for the first ten days at 1.37%) we may assume that under the experimental conditions 3% of the total transfused red cells are lost in the first 24 hours in excess of the average daily losses for the subsequent ten-day period.

Although we speak of loss during the first 24 hours, actually most of the damaged cells are removed from circulation very rapidly after transfusion. Thus blood collected in ACD solution in plain glass containers and transfused after 28 days of storage at 5°C may lose, in 30 minutes posttransfusion, as much as 33.7% of red cell radioactivity (fig. 2). At 24 hours the loss increases to 51.7%. The remaining radioactivity disappears at a rate somewhat less rapid than that prevailing when fresh cells are transfused.

Of the factors contributing to the immediate damage and immediate posttransfusion loss of red cells, several have been previously investigated and discussed. Amongst these factors are the properties of surfaces of containers and the rate of
cooling. Strict control of the rate of cooling has contributed to the reduction of the immediate damage to red cells. But, surprisingly, the use of apparatus with nonwettable surfaces, particularly plastic, which produces a distinct beneficial effect on the overall posttransfusion survival of red cells stored for periods of 24 hours or more, has had doubtful effect in reducing the excess loss of fresh red cells during the first day posttransfusion (fig. 1 and table I).

Table I

Apparent Survival 24 Hours Post-Transfusion of 35 Units of CrB1 Tagged Red Cells, Autotransfused
Immediately after Collection in ACD Solution Using Various Types of Containers

We wish at this time to describe the effect of the low initial pH of the anticoagulant preservative solution on the red cells during collection.

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The pH of the acid-citrate-dextrose solution varies from 4.95 to 5.05. When red cells are introduced in this acid medium swelling occurs, which is due mostly to increased ionization of the hemoglobin. Part of the swelling is due also to the fact that most ACD solutions, such as ACD NIH formula A, with a volume of 75 ml, are hypotonic. Far more hypotonic are ACD solutions with a higher volume of fluid. The hypotonicity can be readily corrected by reducing the volume of the anticoagulant mixture. Dextrose concentration also plays an important role in the final size of red cells; this effect will not be considered at this time.

Figure 3 shows the relationship between the pH, the volume of collected blood and the M.C.V. of red cells. In this experiment 500 ml of blood were obtained at the constant rate of 100 ml/minute and mixed by gentle agitation with 75 ml of ACD solution NIH formula A in plain glass container. It will be noted that the M.C.V. of the cells increases rapidly to a maximum of nearly 112 cu micra, recorded at 2 minutes after initiation of bleeding, when 200 ml of blood have been collected. At this time the pH is 6.4.

Fig. 3. pH and M. C.V. during collection of blood in ACD solution.

After this period the mean corpuscular volume diminishes, until at the end of the collection it is about 104 cu micra.

The determination of the red cells diameter during the process of collection indicates that the immersion in an acid medium causes a considerable change in the distribution pattern of red cell size (fig. 4).

The normal mode of 7.8 micra for red cells of double oxalated venous blood increases to 8.7 micra, when 100 ml of blood are collected in ACD solution during
one minute, and the pH is about 6.0. At the end of collection of 500 ml of blood the pH is 7 and the mode becomes 8 micra.

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Fig. 4. Diameter of erythrocytes of blood collected in ACD solution.

Even more suggestive of the alteration sustained by cells is the spread of the pattern of distribution of red cells towards the larger size, some cells measuring between 9.5 and 10.5 micra in diameter. It would appear not unlikely that some cells thus altered in size and shape are immediately trapped and removed from circulation; it could also be expected that the damage due to the high initial acidity, which we may indicate as acid shock, may also affect the overall survival of red cells.

Attempts have been made to reduce the initial loss of red cells by collecting the blood in a neutral citrate solution and by adding later on to the plasma, separated by light centrifugation, the necessary amount of citric acid and dextrose and finally mixing the acidified plasma with the red cells. So far these attempts have brought no change in the survival rate of red cells during the first 24 hours posttransfusion. The damage sustained by the red cells by the excessive acidity of the medium becomes evident when the amount of blood collected is out of proportion to the total amount of ACD. The permanence in such solution results in considerable damage to red cells; more exactly: it has been our experience that the posttransfusion survival of red cells obtained with collection of 350 ml of blood or less, in a volume of ACD intended for the collection of 500 ml of blood, is considerably less than the survival of cells from units of blood measuring 400 ml or more*.

* Since the presentation of this paper at the Sixth Congress of the International Society of Blood Transfusion, Gibson et al. 6 have reported results similar to those obtained by us.

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These observations recommend the use of a volume of acid anticoagulant solution proportional to the expected volume of blood. When the amount of blood collected is out of proportion to the volume of anticoagulant, the storage of such units should be reduced to a minimum.

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