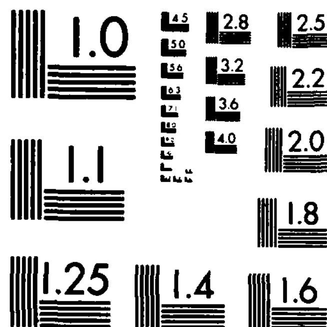
AD-A134 262 BLOOD PRESERVATION STUDY(U) SCRIPPS CLINIC AND RESEARCH FOUNDATION LA JOLLA CA E BEUTLER JAN 81 DAMD17-79-C-9071 1/1

UNCLASSIFIED F/G 6/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(8)

A134262

DTIC FILE COPY

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

Blood Preservation Study

5. TYPE OF REPORT & PERIOD COVERED

Annual Report (January 1980-December 1980)

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

Ernest Beutler, M.D.

8. CONTRACT OR GRANT NUMBER(s)

DAMD17-79-C-9071

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Scripps Clinic and Research Foundation
LaJolla, California 92037

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

62772A.3S162772A874.AD.133

11. CONTROLLING OFFICE NAME AND ADDRESS

US Army Medical Research and Development Command
Fort Detrick
Frederick, Maryland 21701

12. REPORT DATE

January 1981

13. NUMBER OF PAGES

20 pages

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release: Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE NOV 0 1 1983 S E

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Red cell Preservation Adenine

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews progress made under contract DAMD17-79-C-9071. Investigations were carried out on red cells stored in CPDA-2 including: estimations of osmotic fragility of stored RBCs before & after reinfusion into volunteer donors. BAGPM was studied as a preservative medium to improve red cell viability. Storage of platelets made from blood collected in CPD adenine preservatives was studied.

For the protection of human subjects the investigator has adhered to policies of applicable Federal Law 45CFR46.

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

BLOOD PRESERVATION STUDY

ANNUAL PROGRESS REPORT

January 1981

E. BEUTLER

Supported by

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND

FORT DETRICK, FREDERICK, MARYLAND 21701

Contract No. DAMD17-79-C-9071

Scripps Clinic and Research Foundation

10666 North Torrey Pines Road

La Jolla, California 92037

DOD Distribution Statement

Approved for public release: Distribution unlimited

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

TABLE OF CONTENTS

	Page
1. Study of blood stored in CPD and in modified solutions containing adenine	2
1.1. Background	2
1.2. Progress during current period (Jan 80-Dec 80)	3
1.2.1. Biochemical studies	3
1.2.2. Auxiliary studies	4
1.2.2.1. Studies of osmotic fragility	4
1.2.2.2. Studies of complement binding	5
1.2.2.3. Studies of deformability	5
2. Studies with BAGPM	5
2.1. Background	5
2.2. Studies performed (Jan 80-Dec 80)	7
3. Studies of platelet storage	7
3.1. Background	7
3.2. Progress during current period (Jan 80-Dec 80)	8
4. Publications	9
Table I	10
Table II	11
Table III	12
Table IV	13
Table V	14
References	15-16
Distribution list	17

1. Study of blood stored in CPD and in modified CPD solutions containing adenine.

1.1. Background

CPD (citrate-phosphate-dextrose) has been routinely used as the standard medium for preservation of blood for many years. Red cells from blood which has been collected in CPD can only be stored for 21 days. After this, they are no longer sufficiently viable for transfusion. It has been clearly established that the addition of adenine to CPD preservative solution prolongs the length of time that red cells may be stored to 35 or 42 days (1). Moreover, higher concentrations of glucose than those present in CPD are required to sustain red cell concentrates for prolonged periods of time in adenine-containing media (2).

CPD-A1 contains a 1.25 times the glucose content of CPD and sufficient adenine to provide a concentration of 0.25 mM in the blood-preservative mixture. Higher glucose concentrations were not incorporated into this preservative because of the existence of anecdotal reports that high glucose concentrations increased the rate of fall of the pH of platelet concentrates. CPD-A1 was studied by a cooperative group (3) with the demonstration that red cells from whole blood stored for 35 days had viability of 80.53 $\pm$ 6.44% (x $\pm$ 1 S.D.) while red cell concentrates with a hematocrit averaging 75% had a mean viability of 71.38 $\pm$ 10.3% (x $\pm$ 1 S.D.). After these studies were concluded, it was discovered that the manufacturer of the blood bags had inadvertently prepared the bags used from an obsolete plastic film, PL 130, rather than the new plastic formulation, PL 146, which had been intended. These studies have now been repeated in PL 146, with results quite similar to those

obtained in PL 130. In both their series of studies, it was observed that most or all of the glucose was exhausted from cells in some units packed at hematocrits of 75 ± 5% and stored for 35 days. There is reason for concern that under field conditions, where the storage temperature may sometimes rise to higher than 4° and where packing of the red cells, a parameter which is difficult to control, may frequently exceed 80%, that CPD-A1 may prove to be suboptimal for the storage of red blood cells. In the meantime, it has become clear that higher glucose concentrations do not harm platelets. For this reason, two new preservatives, believed to represent improved formulations for storage of cell concentrates have been devised and manufactured by Fenwal Laboratories. These formulations, designated CPD-A2 and CPD-A3 contain respectively 1.75 and 2.00 times the amount of glucose present in CPD and sufficient adenine to provide a concentration of 0.5 mM in the blood-preservative mixture.

Data which have been accumulated over the past 15 years clearly indicate that ATP levels are a disappointing parameter with respect to predicting the viability of stored red cells (4-7). We have also been attempting to identify measurements which may prove to be more useful than ATP in predicting whether or not a given storage system provides red cells which will be viable on reinfusion.

1.2. Progress in current period (January 1980 through December 1980).

1.2.1. Biochemical studies and studies of viability of stored cells.

450 ml of blood has been collected from each of 13 volunteer donors. After an 8-hour holding period at room temperature the red cells were packed to a hematocrit of 80% and stored at 4°C for 42 days without agitation. The first five units were stored in a lying position; the

storage position of the subsequent 8 units was alternated between lying and standing. Viability studies were carried out on 11 of the 13 units. One unit was spuriously reported to be contaminated and was therefore not reinfused, and one donor withdrew her consent to participate in the study. The results of biochemical studies and of the viability of the units is summarized in Table I.

1.2.2. Auxiliary studies.

In the course of these investigations various auxiliary studies were undertaken to aid in better definition of the "storage lesion."

1.2.2.1. Studies of osmotic fragility.

The osmotic fragility of stored red cells was investigated both before and after reinfusion into volunteer donors. The osmotic fragility of red cells stored in CPD-A2 was found to be greatly increased when measured directly by estimating lysis in graded phosphate-buffered salt solutions. Much of this increase in osmotic fragility was found to be due, however, to the accumulation of lactate in the stored cells. Lactate leaves red cells only slowly and therefore exerts a marked osmotic effect. When stored red cells were pre-equilibrated with isotonic sodium chloride solutions until the lactate had been removed from the cells the osmotic fragility was increased to a much smaller extent. However, a "tail" of osmotically fragile cells could still be detected. Studies to determine the fate of these cells were performed by devising a method of sequential hemolysis which permitted us to measure the osmotic fragility of the reinfused cells using the release of ^{51}Cr from the labeled cells as an indicator of hemolysis. These investigations

demonstrated that the osmotic fragility of stored cells rapidly returns to normal after their reinfusion into the circulation. The normalization of the osmotic fragility of reinfused cells does not apparently depend principally upon removal of the most fragile cells, but rather on correction of the increased osmotic fragility of cells in the circulation. It is postulated that this correction is due to transfer of osmotically active substances from the red cell after re-infusion.

1.2.2.2. Studies of complement binding.

According to Dr. I. Szymanski, the binding of complement to red cells may prove to be a useful predictor or viability. In the course of some of the viability studies which have been carried out red cells have been frozen in glycerol according to Dr. Szymanski's instructions and have been shipped to her for study.

1.2.2.3. Studies of deformability

The measurement of erythrocyte deformability by use of the ektocytometer has been pioneered by Mohandas and Bessis. Recently, Mohandas has instituted certain marked improvements in this technology. Samples of blood samples which were studied for viability have been shipped to Dr. Mohandas in San Francisco for measurements of deformability using the ektocytometer.

2. Studies with BAGPM

2.1 Background

BAGPM is a bicarbonate-containing preservative medium designed in this laboratory (8,9) for the purpose of maintaining viability and

2,3-DPG levels of packed red cells in a superior fashion. Presumably because of the removal of platelets, granulocytes and fibrinogen, the system minimizes formation of microaggregates (8). The excellent 2,3-DPG preservation observed depends upon buffering of the stored cells with bicarbonate with loss of CO_2 from the system. This can be accomplished either by using containers made from a very permeable plastic film or by introducing into the bags an efficient CO_2 absorbing system. Our investigations suggest that calcium hydroxide, either in small sialastic ("baggies") or embedded in sialastic blocks ("blockies"), might be suitable internal CO_2 absorbing devices.

In earlier studies it was demonstrated that $Ca(OH)_2$ added to blood produced marked hemolysis. Hence, leakage of calcium hydroxide from the sialastic membrane "baggie" constituted a serious potential hazard. Therefore, the use of calcium hydroxide embedded sialastic blockies of 3 x 3 x 1 cm size were studied as replacements of the old baggies.

Investigations with varying amounts of calcium hydroxide showed that 6 g calcium hydroxide was the most satisfactory amount to provide adequate preservation of 2,3-DPG without compromising the levels of ATP. It was observed initially that calcium hydroxide shed from the raw surfaces when stored at room temperature in ACD and to some extent also in CPD. These difficulties were accentuated after autoclaving in ACD. They were overcome by providing a coating of liquid silicone rubber over the surface of the "blockie."

Recently, Högman and his colleagues have introduced a solution for the storage of red cells, designated SAG (i.e., saline-adenine-glucose) (10). The use of this solution would seem to us to be a retrogressive step (11) because it does little more than to provide additional glucose

to the cells and to reduce the viscosity of the cell suspension. BAGPM, in contrast, provides excellent maintenance of 2,3-DPG levels.

2.2 Studies Performed (January 1980 through December 1980)

Unfortunately, no further studies of BAGPM have been carried out in the current contract period. We have been in continued touch with Fenwal Laboratories but have been unable to obtain from them suitable packs containing CPD and a calcium hydroxide impregnated "blockie" in the primary pack and satellites containing BAGPM. Various technical obstacles have been overcome by Fenwal but their progress in providing the needed materials to us has been painfully slow.

3. Studies of platelet storage.

3.1 Background

The transfusion of platelets has become an important part of the clinical practice of medicine. Platelets, unlike red cells, can only be maintained in storage for up to 72 hours. Little is known about the factors which limit the storageability of platelets. Although there are a number of relatively minor changes in the level enzymatic activities of metabolic intermediates in stored platelets (12,13) none of these seem to decline as abruptly at 72 hours as does the viability of reinfused platelets. Of all of the parameters of platelet storage which have been investigated, pH appears to correlate most closely with post-storage viability (14). In our studies of platelet preservation in CPD solutions containing various amounts of glucose we observed that there was a correlation between the rate of fall of pH and the number of residual white cells in the platelet preparations (15).

The purpose of the studies described below was to more accurately appraise the effect of leukocyte contamination on platelet storage and to determine whether practical means could be devised to maintain platelet pH by removing white cells from the platelet preparations.

3.2 Progress in the current period (January 1980 through December 1980)

Extensive investigations have been carried out to determi the best conditions for removal of leukocytes from platelets durin orage and to measure the effect of leukocyte removal on pH of the st platelets. It was found that centrifuging platelet rich plasma 500 g for 5 minutes resulted in removal of 80 to 90% of the leukocytes with loss of 10 to 20% of the platelets. Centrifuging at appreciably higher speeds or for longer periods of time resulted in greater platelet loss while lower centrifuge speeds or shorter times of centrifugation resulted in less complete leukocyte removal (Table II). The fall in pH and lactate production of platelet concentrates prepared from such treated and control (untreated) plasmas were investigated (see Tables III and IV, V). Although the fall in pH appeared to be less when leukocyte numbers were decreased, the differences observed were relatively slight and it was felt that the loss of platelets and extra labor involved in preparing leukocyte-poor platelet preparations probably did not represent an acceptable means for prolonging platelet storage.

4. Publications

The following publications supported, in part, by this contract, appeared during 1980:

Beutler E, West C: An Improved Assay and some Properties of Phosphoglycolate Phosphatase. Anal Biochem. 106:163-168, 1980.

Beutler E, Kuhl W: Guanosine Triphosphatase Activity in Human Erythrocyte Membranes. Biochim Biophys Acta, 601:372-379, 1980.

Beutler E, Kuhl W: Platelet Glycolysis in Platelet Storage: IV. The Effect of Supplemental Glucose and Adenine. Transfusion, 20:97-100, 1980.

TABLE I - RESULTS OF BIOCHEMICAL AND RE-INFUSION STUDIES PERFORMED ON BLOOD COLLECTED FROM 13 DONORS AND STORED IN CPD-A_2

Donor	Day	MB	CC	WC	JS	MG	LP	DR	PG	AM	RP	PN	KL	TB
Storage Position (L = Lying, S = Standing)		L	L	L	L	L	L	L	L	L	S	S	S	S
24 hr Viability (%)	42	93.6	90.1	81.4	90.4	87.9	-	-	78.9	75.1	85.4	79.2	81.6	75.6
Hematocrit (%)	0	35	39	35	39	36	34	39	29	33.5	37	34	41	43
	42	80	78	80	81	80	84.5	80.3	80	81	85	80	81	80.8
Glucose (mg %)	0	549	589	587	599	590	553	517	531	598	526	534	566	564
	42	97	137	148	127	115	95	76	124	79	127	129	146	153
ATP (μ Moles per gm Hb)	0	5.03	4.05	3.80	4.60	4.20	4.71	4.48	3.87	4.16	4.89	3.86	4.49	4.40
	42	3.61	3.71	2.38	3.22	3.27	3.56	3.62	1.68	2.07	3.71	2.55	2.96	2.30
2,3 DPG (μ Moles per gm Hb)	0	14.9	11.2	12.8	14.6	11.6	12.5	14.3	11.1	10.0	13.0	13.7	10.2	14.0
	42	0.3	0.2	0.1	0.3	0.3	0.1	0.1	0.2	0.1	0.5	0.2	0.2	0.1
Plasma Hb (mg %)	0	14	15	17	19	10	12	26	10	7	11	10	20	21
	42	420	268	720	860	910	2263	264	613	1875	2775	2263	1750	1568
pH (4°C)	0	7.57	7.61	7.57	7.63	7.58	7.61	7.51	7.43	7.50	7.74	7.53	7.55	7.62
	42	6.81	6.92	6.87	6.87	6.92	6.91	6.78	6.76	6.82	6.77	6.79	6.78	6.83
Na^+ (mM)	0	169	174	170	171	174	181	171	166	170	182	172	176	174
	42	94	109	97	87	92	77	83	76	80	75	80	81	82
K^+ (mM)	0	3.3	3.1	3.4	3.3	3.3	3.9.	3.6	3.2	3.3	3.3	3.6	3.3	3.3
	42	97	83	94	100	92	117	104	102	98	114	98	102	102

TABLE II

THE EFFECT OF CONDITIONS OF CENTRIFUGATION OF PLATELET-RICH PLASMA (PRP) ON LEUKOCYTE AND PLATELET YIELD

WBC Platelet count	235 300×10^3	300 g; 5 min	80 210×10^3	34 70	305 $1,150 \times 10^3$
WBC Platelet count	265 420×10^3	400 g; 5 min	70 330×10^3	26 78	270 $1,590 \times 10^3$
WBC Platelet count	304 336×10^3	500 g; 5 min	40 347×10^3	13.1 103	40 790×10^3
WBC Platelet count	1215 400×10^3	500 g; 5 min	30 310×10^3	2.4 77.5	80 $1,350 \times 10^3$
WBC Platelet count	1520 375×10^3	500 g; 5 min	30 334×10^3	1.9 89.0	60 713×10^3
WBC Platelet count	210 188×10^3	500 g; 5 min	30 202×10^3	14.2 107	125 534×10^3
WBC Platelet count	395 352×10^3	500 g; 5 min	25 282×10^3	6.3 80.1	45 $1,492 \times 10^3$
WBC Platelet count	765 608×10^3	600 g; 5 min	75 341×10^3	9.8 56.0	135 $1,280 \times 10^3$
WBC Platelet count	680 475×10^3	600 g; 5 min	15 270×10^3	2.2 56.8	60 $1,170 \times 10^3$

TABLE III. CHANGES IN LACTATE CONCENTRATION IN STORED PLATELET CONCENTRATES WITH VARYING LEUKOCYTE COUNTS

E; additional centrifugation to remove leukocytes.
C; control, with no extra centrifugation.

Subject	$\frac{WBC}{mm^3}$	Platelets $\times 10^3/mm^3$	Volume (ml) platelet Concentrate	µMoles Lactate/ml platelet concentrate — Day 0	1	2	3	4	5	6	7	8
G. H. (E)	60	713	60	1.06	2.39	2.128	4.18	6.689	-	-	-	-
C. S. (C)	200	871	60	1.78	4.57	5.58	7.07	-	-	-	-	-
												Day 11
P. M. (C)	1,310	832	60	1.13	2.34	3.19	4.65	5.75	6.71	12.44	-	12.2
C. S. (E)	125	534	60	.97	1.75	2.39	2.89	3.68	3.69	8.6	-	5.98
C. W. (E)	20	202	25	1.09	2.04	2.92	4.48	5.23	5.56	15.16	-	-
									Day 6	9		11
V. W. (C)	1,385	1,386	60	.917	3.83	7.81	9.36	11.76	12.2	17.2	-	21.3
S. Y. (E)	255	538	60	1.077	1.81	2.77	3.28	3.86	3.99	6.6	-	7.47
D. A. (C)	2,575	2,780	25	3.35	6.87	10.85	13.44	16.48	15.06	20.3	-	24.65
S. H. (E)	45	1,498	25	1.96	3.63	5.94	7.28	8.43	12.4	17.95	-	23.58
D. G. (C)	3260	1,334	34.5	1.45	4.09	5.71	7.73	-	11.7	-	14.56	15.61
G. B. (E)	60	1,495	51.85	1.48	3.29	5.02	6.83	-	9.95	-	13.55	14.14
E. C. (C)	2,573	1,162	61.0	1.13	2.5	3.2	4.88	-	7.15	-	10.13	11.12
C. S. (E)	55	1,045	65.7	.665	1.7	2.85	4.45	-	5.97	-	9.23	11.55

TABLE IV. pH CHANGES IN STORED PLATELET CONCENTRATES WITH VARYING LEUKOCYTE COUNTS

E; additional centrifugation to remove leukocytes.
C; control, with no extra centrifugation.

Subject	$\frac{WBC}{mm^3}$	Platelets $\times 10^3/mm^3$	Volume (ml) platelet Concentrate	pH, Day 0	1	2	3	4	5	6	7	8
G.H. (E)	60	713	60	7.19	7.18	7.26	7.22	7.23	-	-	7.18	-
C.S. (C)	200	871	60	7.13	6.94	7.1	7.12	-	-	-	-	-
P.M. (C)	1,310	832	60	7.12	7.22	7.19	7.34	7.22	7.3	7.34	-	7.42
C.S. (E)	125	534	60	7.2	7.25	7.28	7.49	7.39	7.5	7.58	-	7.83
C.W. (E)	20	202	25	7.2	7.37	7.42	7.69	7.6	7.7	7.59	-	7.82
									Day 6	9	10	11
V.W. (C)	1,385	1,386	60	7.20	7.04	6.93	6.86	6.84	6.76	6.42	6.56	6.35
S.Y. (E)	255	538	60	7.28	7.35	7.42	7.44	7.49	7.51	7.58	7.65	7.65
D.A. (C)	2,575	2,780	25	7.11	7.0	7.02	6.94	6.95	6.75	6.37	6.25	6.13
S.H. (E)	45	1,498	25	7.24	7.22	7.24	7.27	7.21	7.01	6.67	6.54	6.42
D.G. (C)	3260	1.334	34.5	7.17	7.16	7.23	7.24	-	7.23	-	7.13	7.09
G.B. (E)	60	1,495	51.85	7.19	7.16	7.13	7.10	-	7.08	-	6.99	6.92
E.C. (C)	2,573	1,162	61.0	7.2	7.19	7.19	7.19	-	7.2	-	7.12	7.10
C.S. (E)	55	1,045	65.7	7.19	7.2	7.22	7.21	-	7.21	-	7.10	7.08

TABLE V. CHANGES IN pH AND LACTATE CONCENTRATION IN STORED PLATELET CONCENTRATES WITH VARYING LEUKOCYTE COUNTS

Lactate and pH change in stored platelet concentrates
E; additional centrifugation to remove leukocytes
C; control, with no extra centrifugation.

Subject	WBC	Platelets	Volume (ml) platelet	pH, Day							µmoles Lactate/ml concentrate Day						
	mm^3	$x 10^3/mm^3$	Concentrate	1	2	3	4	5	6	7	1	2	3	4	5	6	7
G.H. (C)	7,000	1,062	70	7.6	7.06	7.01	7.0	6.88	-	6.91	3.24	2.54	4.22	9.42	15.6	-	13.6
S.W. (E)	250	955	62	7.3	7.2	7.4	7.4	7.3	-	7.2	1.04	1.54	2.29	3.38	6.88	-	7.11
D.A. (C)	7,226	242	48	7.3	6.84	6.36	5.9	5.76	-	5.74	-	-	18.82	23.3	17.19	-	18.67
G.B. (C)	1,086	3,133	43	7.2	7.14	6.93	6.93	7.03	-	6.96	-	-	10.48	12.31	13.63	-	14.8
S.H. (E)	170	1,156	47	7.27	7.25	7.32	7.33	7.34	-	7.25	-	-	6.68	5.3	7.99	-	10.27
L.T. (E)	40	1,545	48	7.23	7.03	7.02	7.03	7.08	-	7.05	-	-	5.03	9.03	9.16	-	11.99
S.D. (C)	730	2,667	43	7.17	7.04	6.98	-	-	-	-	2.06	5.88	9.35	-	-	-	-
E.G. (E)	305	1,146	54	7.36	7.41	7.51	-	-	-	-	1.52	2.09	3.11	-	-	-	-
L.S. (E)	270	1,594	48	7.35	7.32	7.36	-	-	-	-	1.22	1.25	4.36	-	-	-	-
J.L. (E)	40	790	55	7.36	7.41	7.42	7.49	-	-	7.59	1.52	2.17	2.30	3.75	-	-	5.73
D.C. (E)	80	1,350	60	7.29	7.25	7.22	7.31	-	-	7.33	1.38	2.62	3.32	-	4.81	-	7.9
D.G. (C)	2,010	1,650	42	7.22	6.96	6.82	6.78	6.78	-	-	-	-	-	-	-	-	-
S.H. (E)	135	1,280	50	7.28	7.19	7.17	7.23	7.28	-	-	-	-	-	-	-	-	-
E.V.A. (E)	60	1,170	43	7.28	7.27	7.29	7.36	7.41	-	-	-	-	-	-	-	-	-

REFERENCES

1. Simon, E.R.: Adenine in Blood Banking. Transfusion 17:317-325, 1977.
2. Bensinger, T.A., Metro, J., Beutler, E.: In Vitro Metabolism of Packed Erythrocytes Stored in CPD-Adenine. Transfusion 15:135-139, 1975.
3. Zuck, T.F., Bensinger, T.A., Peck, C.C., Chillar, R.K., Beutler, E., Button, L.N., McCurdy, P.R., Josephson, A.M., Greenwalt, T.J.: Report of a Multi-Institutional Cooperative Effort. Transfusion 17:374-382, 1977.
4. Wood, L., Beutler, E.: The Viability of Human Blood Stored in Phosphate Adenine Media. Transfusion 7:401-408, 1967.
5. Strauss, D., Meurer, W., Dekowski, D.: Verhalten Von Lebrensfähigkeit, ATP-U 2,3-DPG-Gehalt Resuspendierter Erythrozyten Während Mehrwöochiger Kältelagerung. Acta Biol Med Germ. 36:543-548, 1977.
6. Akerblom, O., Kreuger, A.: Studies on Citrate-Phosphate-Dextrose (CPD) Blood Supplemented with Adenine. Vox Sang. 29:90-100, 1975.
7. Dern, R.J., Brewer, G.J. and Wiorkowski, J.J.: Studies on the Preservation of Human Blood. II. The Relationship of Erythrocyte Adenosine Triphosphate Levels and Other In Vitro Measures to Red Cell Storageability. J Lab Clin Med. 69:968-978, 1967.
8. Chillar, R.K., Bensinger, T.A., Beutler, E.: Maintenance of Low Screen Filtration Pressure in Blood Stored in a New Liquid Medium: BAGPM. J Lab Clin Med. 89:504-508, 1977.

9. Bensinger, T.A., Chillar, R., Beutler, E.: Prolonged Maintenance of 2,3-DPG in Liquid Blood Storage: Use of an Internal CO_2 Trap to Stabilize pH. J Lab Clin Med 89:498-503, 1977.

10. Högman, C.F., Hedlound, K., Akerblom, O., and Venge, P.: Red Blood Cell Preservation in Protein-Poor Media. I. Leukocyte Enzymes as a Cause of Hemolysis. Transfusion 18:233-251, 1978.

11. Beutler, E.: Red Cell Suspensions. N Engl J Med 300:984 (Letter), 1979.

12. Tegos, C., Beutler, E.: Platelet glycolysis in platelet storage: I. The glycolytic enzymes. Transfusion 19:203-205, 1979.

13. Beutler, E., Kuhl, W., Tegos, C.: Platelet glycolysis in platelet storage: II. Levels and turnover of metabolic intermediates. Transfusion 19:467-471, 1979.

14. Murphy, S., Gardner, F.H.: Platelet storage at 22° C: Role of gas transport across plastic containers in maintenance of viability. Blood 46:209-218, 1975.

15. Beutler, E., Kuhl, W.: Platelet glycolysis in platelet storage: IV. The effect of supplemental glucose and adenine. Transfusion 20:97-100, 1980.

Distribution List

4 copies	Commander US Army Medical Research and Development Command ATTN: SGRD-RMS Fort Detrick, Frederick, MD 21701
12 copies	Defense Technical Information Center (DTIC) ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314
1 copy	Dean School of Medicine Uniformed Services University of the Health Sciences 4301 Jones Bridge Road Bethesda, MD 20014
1 copy	Commandant Academy of Health Sciences, US Army ATTN: AHS-CDM Fort Sam Houston, TX 78234
4 copies	Commander Letterman Army Institute of Research (LAIR), Bldg. 1110 ATTN: Dr. J. Ryan Neville Presidio of San Francisco, CA 94129

F