Arterial Versus Venous Transfusion in Cardiac Arrest From Exsanguination: Further Studies in Dogs

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REPLACEMENT of the circulating blood volume is obviously the most effective treatment in impending death from massive hemorrhage. When the arterial pressure decreases rapidly to 30 to 50 mm. Hg, the rate rather than the route of blood transfusion is of vital importance.[1-6] After prolonged hypotension, especially when clinical death supervenes, intra-arterial transfusion of blood has been found more effective than intravenous administration.[7-12]

Nowadays, when closed-chest cardiac massage is being successfully applied in the treatment of sudden cardiac arrest, it seems expedient to use this technic also for the resuscitation of an organism dying from exsanguination. Points of view differ with regard to the best technic of blood replacement under such conditions. According to Kirimli and Safar,[11] intravenous transfusion with cardiac massage is as effective as intra-arterial transfusion *without* cardiac massage. Riabova[13] had reported earlier that when intra-arterial blood transfusion was combined with open-chest cardiac massage, better results were obtained than with intravenous transfusion in cases of clinical death from blood loss and myocardial atony.

In the light of such earlier reports, we undertook a new study, to compare the effects of intra-arterial versus intravenous blood transfusion in association with closed-chest cardiac massage in dogs in the treatment of clinical death caused by hemorrhage.

TECHNIC

Twenty-six adult dogs, weighing 8 to 20 kg. each, were given 4 mg./kg. (body weight) of pantopon subcutaneously at 40

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TABLE

Averages and Range: Transfusion and Survival Data for 26 Dogs

Group	Route of transfusion	Rate of transfusion, ml./kg./min.	Duration of dying, sec.	Duration of agony and clinical death, sec.	Blood loss volume, ml./kg.	Restoration of cardiac activity, sec.	Restoration of respiration, sec.	Restoration of corneal reflex, sec.	Circulatory arrest maximum*, sec.	Dogs survived	Dogs died
I	Intra-arterial	15	674±62.1	530±58	58±3.8	68±19.3	278±38.5	814±79.4	680	10	1
			330-1080	413-680		25-190	110-570	530-1405			
II	Intravenous	15	671±63	572±46	49±2.3	259±40.3	634±123	1255±137	510	5	10
			325-1063	400-835		100-505	190-888	850-2000			

*With positive results.

minutes before the experiments. Femoral vessels were cannulated under local anesthesia with procaine. All animals were awake before being bled. Pulse frequency, respiration rate, and rectal temperature differed from initial values, but these differences were not statistically important. Clinical death (5 min.) was produced by free bleeding from the femoral artery after prior intravenous injection of heparin.

The procedure of resuscitation consisted of closed-chest cardiac massage, artificial respiration, and reinfusion of the heparinized and warmed blood. All transfused blood was autologous, but 0.5 to 1 ml. of a 1:1000 solution of adrenalin was added. Transfusion (15 ml./kg. body weight) was intra-arterial in 11 dogs (group I) and intravenous in 15 animals (group II).

Chest-compression rate was 50 to 60 per minute and artificial respiration was performed by the French RPR (Respirateur Pause Réglable: Rosenstiel) * at a frequency of 16 to 18 cycles/min. and a tidal volume of 30 ml. of oxygen/kg. of body weight. Defibrillation was achieved by an external electric defibrillator. Arterial and venous blood pressure, respiration rate, and the electrocardiogram, by standard leads, were recorded. In several experiments, organic-acid concentration in plasma was also measured.

RESULTS

The pattern of clinical death was similar in both groups of animals, as shown in the table. A rapid decrease of arterial blood pressure was observed during the first 2 minutes of exsanguination. At the end of the 3rd minute of dying, arterial pressure decreased to 15 to 20 mm. Hg. Pulse-beat amplitude diminished dramatically, disappearing completely in many dogs before the onset of agony. The duration of the agony and clinical death varied from 6 min. 40 sec. to 13 min. 55 sec., during which time the circulation of blood was suspended completely. Blood loss in each group is shown in the table.

Group I.—Intra-arterial administration of blood during closed-chest massage raised the arterial pressure within 5 to 10 seconds to the level of 46 ± 5.1 mm. Hg. In 8 of the 11 animals of this group, the relatively rapid restoration of spontaneous cardiac activity took place within 44 ± 5 seconds, by

*Comparable to Ambu bag. Ed.

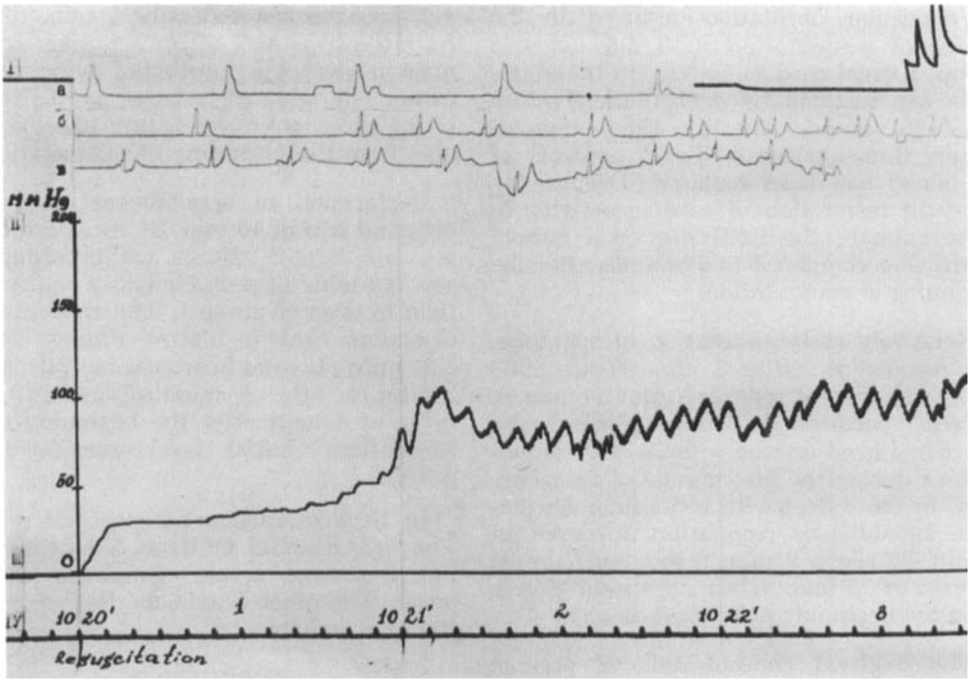

FIG. 1. Recording of arterial blood pressure, respiration, and ECG during resuscitation by closed-chest cardiac massage and intra-arterial blood transfusion. In kymogram: I. Respiration; II. Arterial blood pressure; III. Zero level of arterial blood pressure; IV. Time (5-second increments). In tracings of ECG attached (a, b, uninterrupted tracing from the beginning of resuscitation, designated as mB) gradual normalization of ventricular complex as effective cardiac activity returns.

which time only approximately a third (35 ± 9 percent) of the blood had been replaced. At the moment of heartbeat revival, there was a rise of arterial blood pressure to 85 ± 10 mm. Hg; within 1 minute, this rose to 100 mm. The ECG showed restoration of the sinoatrial rhythm and differentiation of initial and terminal parts of the ventricular complex within the first 30 seconds after the beginning of resuscitation. Within 3 to 4 minutes, the ventricular complex appeared almost normal (fig. 1).

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A native of the Ukraine, Professor Negovský, through his own investigations, and through team leadership in his Institute, has been a major force in establishing "Resuscitology" as a new specialty in Russia.

He graduated from Moscow Medical Institute in 1933, received his M.D. degree from the Ministry of Higher Education in Moscow in 1942, and has since been Laureate of two State Prizes (1952 and 1970) for his investigations into the pathophysiology and therapy of terminal states.

Ventricular fibrillation occurred in the course of resuscitation in 3 dogs of this group; normal cardiac activity in these animals was restored by defibrillation within 144 ± 25 seconds. By this time, approximately three-quarters (73 ± 17 percent) of the blood had been replaced. Despite the delay in restoration of cardiac activity in these animals, the ECG showed a normal ventricular complex 4 to 6 minutes after the beginning of resuscitation.

Relatively early restoration of spontaneous respiration (after 3 min. 47 sec. ± 33 sec.) and corneal reflexes (after 11 min. ± 46 sec.) occurred in 8 dogs in which the heart had been revived without any complications during the first minute of resuscitation. In the 3 dogs with ventricular fibrillation, spontaneous respiration appeared at 6 min. 36 sec. ± 2 min. 6 sec. and corneal reflexes at 18 min. 41 sec. ± 4 min. 17 sec. after the beginning of resuscitation.

The highest concentration of organic acids in plasma was at the moment of restoration of cardiac activity: 22.5 ± 1.5 mEq./L. After 30 minutes it decreased to 15.1 ± 1.5 mEq./L., and after 1 hour, it attained a level of 13.7 ± 0.6 mEq./L. (initial level 9.4 ±0.29 mEq./L.).

Of the 11 dogs in group I, 1 died (of pneumonia) on the 7th day. Of the 10 survivors, 3 showed postresuscitation neurologic disturbances.

Group II.—In this group, intravenous administration of blood during closed-chest cardiac massage produced an increase of arterial pressure to 20 to 25 mm. Hg only after 20 to 40 seconds (fig. 2). Ventricular ECG complexes maintained the monophasic pattern usually observed after 3 to 5 minutes of clinical death due to exsanguination (complexes of the "dying heart"). Ventricular fibrillation developed after 30 to 50 seconds in 14 of the 15 dogs of this group.

The defibrillation procedure produced asystole and atrioventricular block, while the continued performance of cardiac massage led to the resumption of fibrillation. In 4 dogs, normal cardiac activity could not be restored in consequence of these complications. In 10 dogs, the first contractions of the heart appeared 4 min. 19 sec. ± 40.3 sec. after repeated (3 to 5) defibrillations when the blood volume had been restored by 89 ± 6.6 percent. Even in a dog in which ventricular fibrillation did not develop, cardiac activity was restored only 1 min. 52 sec. from the beginning of resuscitation. In animals in which the duration of dying did not exceed 13 minutes, relative normalization of the ECG took place within 10 to 12 minutes from the beginning of resuscitation.

Restoration of spontaneous respiration occurred within 10 min. 34 sec. ±2 min. 12 sec. and corneal reflexes, within 20 min. 55 sec. ±2 min. 17 sec., obviously much later than in dogs of group I. The concentration of organic acids in plasma attained 24.4 ± 3.04 mEq./L. after heartbeat revival; 26.4 ± 2 mEq./L. after 30 minutes; and 23.9 ±0.8 mEq. at 1 hour after the beginning of resuscitation (initial level was 9.6 ± 0.13 mEq./L.).

In 10 dogs, cardiac activity and respiration were restored. Of these, 5 dogs survived but 2 showed severe neurologic disturbances. The other 5 animals died soon after the experiments.

DISCUSSION

Our study showed that, under similar conditions of death from exsanguination, intra-arterial administration of blood is preferable to intravenous transfusion during closed-chest massage, contributing to an earlier increase in arterial pressure, normalization of conductivity, and restoration of spontaneous cardiac activity. Of particular importance is the observation that ventricular fibrillation developed in 14 of the 15 dogs given intravenous transfusion as compared with only 3 of the 11 receiving blood per artery.

The more prompt restoration of cardiac activity and of the normal circulation with intra-arterial transfusion promoted the more prompt restitution of other functions and consequently survival. In animals of this group, spontaneous respiration and corneal reflexes appeared earlier than in the dogs treated by intravenous transfusion, as did normal acid-base balance.

The successful results demonstrated by Kirimli and Safar[11] in experiments with intravenous transfusions may be related to the less prolonged period of dying as a result of more rapid bleeding from the aorta. Investigations in our laboratory have shown that the effectiveness of cardiac massage depends to a great extent upon the duration of hypoxia during the dying period and clinical death. Closed-chest cardiac massage raises arterial pressure to more than 60 mm.

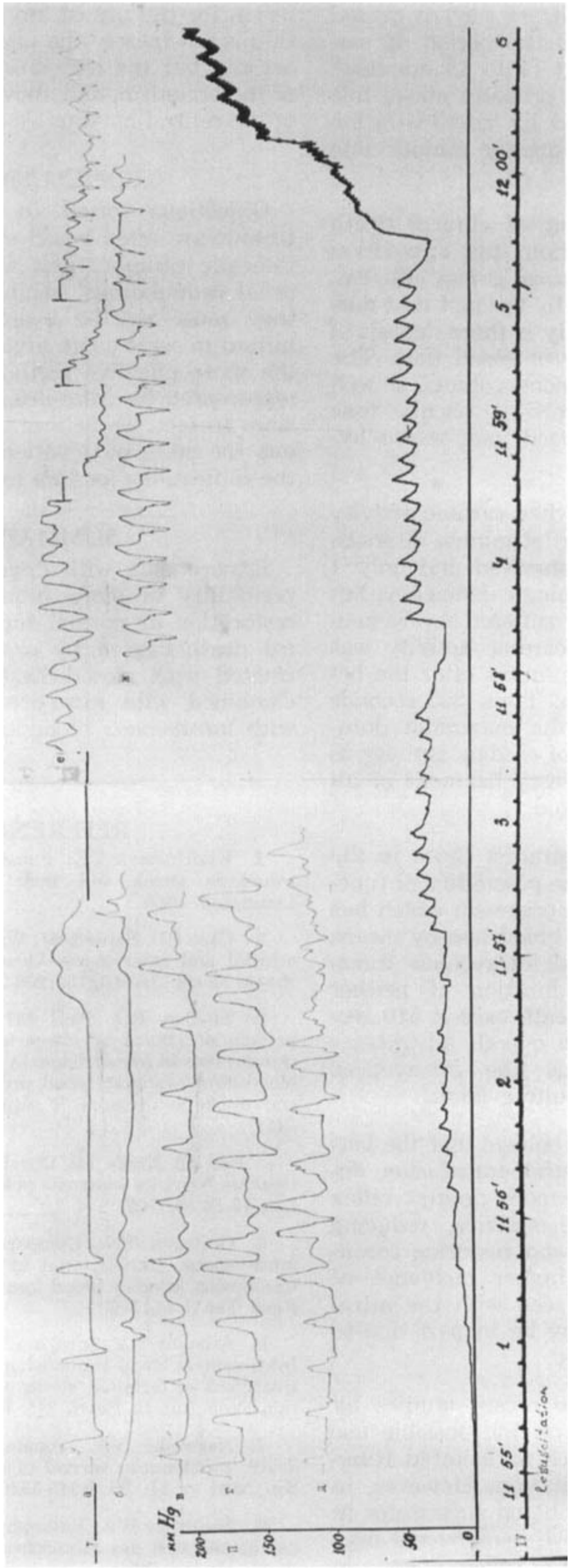

FIG. 2. The same designations as in figure 1. Slow restoration of cardiac activity during intravenous transfusion. In ECG (a-II), atypical ventricular complexes of monophasic pattern turning into fibrillation (d-e). After defibrillation (e–) deformation of ventricular complex pointing on the disturbance of intraventricular conductivity, In kymogram: Restoration of effective cardiac activity after defibrillation (on the right-hand side).

Hg in the case of a sudden and short-term (up to 5 min.) cardiac arrest, such as caused by electrocution. When the period of cardiac arrest is prolonged (7 to 15 minutes) the support of arterial pressure above this level should be assured by administration of supplementary vasopressor amines into the vascular bed.

During the treatment of clinical death caused by exsanguination, the circulation created by cardiac massage is less efficient. This may be explained by the fact that during hemorrhage, not only is there deposit of blood but also slowing of blood flow. The natural diminution of blood volume, as well as the decrease of peripheral vascular tone results in more prolonged and severe hypoxia.

In our experiments, when cardiac activity was restored within the 1st minute of resuscitation, all the dogs survived and only 1 animal developed neurologic deficiency, but the animals perished or suffered severe neurologic damage when cardiac activity was not restored within 5 minutes after the beginning of resuscitation. Thus, 220 seconds should be considered the maximum duration of the restoration of cardiac activity in which the complete re-establishment of all functions can be expected.

Our data do not contradict those in the literature concerning the possibility of functional restoration of an organism which has suffered lethal massive blood loss by means of cardiac massage and intravenous transfusion, provided the duration of neither agony nor of clinical death exceed 510 seconds. Nevertheless, the overall advantages of intra-arterial versus the intravenous blood transfusion are quite evident.

There are reasons to believe that the better effect of intra-arterial transfusion derives in part from the more prompt reflex stimulation of cardiac activity, reducing myocardial irritability and restoring coronary blood flow. The higher incidence of ventricular fibrillation seen with the intravenous transfusions may be in part due to the adrenalin injections.

Of great interest are recent studies by Kirimli and Safar[14,15] on the possible use of blood substitutes such as lactated Ringer's solution in resuscitation. However, in our opinion, the use of blood substitutes in the treatment of massive hemorrhage may lead to the development of severe anemia in the postreanimation period. The final criterion for the use of any fluid in resuscitation is not merely the restoration of cardiac activity but the restoration of all functions of the organism, and above all the functions of the central nervous system.

CONCLUSIONS

Objections raised to the intra-arterial technic are often based on time delays and ischemic complications associated with arterial cannulations. While these risks exist, they must not be overestimated or permitted to serve as an argument for rejecting the more effective method of resuscitation represented by intra-arterial blood transfusion. In fact, we believe that the more serious the state of a patient, the greater are the indications for this modality.

SUMMARY

Experiments with dogs have shown the possibility of more prompt and complete restoration of normal functions after clinical death caused by exsanguination when treated with closed-chest cardiac massage combined with *intra-arterial* as compared with *intravenous* blood transfusion.

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There are three things which are real: God, human folly and laughter. The first two are beyond our comprehension, so we must do what we can with the third.

—*John F. Kennedy*

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"IF I DON'T GO, I DON'T GET"

"In the South is an old man with a rowboat who ferries passengers across a mile-wide river for 10 cents. Asked, 'How many times a day do you do this?' he said, 'As many times as I can because the more I go, the more I get. *And if I don't go, I don't get.*' That's all you need to know—all there is to know—about business, economics, prosperity—*and self-respect.*"

* * *

This may not be the best of all possible worlds, but to say that it is the worst is mere petulant nonsense.

—*Thomas Huxley*