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US ARMY MEDICAL RESEARCH LABORATORY

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REPORT NO. 762

AD 656177

INVESTIGATION OF MATERIALS AND METHODS FOR AIR DELIVERY OF WHOLE BLOOD AND BLOOD PRODUCTS

(Progress Report)

by

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24 January 1968

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UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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Acknowledgment

The authors are greatly appreciative of the fine work and support given by the members of the staff of the Department of Hematology, Walter Reed Army Institute of Research, then under the direction of Colonel Crosby, and especially to SFC E7 Floyd F. Craig and the staff of the Blood Transfusion Division, US Army Medical Research Laboratory, Fort Knox, Kentucky.

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Study of Transport and Logistic Problems of
Stored Whole Blood and Blood Components
in the Military
Work Unit No. 157
Combat Surgery
Task No. 00
Combat Surgery
DA Project No. 3A025601A821

USAMRL Report No. 762
DA Project No. 3A025601A821

ABSTRACT

INVESTIGATION OF MATERIALS AND METHODS FOR AIR DELIVERY OF WHOLE BLOOD AND BLOOD PRODUCTS

OBJECTIVE

Evaluation of protective materials used during both routine and unusual military methods of transportation and delivery of blood and blood products.

METHODS

Newly designed containers and materials were compared to other standard items for shipment of blood and blood products. Physical appearance and certain chemical changes were categorized. Units were subject to a variety of methods of delivery, including free fall, free fall with forward motion, and parachute drop with forward motion--all at various heights.

RESULTS AND CONCLUSIONS

The present standard shipping box has proved reliable over the years for long-distance shipment. However, the standard unit, when subjected to such maximum stresses as free fall air drop, did not provide very good physical protection to the blood units. The use of either chute, or additional packing made of foam or air bubble material, did provide more protection. A newly developed shipping box of foam, though slightly more protective, did better with additional material. A different type of container, in the form of an air pillow, did protect the blood units in free fall delivery. However, this form of container was limited in space, holding only 1 to 5 units, did not provide any temperature protection and was not physically suitable for long-distance shipping. An additional problem was noted in that the blood bag was particularly vulnerable to trauma when cold, even in the air pillow. Similarly, the plastic unit containing frozen plasma was easily broken during shipment. However, use of the air bubble material around each unit was more protective, permitting long-term shipment of this item.

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INVESTIGATION OF MATERIALS AND METHODS FOR AIR DELIVERY OF WHOLE BLOOD AND BLOOD PRODUCTS

INTRODUCTION

Since blood transfusion therapy has become an essential part of the care of the combat casualty, there is a requirement for finding better ways of solving the continuous problem it poses in medical logistics. Most of these problems stem from the fact that blood must come from another human, it is perishable and requires special handling, including refrigeration.

In the early part of this century, whole blood was successfully used in transfusion therapy, though it could be stored for only a short time. However, it was not until World War II with the urgent need for banked blood in multiple areas that a practical collecting solution was evolved. The solution, acid-citrate-dextrose, provided useful whole blood over storage periods up to 21 days. Even with this improved solution, stored blood was better preserved if maintained undisturbed under constant and controlled refrigeration (1-4). Thus, an adequate collecting solution permitted storage but the problem of shipping remained, particularly for overseas military operations.

In considering shipment, both the unit and the blood needed to be protected from mechanical buffeting, as well as temperature variation. The protection needed has to be considered in terms of space, weight, cost, and capacity. Over the course of World War II and the Korean conflict, various box designs were refined, and a container capable of holding 9 to 18 units with recipient sets was developed (Fig. 1, next page). While such a unit is presently in use, recently other containers have been designed. Some of these are a result of further developments in insulating materials, some of which have been shown to have improved temperature control qualities (5).

In World War II, dried pooled plasma was used as a volume expander, but was replaced by whole blood as better preservation methods improved the available supply. Plastic containers have since replaced the formerly used glass containers and therapeutic approaches have advanced to take advantage of this change. Single units of fresh frozen plasma can be employed, decreasing the risk of hepatitis and leading to better preservation of labile clotting factors. Shipment of

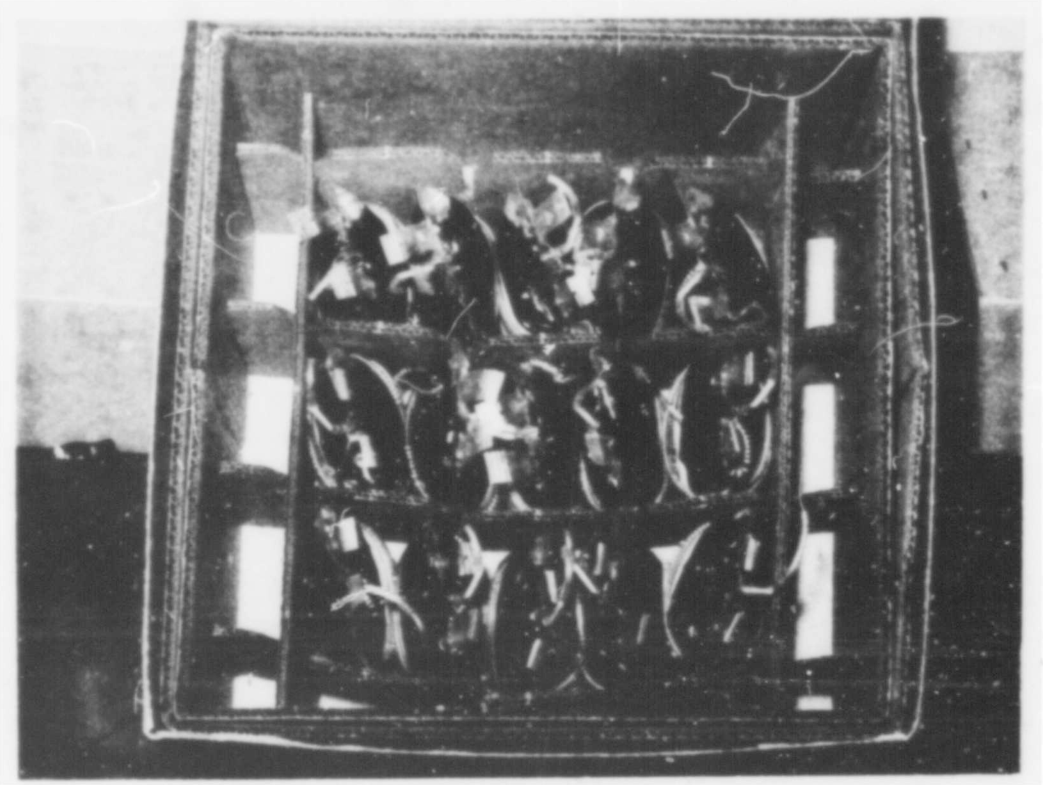

Fig. 1. Standard shipping box containing 15 units of whole blood.

these frozen products creates new logistic problems, however, in that the container does become brittle after freezing and may be damaged during transit (Fig. 2, next page).

The present study was designed to evaluate the protective effect of various materials on blood products when transported by routine delivery methods and under unusual circumstances designed to meet potential demands raised by new developments in military operations.

GENERAL BACKGROUND

Despite the obvious physical buffeting occurring during the transportation of the blood units, gross mechanical breakdown of the red blood cells is seldom observed. Early work using simple mechanical agitation did not show any immediate effects of erythrocyte damage (1), and the cell survival was not seriously altered unless refrigeration was

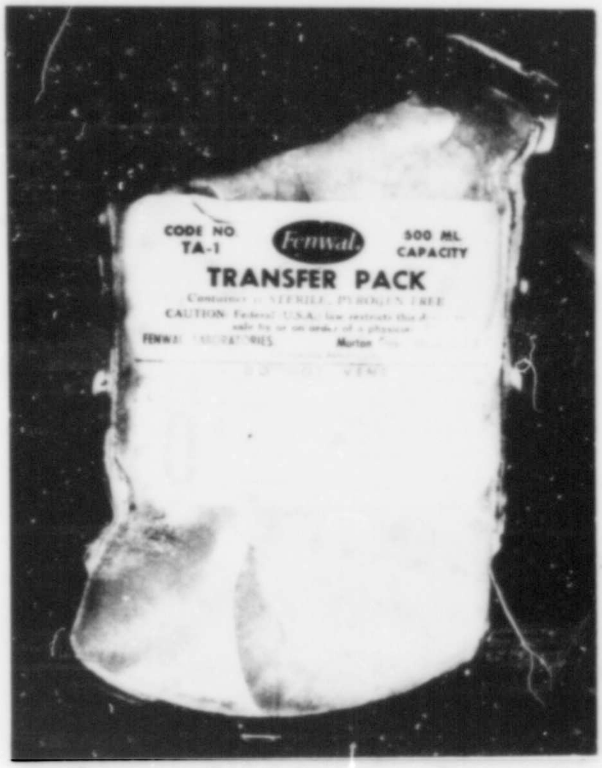

Fig. 2. Fresh frozen plasma contained in plastic container. Note that breakage has occurred after shipment.

inadequate. More recently, with the advent of successful rocket vehicles, in vitro tests of blood carried out with shake and acceleration tables, as well as actual orbital flights, have also failed to show much mechanical damage (6). Though the red blood cell seemed to survive the physical effects, a program evaluating delivery of medical supplies by parachute reported the plastic blood container as the most vulnerable item tested (7). This, combined with the evidence of breakage of the plastic bag containing frozen plasma, indicated that the cushioning effect was needed more for the protection of containers than for the erythrocyte, though ultimately both would benefit from such protection.

Several different kinds of cushioning material was considered, though most, such as cotton batting, paper, peanut shells, popcorn, and vermiculite, tend to have more weight in relation to their protective effect compared to foam substances. In addition, foam materials can be compressed repeatedly without loss of their original structure or resilience. Part of this effect is related to the trapped gas which has a certain compressibility. Two such "pneumatic" cushioning materials were evaluated in these studies. One was a new design in which the shipping container had both a foam cushion and a space which could be filled with air to form a protective pillow (Airlock design, Tuffy Co., see Fig. 3, below). The other consisted of two plastic sheets so joined as to trap bubbles of air across the surface (Aircap design, Sealed Air Corp., see Fig. 4, next page).

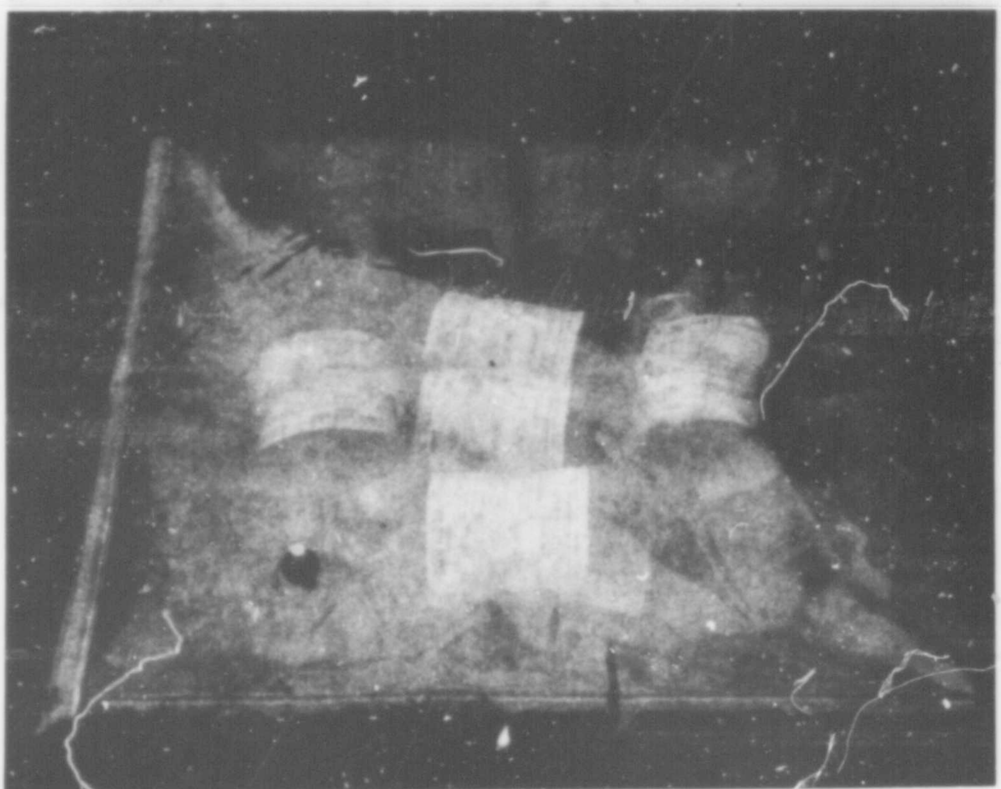

Fig. 3. Fluid-filled plastic units held down by a transparent air-filled pocket against a foam base. Note valve which permits easy filling of air pocket.

The effects of the method of delivery on blood were also studied. With the ever-increasing mobility of our forces, numerous supply items

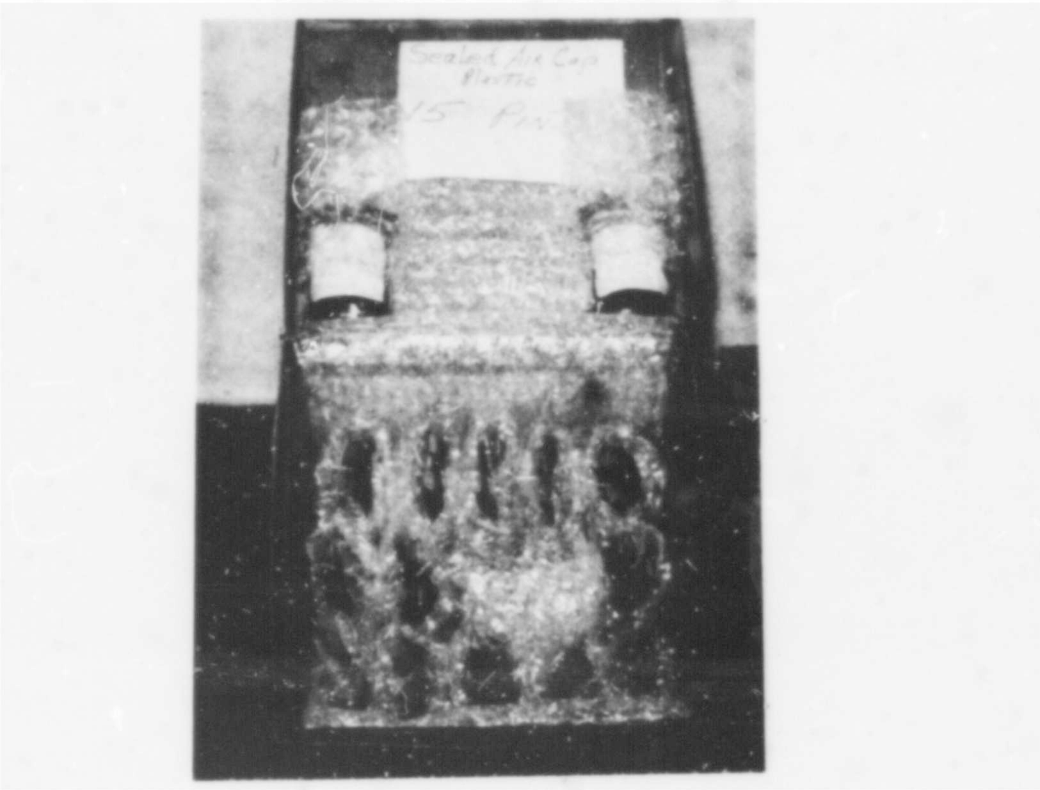

Fig. 4. Sealed air bubble cushioning material used to wrap individual units and to line standard shipping box. Note that these contain the same number of units as in the non-wrapped standard box.

have had to be delivered by airdrop techniques. This has likewise afforded an opportunity to study physical effects under the most adverse circumstances conceivable. As already mentioned, chutes have proved effective in delivery of most medical supplies, yet plastic blood containers are found to be damaged frequently. As an additional variation, free drop without chute has been tried for delivery in those instances where aircraft could not land (8, 9). Some of these efforts were unsuccessful (7), while others reported some success though the plastic blood container continued to show damage (9).

ONGOING TEST PROGRAM

In early 1964, one of the authors began the test programs, first at Walter Reed Army Institute of Research, Washington, D. C., and subsequently at US Army Medical Research Laboratory, Fort Knox, Kentucky. In these studies, free fall delivery was considered the maximum physical stress, and it was hoped that the shipping container would survive physically and also maintain the required temperature, thus providing a composite economical answer to the majority of the shipping problems. Recent changes in design and packing materials have been more successful than older types, as shown in the following summaries and tables.

In Table 1 (next page), most of the drops tested the air pillow, a new type of shipping container. Originally introduced to ship delicate instrument parts, these units were relatively small and were only able to hold one blood bag. A later design holds five blood bags and recipient sets (see Fig. 3, page 4). Unfortunately, these containers do not supply any refrigeration protection for the blood. Others also report using the small, single-unit air pillow, that when the plastic blood bag is cooled it is more susceptible to breakage, even in the air pillow.

As can be seen by the table, two forms of free fall delivery were tried: static fall from a hovering aircraft, and free fall from a moving aircraft. Different altitudes were used, with decreasing accuracy with increasing height. In these initial studies, the air pillow delivered the greatest number of intact units.

A more important part of this study than the possible ability to deliver intact blood units from a tactical point of view is the evaluation of changes in blood after maximum physical injury. Various *in vitro* tests were employed to evaluate possible changes in the blood and these were compared with samples drawn from the surviving post-drop unit. The tests included plasma hemoglobin, potassium, hematocrit, and osmotic fragility, with the average values being shown in Table 2, page 8. There were no real changes in either plasma hemoglobin or potassium under the conditions of the experiment. In addition, there was seldom evidence of visible hemolysis. These findings tend to support the previously mentioned work, indicating little overt damage from physical trauma. However, when the dropped units were stored, certain changes were observed (10) which suggested that damage had, in fact, occurred and, though inapparent in the first few days, ultimately became detectable. It might be anticipated that air delivery of blood would be for emergency use; hence, unlikely that the blood would be stored.

TABLE 1

Number of Plastic Blood Units Recovered After Selected Methods of Delivery of the Shipping Containers

Phase	Container Type	Container No.	Blood Unit Total Used	Blood Unit Recovered	%*	Remarks
Static:						
50 Ft	Standard	4	48	14	30	Boxes broke
	Air Pillow	4	20	16	80	One case torn
Free fall:						
150 Ft	Standard	2	24	4	20	All
300 Ft		2	24	1	0	boxes
500 Ft		2	24	1	0	broke
150 Ft	Tuffy (large)**	2	10	8	80	All
300 Ft		2	10	5	50	cases
500 Ft		2	10	5	50	torn
Free fall-foward speed 100 knots:						
100 Ft	Standard	2	24	8	30	All boxes
50 Ft		2	24	7	30	broke
100 Ft	Tuffy (large)	3	15	15	100	Two cases split
50 Ft		2	10	8	80	Two cases split

*Approximate.

**Air pillow, see text for description.

TABLE 2*

Results of In Vitro Chemical Analysis of Blood Samples from Plastic Units Before and After Free Fall Air Drop of the Shipping Containers

Conditions		Plasma Hgb. mg/100 ml	Potassium mEq/L	Hematocrit %	Osmotic Fragility 0%**	Osmotic Fragility Slope†
Standard box:						
100 Ft	pre	118 ± 10‡	20 ± 3	40 ± 5	9.0 ± 1.0	.42 ± .09
	post	123 ± 10	18 ± 3	40 ± 5	9.3 ± 1.0	.41 ± .09
50 Ft	pre	121 ± 10	19 ± 3	38 ± 5	9.1 ± 1.0	.43 ± .09
	post	126 ± 10	20 ± 3	40 ± 5	8.9 ± 1.0	.44 ± .09
Air pillow:						
100 Ft	pre	125 ± 10	20 ± 3	41 ± 5	9.3 ± 1.0	.41 ± .09
	post	126 ± 10	21 ± 3	41 ± 5	9.1 ± 1.0	.40 ± .09
50 Ft	pre	121 ± 10	18 ± 3	40 ± 5	8.9 ± 1.0	.42 ± .09
	post	124 ± 10	20 ± 3	41 ± 5	9.0 ± 1.0	.42 ± .09

*From study using 100-knot air speed, and units after 23-27 days' storage.

**0% indicates onset of hemolysis. The lower the value, the greater the fragility.

†Slope of curve at maximum rate of hemolysis, with the lower values indicating fragility.

‡Standard deviation of the mean.

A study of the protective effect of cushioning materials on filled plastic blood bags under a variety of selective methods of delivery was designed. Polyurethane foam has been utilized as an insert for a blood shipping box (Model CB-2, Phillips-Foscue Co., see Fig. 5, below).

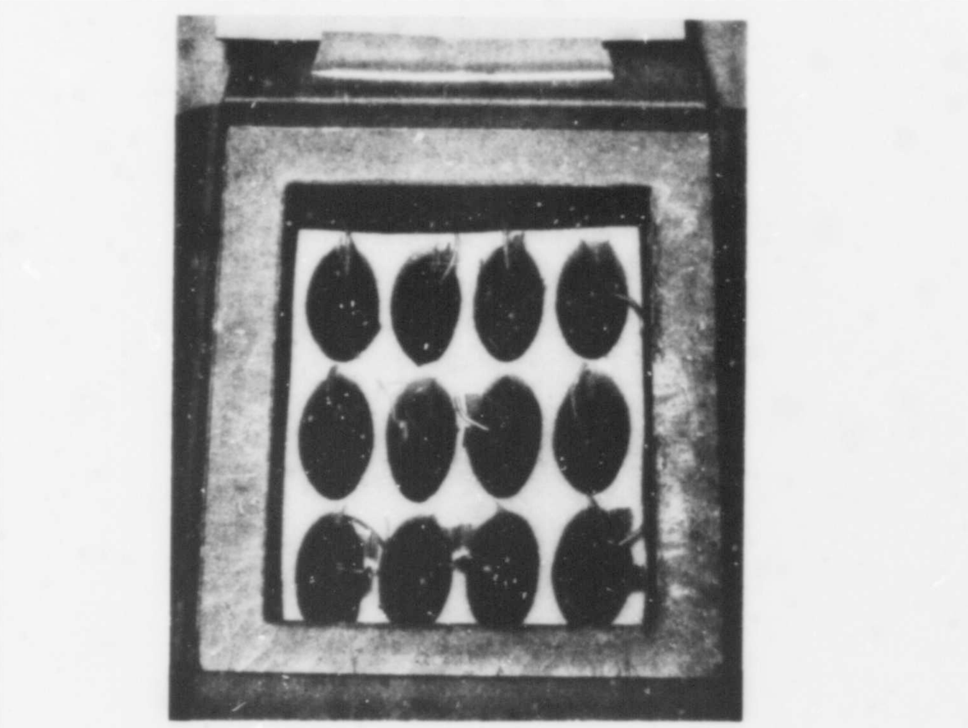

Fig. 5. Fixed urethane foam is used as lining and the individual units are held by a flexible pre-cut polyfoam cushion. Note only 12 units can be packed.

Aircap material (TM 20) was used as a protective wrap around each unit as well as a standard blood box liner (see Fig. 4, page 5). Comparisons of the protective effect of these two materials against the standard blood box and the air pillow were made. Table 3 (next page) contains a summary of the results of the most recent series of drops. These deliveries were made from a Model OH23G Hiller helicopter* or occasionally a U6A fixed-wing aircraft* was used. Before designing

*Piloted by Major J. C. Rothwell, MSC, Operations Training Officer, USAMRL, Fort Knox, Kentucky.

TABLE 3

Number of Plastic Blood Units Recovered After Selected Methods of Delivery of the Shipping Containers

Phase	Container Type	Container No.	Blood Unit No.	Blood Unit Recovered	%*	Remarks
Static:						
90 Ft	CB-2**	1	12	12	100	
	CB-2	1	12	1	0	
500 Ft	Standard	1	15	0	0	
	Tuffy***(small)	1	1	1	100	
	(large)	1	5	5	100	
Free fall, with forward speed-60 knots:						
Open terrain-						
50 Ft	CB-2	1	12	7	60	
		5	60	54	90	Aircap used†
	Tuffy (small)	2	2	2	100	
	(large)	2	10	10	100	No ice added
		1	5	1	20	Ice added
	Standard	2	30	18	60	
		1	15	14	90	Foam padded
		7	87	81	90	Aircap used
Timber land-						
50 Ft	CB-2	1	12	12	100	
	Standard	1	15	8	50	
Cargo chute,‡ 60 knot air speed:						
100 Ft	CB-2	1	12	11	90	
	Standard	3	36	34	95	Aircap used

*Approximate percentage recovered.
**Special foam container, see text for description.
***Air pillow, see text for description.
†Aircap, TM 240.
‡68-inch cargo, see text for description.

these experiments, previous work utilizing chutes was reviewed. The 68-inch chute was most accurate but did not effectively open below 60 feet. The cargo chute (G13) was less accurate but more effective in slowing a larger load (8, 11).

To obtain a maximum amount of information, the cargo was delivered under simulated tactical conditions of accurate, low-level drops carried out while moving. The 68-inch chute was used for maximum braking and supporting effect. The boxes were also provided additional impact cushioning (see Fig. 6, below). The effect of the fall on

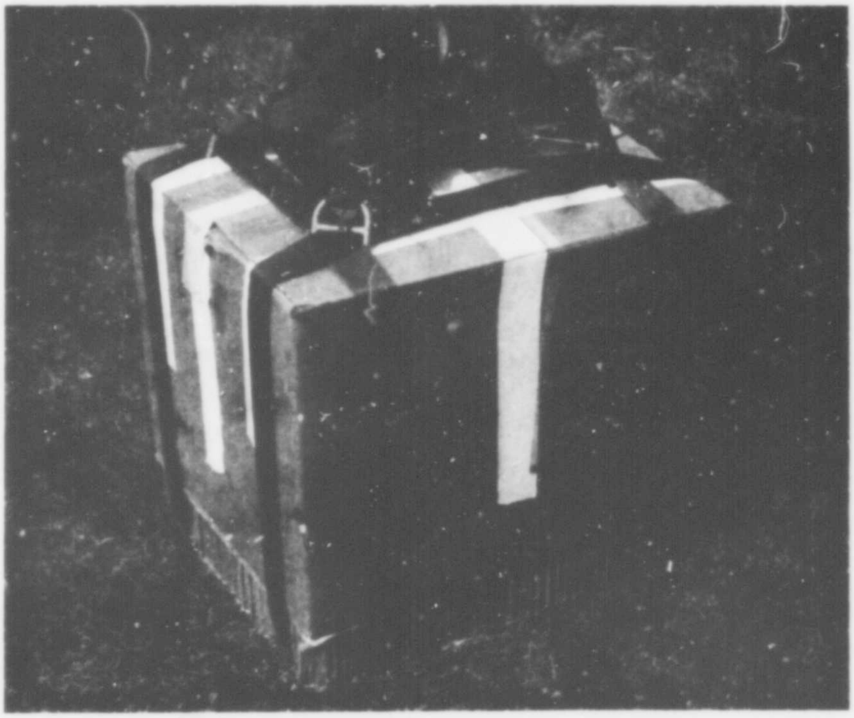

Fig. 6. Standard blood box has been rigged with the standard 68-inch chute. The cardboard honeycomb base has been added for extra protection.

some of the boxes is shown in Figures 7, 8 (page 12), and 9 (page 13). Free fall from 500 feet was a total loss except for the air pillow, but

Fig. 7. A standard blood box at point of impact after 50-foot free fall. The forward motion adds additional damage at impact. As was seen with many boxes, the force can exceed the bursting strength of the outside walls allowing the contents to be subjected to secondary impact stresses.

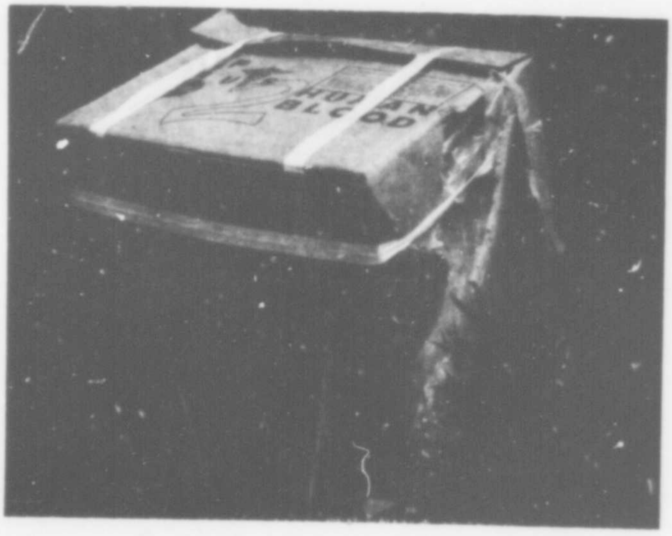

Fig. 8. Standard blood box after 50-foot free fall with side wall breakage.

Fig. 9. Standard blood box after 50-foot free fall has burst but the individual units wrapped in extra packing material have survived.

the 50-foot drop, while moving, was relatively successful. During the 50-foot series, two boxes were dropped in the scrub timber rather than open fields. Since these boxes had more intact units recovered than those from open areas, their fall may have been partially broken with perhaps less physical stress to the units. The additional packing material did increase the recovery in both types of shipping boxes. Though the air pillow was highly successful, when ice was added and the plastic blood bags were cold, most of these bags broke. Thus, it was impractical to add refrigeration to this drop system. The chute delivery was successful even without the additional packing material, and a higher altitude could be used without loss of accuracy.

The protective effect of the Aircap material became apparent during these studies, and the final one was designed to demonstrate this effect on frozen plastic bags subjected to severe trauma. The air bubble material, with both supportive and insulating properties, was prepared as individual bags for plasma units. These were then placed in standard shipping boxes (see Fig. 10, below). The results are shown in Table 4 (below). The findings provide good evidence of the protective effect of this material and suggest that it would provide additional protection for normal frozen product shipments.

Fig. 10. Individual fresh-frozen plasma units wrapped in air bubble material.

TABLE 4

Number of Frozen Plasma Units Recovered After Air Delivery in Standard Shipping Containers

Phase	Blood Unit No.	Blood Unit Recovered	%*	Remarks
Frozen plasma phase, free fall, 60 knots:				
50 Ft	11	11	100	Aircap used
100 Ft	11	9	90	Aircap used

*Approximate percentage recovered.

SUMMARY

Continuous evaluation of possible improvements in blood shipping methods is part of the mission of the Blood Transfusion Division of the US Army Medical Research Laboratory. Studies of the effect of air drop on whole blood demonstrate that packing materials of either the foam or air bubble type increase the protection of units to trauma. Cargo chutes also offered definite protection. A shipping container in the form of an air pillow provided considerable protection in free fall air delivery. Each pillow unit can transport only 1 to 5 units and provides no temperature protection; thus, all blood so delivered would require immediate usage. These studies further show that the plastic bags may be more vulnerable to trauma of this type than the blood itself. Though the immediate effects of trauma appear to be minimal, there is evidence that the blood might not withstand storage following trauma as well as non-traumatized units. Finally, Aircap material has been demonstrated to afford considerable protection to frozen plastic bags, reducing their vulnerability to routine shipping methods.

LITERATURE CITED

1. Gibson, J. G., T. Sack, R. D. Evans, and W. C. Peacock. The effect of varying temperatures on the post-transfusion survival of whole blood during depot storage and after transportation by land and air. J. Clin. Invest. 26: 747, 1947.

2. Kendrick, D. B., J. Elliott, J. Reichel, and E. K. Vaubel. Supply of preserved blood to European theater of operations. Preliminary Report. Bull. U. S. Army Med. Dept. (No. 84), 3: 66, 1945.

3. Kendrick, D. C. Blood Program in World War II. Prepared and published under the direction of LTG Leonard D. Heaton, The Surgeon General, United States Army, Office of The Surgeon General, Department of the Army, Washington, D. C., 1964.

4. Strumia, M. M., A. D. Blake, and W. A. Wicks. The preservation of whole blood. J. Clin. Invest. 26: 667, 1947.

5. Bellamy, D. Design and test consideration to provide an improved blood shipping container. Transfusion, 5: 550, 1965.

6. Technical Report. Human blood in the space environment--*in vitro* studies in earth orbit. SSD-TDR-64-1, Jan 1964, Manned Environmental Systems Directorate, USAF.

7. Technical Report. Overpack for medical supplies, Dec 1964. Thiokol Chem. Corp., Bristol, Pennsylvania.

8. Lukeman, J. M., M. J. Skvorak, and A. B. Papineau. Aerial delivery of blood. Mil. Med. 131: 796, 1966.

9. Warbner, C. K. Report No. 65-1, US Army Aeromedical Research Unit, Fort Rucker, Alabama.

10. Shields, C. E. and T. E. Allen. Red cell changes as observed by a simple method for continuously recording osmotic fragility. Transfusion, 6: 336, Jul-Aug 1966.

11. TM 10-500-62. Air drop of supplies and equipment rigging whole blood.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Medical Research Laboratory Fort Knox, Kentucky 40121	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

INVESTIGATION OF MATERIALS AND METHODS FOR AIR DELIVERY OF WHOLE BLOOD AND BLOOD PRODUCTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Progress Report (Oct 1963-June 1967)

5. AUTHOR(S) (First name, middle initial, last name)

LTC Charles E. Shields, MC, Dailey W. McPeak, MAJ J. C. Rothwell, MSC, George H. Seeger, and LTC Frank R. Camp, Jr., MSC

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
24 January 1968	16	11

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) 762
b. PROJECT NO. 3A025601A821 c. Task No. 00 d. Work Unit No. 157	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY US Army Medical Research and Development Command, Washington, D.C. 20315

13. ABSTRACT

The present standard shipping box has proved reliable over the years for long-distance shipment. However, the standard unit, when subjected to such maximum stresses as free fall air drop, did not provide very good physical protection to the blood units. The use of either chute, or additional packing made of foam or air bubble material, did provide more protection. A newly developed shipping box of foam, though slightly more protective, did better with additional material. A different type of container, in the form of an air pillow, did protect the blood units in free fall delivery. However, this form of container was limited in space, holding only 1 to 5 units, did not provide any temperature protection, and was not physically suitable for long-distance shipping. An additional problem was noted in that the blood bag was particularly vulnerable to trauma when cold, even in the air pillow. Similarly, the plastic unit containing frozen plasma was easily broken during shipment. However, use of the air bubble material around each unit was more protective, permitting long-term shipment of this item. (U)

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Whole Blood Transport Blood Shipping Container Medical Supply Shipment Air Dropped Supplies						

AG 3282-O-Army-Knox-Apr 68-375