shaped metal box 30 inches long, closed at the base with a 17 by 13 inch Levy West fluorescent screen. At the other end was fitted a Leica camera, with an F/1.5 lens and auxiliary front lens to permit focusing at 30 inches. The camera was mounted with the lens protruding through a brass plate half an inch thick, which prevented fogging of the spooled film; no evidence was obtained of x rays having penetrated the lens system. The tube and camera unit were connected by an interlocking bar, fixing the focal screen distance of 3 feet; adjustment of the screen to the patient's height automatically adjusted the tube height. All direct radiographs required as a result of the inspection of the miniature radiographs were taken with the same x-ray tube and a vertical cassette holder.

The camera was provided with a special fitting to hold the shutter open immediately each exposure on the film was wound on, 36-exposure film in daylight-loading spools being used. The exposure was controlled by the x-ray timer: there is evidence that a certain amount of "afterglow" in the screen augments the photographic image without causing any difficulty with the next exposure.

With screen photography higher voltages than are possible with direct radiography can be used without producing over-penetration. Using a focal screen distance of 3 feet, 85 kV, 100 mA, a photograph of satisfactory density can be obtained of an average-sized chest with an exposure of approximately 0.2 second. (During the survey, difficulties experienced with electrical supply conditions made it necessary to increase the exposure time for men with large chests.) Although Ilford H.P.2 film was used at first, it was found that the grain size of the faster Kodak Super XX (32 Scheiner) introduced no difficulties. It is necessary to use a fine-grain developer and to develop out as far as possible.

APPENDIX II

Procedure Employed for Miniature Radiography of Chests of Recruits in Camp

Recruits from the units are paraded at times arranged: (i) in single file, graded in height; (ii) stripped to the waist, without hats and with clothes left in the ranks (carrying any articles of clothing definitely slows the procedure); (iii) pay-books in hand. Space is essential to permit a steady forward movement and to provide ventilation—a necessity when dealing with 1,500 daily. X-ray record sheets were prepared beforehand containing columns for (1) Spool No.; (2) Serial No.; (3) Name and Initials; (4) Regimental No.; (5) Rank; (6) Unit; (7) Remarks. The last-mentioned was used for the reports on the small films. A sheet corresponds with one spool, and so has thirty-six spaces on it.

Each man presents his pay-book, and one orderly reads out required facts to a clerk. The recruit is given a small ticket bearing a number corresponding to his serial number on the sheet, and his pay-book is stamped. The ticket-books are made with every thirty-sixth page in red. The red ticket is handed out in turn and is marked "End of Spool No. —," the number being the spool on the sheet just finished. The red ticket signifies "end of spool" to the staff in the second room, and its number is a check on the next spool number to be placed on the camera unit.

The man proceeds to the x-ray room, where his progress is regulated by another orderly, who also checks the ticket numbers and makes sure the men are in their correct order. The recruit then passes before two orderlies seated at a table, where are prepared strip metallic figures on adhesive strapping, the numbers corresponding with the serial number on the record sheets and in addition the recruit's regimental number. A technician takes the man's ticket, checks it against the prepared number, and if correct the adhesive number and the man are ready to follow on to the camera unit.

Each man is told to watch the man in front and do what he does; it is arranged that he has the opportunity of seeing three people radiographed before being done himself. Each man is placed in position by a sergeant-technician, and an exposure made with the chest in full inspiration. As the recruit leaves the hut an N.C.O. from his unit marks a nominal roll. The adhesive numbers are placed on the top left-hand corner of the screen unit, the spool number in the

right-hand corner. The camera unit and tube are adjusted to the height of each man—a movement greatly facilitated by accurate grading and height. After each exposure the camera film is moved on and the shutter reopened by the special attachment.

The importance of adequate protection of personnel must be stressed, for the scattered radiation is very great when doing large series of men in a short time. Heavy lead screens are used, and the staff have blood examinations at frequent intervals.

APPENDIX III

Recruits examined by microradiography	9,000
No. of 14 by 17 inch films ordered	541 (6%)
No. of microradiographs showing evidence of hilar calcification suggestive of a healed primary tuberculous infection	4,830 (54%)
No. of films showing evidence in lung fields of past or present tuberculous infection of the secondary adult type of tuberculosis	120 (1.33%)
No. of recruits showing radiological evidence of active pulmonary tuberculosis	49 (0.55%)
No. of recruits showing fibrotic or calcified areas in lung fields in which the radiological appearances, while suggestive of a quiescent lesion, were not definitely those of a non-active tuberculous lesion	29 (0.3%)
No. of men showing fibrotic or calcified areas in the lung fields suggesting a healed or quiescent lesion	43 (0.47%)
No. of films showing cavities in the lung fields	15 (0.17%)
No. of recruits in whom radiological examination suggested tuberculosis of the lungs, and of whom subsequent examination of the sputum and stomach contents showed tubercle bacilli in smear or culture	16 (0.18%)

SERUM AND PLASMA IN TREATMENT OF HAEMORRHAGE IN EXPERIMENTAL ANIMALS

BY

J. W. MAGLADERY, M.D.Toronto, D.Phil.Oxon.

Research Associate in Physiology, University of Toronto

D. Y. SOLANDT, M.D.Toronto, Ph.D.Lond.

Associate Professor of Physiology, University of Toronto

AND

C. H. BEST, M.D.Toronto, D.Sc.Lond., F.R.S.

Professor of Physiology, University of Toronto

(From the Departments of Physiology and Physiological Hygiene, University of Toronto)

The stability of serum or plasma, and the growing body of evidence that pooled samples of them can be safely used in human patients of any blood type, prompted us to reinvestigate the extent to which these fluids could replace whole blood in the treatment of animals suffering from acute haemorrhage.

Although Rous and Wilson (1918) had stressed the importance of the fluid in contrast to the cellular elements in the treatment of haemorrhage, whole-blood transfusions have until recently been considered the only satisfactory treatment for blood loss. Bond and Wright (1938), however, reported the successful use of "lyophilized" serum in the treatment of haemorrhage in experimental animals, but the conditions of these trials were not described in detail. Since we began our experiments Levinson, Neuwelt, and Necheles (1940) and Strumia, Wagner, and Monaghan (1940) have published interesting papers bearing on this subject. Strumia and his co-workers report the successful treatment, with relatively small doses of plasma, of patients suffering from surgical shock and haemorrhage. Levinson *et al.* adopted the experimental method of Blalock (Johnson and Blalock, 1931) and subjected dogs to repeated bleedings. The efficacy of the replacement therapy was gauged by the time of survival of the animals. These

workers found that isotonic serum was an excellent substitute for whole blood in the treatment of acute haemorrhage. It is interesting in this connexion that they were able to remove in successive small bleedings some 40% more fluid than the amount represented by the animal's original blood volume. This was made possible by the substitution of an equivalent amount of isotonic serum after each bleeding. Both groups stress the need for rapid restoration of blood volume after haemorrhage. Levinson (1940) has recently applied his experimental findings in the clinic, and has reported several cases of massive acute haemorrhage which were treated effectively by the administration of isotonic human serum.

There are many difficulties in appraising the results of the treatment of acute haemorrhage, since the amount of blood which must be removed before recovery without treatment fails to take place varies widely from animal to animal. For this reason we have studied animals that have been reduced by bleeding to a state in which recovery without treatment was certain not to occur. Our results serve to emphasize again the usefulness of serum or plasma and the predominant part played, under the conditions of these experiments, by the fluid and the protein components, in contrast to the oxygen-carrying elements of the blood, in the treatment of haemorrhage.

Methods

This study deals with results obtained in some 55 dogs, which varied in weight from 5 to 16 kg. Anaesthesia was usually produced by injections of pentobarbital sodium, but ether was occasionally used. The animals were prepared in the usual way for the recording of blood pressure and the administration of fluids. After the blood pressure had reached a reasonably steady level and control blood samples had been obtained, bleeding was begun through an arterial cannula at a rate which produced a gradual reduction of the pressure to about 30 mm. Hg. It soon became apparent that neither the weight of the animal nor its initial blood pressure afforded any precise indication of the quantity of blood which had to be removed before typical post-haemorrhagic shock appeared. When enough blood was removed, however, this condition usually developed (Table I). It was characterized by a low body temperature and a failure of the blood pressure to rise above the level of 30 to 50 mm. Hg after cessation of bleeding. When death was imminent treatment consisting of the application of heat and the intravenous injection of serum or plasma was instituted.

Determinations of blood volumes were made by the dye method of Gibson and Evans (1937) as adapted to the photo-electric colorimeter (Gibson and Evelyn, 1938), but after many control experiments it became apparent that samples taken more than thirty minutes after the injection of the dye (T 1824) gave unreliable results when the animal was in post-haemorrhagic shock. For this reason satisfactory blood-volume determinations were secured in only eleven experiments. Cell volumes were determined by the haematocrit.

Results

In Table I the findings in 18 cases of untreated haemorrhage are summarized. The weight of the animal, its initial blood pressure, and the haematocrit value give no useful indication of the volume of blood which must be removed to produce shock. In these experiments, however, no animal losing more than 55% of its calculated blood volume recovered without some form of treatment. In only 3 cases out of 12 was there a significant decrease in the cell volume as determined by the haematocrit. Blood-volume determinations were made on 7 animals of this series. In those cases in which the bleeding was

continued until shock developed the blood volume was never reduced by more than 30%, although in many instances 60% of the calculated initial blood volume had been removed. The results of these studies suggest that blood pressure is the best index of the condition of an animal suffering from loss of blood.

In the treatment of post-haemorrhagic shock an attempt was made to compare the efficacy of various blood substitutes. In each experiment the animal was bled until, on the basis of previous experience (Table I), we believed early death to be inevitable unless effective treatment was instituted. Isotonic saline, hypertonic saline, and glucose solutions were tested. Even when administered in large quantities these solutions produced rises in blood pressure which were so evanescent that they were considered to have relatively little value as blood substitutes under the conditions of our experiments.

In Table II the results of treating 10 animals in post-haemorrhagic shock with their own heparinized blood are summarized. About 40% of the blood removed had to be replaced to secure recovery of an animal in well-established post-haemorrhagic shock. The accompanying chart shows the result of treatment with isotonic serum,

Chart showing results of isotonic serum treatment of post-haemorrhagic shock in a dog (11.6 kg.).

and Table III gives details of 9 experiments in which this blood substitute was used. As in the case of whole blood, a volume of serum equivalent to approximately 40% of the volume of blood removed had to be administered to obtain permanent benefit. There is no need to differentiate here between serum and plasma. In theory and in our experience they are therapeutically identical.

Concentrated blood serum has a certain therapeutic value in the treatment of traumatic shock in dogs (Best and Solandt, 1940). In post-haemorrhagic shock, where large quantities of fluid have been lost from the body, we would not expect concentrated serum to be more efficacious than an equal volume of isotonic serum. In 4 experiments we found this to be true.

With all effective blood substitutes the best results were obtained by the rapid administration (50 to 100 c.c.m./min.) of the whole volume to be given. If the blood pressure could be raised to over 100 mm. Hg in this manner without the use of specific vasoconstrictor drugs a good end-result was assured. It was also apparent, as others have previously observed, that the longer the period between the onset of shock and the initiation of treatment the less effective was the treatment.

In all the work thus far described a satisfactory therapeutic result was represented by a return of the blood pressure to within normal limits and its maintenance there over a period of several hours. Table IV gives a summary of experiments in which post-haemorrhagic shock was induced in 5 animals and in which observations were continued for more prolonged periods after treatment. One animal returned to consciousness but refused to take fluids, and died twenty-four hours after treatment.

TABLE I.—*Production of Post-haemorrhagic Shock in Dogs*

Weight of Dog	Initial Haematocrit Value	Percentage of Calculated Initial Blood Volume Removed	Duration of Bleeding	Blood Pressure at End of Bleeding	Haematocrit Value at End of Bleeding	Haematocrit Value Just Before Death	Results
Kg.			Min.	mm. Hg			
10.0	44	67	150	45	32	25	Death 120 min. after bleeding stopped
6.0	37	68	30	20	33	29	" " " " " "
5.0	54	29	30	25	50	54	" 35 " " " "
6.4	55	62	140	40	48	49	" 30 " " " "
6.4	48	76	120	22	45	47	" " " " " "
12.0	46	54	120	20	41	41	" " " " " "
10.4	—	75	150	25	—	—	" 15 " " " "
10.4	50	37	12	20	—	—	Almost immediate death from haemorrhage
4.5	45	37	10	20	28	—	" " " " " "
5.0	—	44	20	20	—	—	" " " " " "
5.0	41	55	60	32	40	—	" " " " " "
10.4	—	62	90	30	—	—	" " " " " "
9.2	47	41	20	20	41	47	Blood pressure 90, sustained
10.4	50	31	1	15	50	52	Complete recovery
12.0	49	55	10	10	53	56	" " " " " "
5.4	46	53	70	55	48	48	Blood pressure 90, sustained
6.0	56	18	20	25	—	—	Complete recovery
6.8	44	42	35	45	—	—	" " " " " "

TABLE II.—*Treatment of Post-haemorrhagic Shock with Whole Blood*

Weight of Dog	Initial Haematocrit Value	Percentage of Calculated Initial Blood Volume Removed	Duration of Bleeding	Blood Pressure at End of Bleeding	Haematocrit Value at End of Bleeding	Blood Pressure Beginning Treatment	Amount of Blood Given	Final Haematocrit Value	Results
Kg.			Min.	mm. Hg		mm. Hg	c.cm.		
9.2	66	45	90	30	60	30, falling	200	—	B.P. 140, sustained
9.2	37	24	60	38	38	30, "	100	34	" 125, "
9.2	—	48	40	40	—	25, "	200	—	" 120, "
12.8	50	63	120	40	—	23, "	360	—	" 120, "
13.6	48	58	60	45	—	40, "	300	—	" 158, "
13.2	40	53	180	30	40	27, "	160	46	" 130, "
8.2	42	50	80	30	47	24, "	100	52	" 75, fall to shock level in 50 min.
6.0	39	46	20	35	35	25, "	100	37	" 120, decline to 70 in 180 min.
11.6	43	74	180	32	36	30, "	200	37	" 80, fall to death in 30 min.
16.4	56	60	160	38	36	18, "	300	35	Practically no response; death in 15 min.

TABLE III.—*Treatment of Post-haemorrhagic Shock with Isotonic Serum*

Weight of Dog	Initial Haematocrit Value	Percentage of Calculated Initial Blood Volume Removed	Duration of Bleeding	Blood Pressure at End of Bleeding	Haematocrit Value at End of Bleeding	Blood Pressure Beginning Treatment	Amount of Serum Given	Final Haematocrit Value	Results
Kg.			min.	mm. Hg		mm. Hg	c.cm.		
12.4	41	53	120	40	41	20, falling	425	—	B.P. 115, sustained
11.6	60	62	120	30	58	26, "	350	33	" 150, "
11.6	50	64	150	38	41	24, "	360	27	" 160, "
8.0	42	50	60	32	40	25, "	100	23	" 100, "
13.2	—	58	65	22	—	18, "	375	—	" 135, "
8.4	45	56	120	32	—	20, "	225	25	" 165, "
9.0	48	55	90	40	45	43, "	300	—	" 135, died 24 hours later. Nemb.
8.0	53	77	150	30	42	25, "	140	23	" 70, decline to death in 60 min.
6.8	52	64	75	23	49	20, "	120	26	" 72, decline to death in 90 min.

TABLE IV.—*Treatment of Post-haemorrhagic Shock with Isotonic Serum in Survival Experiments*

Weight of Dog	Percentage of Calculated Blood Volume Removed	Blood Pressure			Amount of Serum Given	Results
		Initial	At End of Bleeding	After Treatment		
Kg.		mm. Hg	mm. Hg	mm. Hg.	c.cm.	
9.0	55	165	43, falling	145	300	Slow initial recovery. Died 24 hours later
9.2	50	190	32, "	150	300	Uneventful recovery. Killed 3 days later
11.0	70	165	25, "	140	400	Uneventful initial recovery, but died of tracheitis 18 hours later
6.8	50	125	25, "	110	150	Uneventful recovery. Killed 2 days later
11.2	46	180	25, "	160	280	Uneventful recovery. Killed 3 days later

Another animal died from a purulent tracheitis. The 3 remaining animals made a complete and uneventful recovery.

Summary and Conclusions

In the treatment of post-haemorrhagic shock, such as we have produced in experimental animals, approximately 40% of the blood removed must be restored to secure recovery. Comparable volumes of serum or plasma produce equally satisfactory results. These findings indicate: (1) that *under these conditions* the volume of the red cells restored to the animal is more important than their oxygen-carrying capacity; and (2) that serum and plasma,

which can be stored for long periods, are effective blood substitutes for the treatment of haemorrhage. Our results indicate the importance of administering blood or blood substitutes at a rapid rate (50 to 100 c.cm./min.) and, of course, as soon as possible after the haemorrhage.

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