Replacement for Intraoperative Blood Loss

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While whole blood has long been considered the "ideal" replacement for blood loss, the hazards, expense, and scarcity of whole blood prompt a search for suitable fluid replacement during surgical blood loss. Because of rapid equilibration across capillary membranes, only a fraction of infused isotonic crystalloid solutions remains in circulation for clinically useful periods. Isovolemic hemodilution may be reliably achieved with one of two types of colloid solutions: blood products (albumin, plasma protein fraction—hereafter referred to simply as plasma) or nonprotein colloidal suspensions (dextran and cellulose). There are large differences in the costs of these fluids. In our hospital costs to the patient range from $10 a liter for dextran to $240 a liter for plasma. Therefore, we designed a prospective study of deliberate, elective, intraoperative hemodilution to compare the clinical effectiveness of plasma or dextran-75 hemodilution with whole-blood replacement.

Our basic assumption was that the most successful therapy would minimize the total number of transfusions of whole blood administered to patients in the perioperative period. Although a larger study was anticipated, we were surprised to find, after analysis of the pilot study, that plasma replacement was superior to either dextran-75 or whole-blood replacement by these criteria.

Twenty-seven patients less than 70 years old were studied while undergoing elective total hip arthroplasty under the care of one of three surgical teams (two board-certified senior orthopedic surgeons and one resident training service). The patients had no significant cardiorespiratory disease, and their hemoglobin concentrations preoperatively were normal. We randomly assigned the fluids used for initial replacement from a balanced block design so that three patients from each service received each of the three replacements: whole blood, plasma, and dextran-75. The anesthetic management was usually continuous hypobaric catheter spinal analgesia with the patient in the lateral position, with intravenous administration of sedatives to provide light sedation.[1] Two patients in each group received general anesthesia with nitrous oxide–oxygen and *d*-tubocurarine with controlled respiration. The surgical techniques varied but slightly, consistent with the decision to use one of three different prosthetic devices. All wounds were drained through two Hemovac catheters inserted during wound closure. Preoperative hemoglobin and hematocrit measurements were performed on the morning of operation. Blood volumes were estimated from sex and body habitus[2] (table 1). ^{131}I-albumin dilution measurements of blood volumes of 12 of the 27 patients were made and results were generally in accord with the estimated volumes. Knowledge of the absolute blood volume was not essential to the design or analysis of the study.

TABLE 1. Blood Volume Estimates for Healthy Patients as Percentage of Body Weight*

	Obese	Thin	Normal	Muscular
Male	6.0	6.5	7.0	7.5
Female	5.5	6.0	6.5	7.0

* Adapted from Moore.[2]

Isovolemic hemodilution was carried out by initially replacing the blood loss, milliliter for milliliter, with plasma or dextran-75 until hemoglobin and hematocrit were decreased to 10 g/100 ml and 30 per cent, respectively. Blood loss was calculated by adding the amounts measured in the suction bottles, weighed on the sponges, and estimated on the drapes. Following the allowable hemodilution in the two groups, or soon after the incision in the blood-replacement

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group, operative blood loss was replaced, milliliter for milliliter, with whole bank blood. In addition, the patients received variable fractions of their daily fluid requirements as 5 per cent dextrose in water or in half-physiologic saline solution, physiologic saline solution, or balanced salt solutions.

Following operation, the patients were seen daily by one of us (TK) for at least five days, and intermittently thereafter until discharged. Information on hemoglobin or hematocrit, other laboratory data, blood loss through drainage, other fluid intake and output, whole blood transfusions prescribed and received, and any complications was collected.

All colloid volume expanders were infused intraoperatively. Whole-blood therapy was administered in the operating room after the target hemodilution had been obtained, in the recovery room when documented blood loss was noted or major signs of hypovolemia were present, and in the postoperative period for a variety of indications not always noted on the hospital record by the prescribing physicians. The latter indications generally included afebrile tachycardia, orthostatic hypotension, notable complaints of weakness, and hemoglobin or hematocrit values below 9 g/100 ml or 27 per cent, respectively.

Statistical analysis consisted of non-paired two-tailed Student's t tests, accepting $P < 0.05$ as significant.

Results

The three groups of patients were similar in age, sex, height, weight, and preoperative hemoglobin.

The group that received blood from the start of operation averaged 1 liter of blood loss and received two blood transfusions and approximately 2 liters of clear fluids intraoperatively. About half of the patients received an additional blood transfusion in the immediate convalescent period. The average decrease of hemoglobin values was 3.5 g/100 ml (table 2).

Blood loss in the dextran group was nearly twice that experienced in the blood-replacement group. We were unable to discern any cause for this increased bleeding associated with the surgical dissection, complicated pathology, abnormal blood clotting tests, or gross prolongation of operative time. This supports the impression of our surgeons that dextran replacement tends to increase operative oozing. The difference in blood loss was statistically significant. In addition to losing more blood, this group experienced a greater decrease in hemoglobin concentration, 5.6 g/100 ml on the average, in spite of receiving almost the same amount of transfused blood in the total perioperative period. Four of the patients required blood intraoperatively, and one of these and three others required blood postoperatively.

The estimated blood loss in the plasma-replacement group was intermediate between the losses in the blood and dextran groups and not significantly different from either. The average decrease in hemoglobin was also intermediate. Four patients received no blood at all. Three others had but a single transfusion. One case presented operative difficulties to the surgeon, resulting in a measured loss of 5 liters of blood which was replaced with 7 units of blood after 1,750 ml of plasma protein fractions.

Because blood losses were not normally distributed in any of the three groups, we compared median losses as well as average losses (table 1). One patient of the plasma-replacement group who represented exceptional surgical difficulty and bleeding was responsible for elevating the average out of proportion to the median. This is also reflected by a large standard error of mean loss.

If there was morbidity or other costs or risks of our deliberate hemodilution, it was not evident. There were no complications in either of the two hemodiluted groups compared with the control group.

Discussion

This study was planned as a pilot experiment to determine the risk/reward ratio of several replacement therapies, championed both locally and in the current literature. We considered the results sufficiently clear-cut as to obviate the need for a larger study.

Our current practice is based on these results. For patients of A.S.A. physical status 1 or 2, an initial hemodilution to approximately 10 g/100 ml of hemoglobin is achieved by replacing blood loss, milliliter for milliliter, with plasma protein fraction or 5 per cent albumin in saline solution. The volume of plasma needed to reach this hemoglobin concentration is estimated from the formula:

TABLE 2. Blood Losses and Hemoglobin Concentrations in Groups Receiving Various Replacement Therapies during Hip Operations

		Initial Replacement Fluid		
		Blood	Dextran	Plasma
Number of patients		9	9	9
Operative blood loss (ml)				
On sponges		465	700	595
In suction		250	575	500
On drapes		135	280	255
TOTAL	Mean	850	1,550	1,350
	SE	± 125	± 290	± 470
	Median	795	1,125	900
Hemovac drainage	Mean	135	190	44
Total known blood loss	Mean	985	1,745*	1,395
	Median	945	1,315	945
Hemoglobin, mean ± SE (g/100 ml)				
Preoperative		13.6 ± 0.8	14.1 ± 0.4	14.7 ± 0.3
Operative evening		11.3 ± 0.7	9.6 ± 0.2	10.6 ± 0.5
Lowest postoperative	Mean	10.4 ± 0.6	8.4 ± 0.7	9.9 ± 0.5
	Median	10.2	9.1	9.7
Total blood transfusions (units)		22	21	13*
Number of patients not transfused		0	2	4*

* $P < 0.05$ compared with blood-replacement group.

$$EBV \times \frac{Hb - 10}{Hb} \quad \text{or} \quad EBV \times \frac{Hct - 30}{Hct}$$

(EBV = estimated blood volume).

As much as 500 ml of the initial replacement fluid may consist of dextran (40 or 75) if the surgeon wishes to incorporate this in a program of prophylaxis against phlebitis. Further blood loss is replaced, milliliter for milliliter, as it occurs, so that when the patient arrives in the recovery room the blood volume is as near normal as possible. That this can be achieved is attested to by the narrow range of postoperative hemoglobin values (9.0 to 11.0 g/100 ml), and the stability of the average hemoglobin in the first five postoperative days (range 8.5 to 10.8 g/100 ml). We expect to save nearly half the patients the risk of blood transfusion, while assuring a state of normovolemia, and tolerance of hidden bleeding, opioids and other medications which alter hemodynamics. The patients receive iron supplementation postoperatively to aid restoring normal hemoglobin concentration.

We designed this study based on reports that dextran does not alter clotting function in doses below 20 ml/kg; we confirmed, however, a strongly held clinical impression that 15 ml/kg of dextran-75 increases oozing intra- and postoperatively. The initial monetary saving afforded by dextran hemodilution is quickly expended in the need for whole blood thereafter. The plasma-replacement patients incur greater costs for their hemodilution, but many are saved the risk of transfusion.

In summary, when plasma is used for initial blood replacement the patient is likely to be spared at least one transfusion and will not become comparatively more anemic. In contrast, dextran replacement is associated with a greater likelihood of blood loss and a slightly larger dilutional anemia, and in the end will probably receive the same number of transfusions as those given blood from the onset.

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