MICROCIRCULATION AND BLOOD VOLUME IN RATS BEFORE AND AFTER SPINAL CORD INJURY*

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In the acute phase of spinal cord injury clinical symptoms can be observed which are similar to those found in haemorrhagic shock. Therefore some authors (Desmond & Laws, 1974; Seifert, 1979) compare clinical findings of spinal shock with circulatory disturbances, seen after severe blood loss, although there are differences by definition (Guttmann, 1973). To contribute to this controversy animal experiments were performed, in which the circulating blood volume as well as the cardiac output and the microcirculation of the main organs was determined before and after selective dissection of the spinal cord. The results of these investigations were compared to former blood volume findings after haemorrhagic shock in rats (Seifert & Messmer, 1971).

Material and Methods

Sprague Dawley rats were anaesthetised with chloral hydrate (360 mg/kg b.w.). After cannulation of the carotid artery and the femoral artery blood flow studies were performed with the microsphere technique in different organs (muscle, paw, kidney, spleen, intestine and lung). For this purpose radioactively labelled particles (15 μ ; Strontium-85; Iodine-125, 3M Company, U.S.A.) were injected via the carotid artery into the left heart. According to the cardiac output these particles were distributed in the different organs of the rats. Various investigations can be discriminated by differently labelled particles. At the end of the observation time animals are sacrificed and the radioactivity in organs measured in a multichannel gamma counter (Packard Company, U.S.A.). During injection of microspheres a reference sample was withdrawn out of the femoral artery. By means of this technique it was also possible to estimate changes of the cardiac output (Lenz; Seifert; Brendel & Halle, 1977) (Fig. 1).

Blood volume (Seifert & Messmer, 1971) and mixing time (Messmer & Seifert, 1972) were measured with Cr-51-labelled homologous erythrocytes (Seifert & Messmer, 1970). Arterial blood pressure was determined by a statham strain gauge transducer.

Animals were divided in two groups; in the first group blood flow studies were performed. After a 30-minute control interval the spinal cord was dissected between Th 7-8. Flow values before and after the dissection were compared to control animals without spinal cord injury. In the second group blood volume studies and the evaluation of the mixing time of rat erythrocytes was observed in the animals before and 30 minutes after the dissection of the spinal cord.

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FIG. 1

To measure blood flow, microspheres are injected into the left heart. A reference sample is collected from the femoral artery to calculate cardiac output.

For the statistical analysis the mean values, and standard deviation were calculated and the significance of differences was controlled by means of the student *t*-test.

Results and Discussion

As shown in Figure 2, the influence of a 30-minute anaesthesia decreases blood flow values in the kidney, spleen and lung, whereas blood flow in muscle, paw and gut remains essentially unchanged.

These variations in blood supply are due to the experimental set-up, which consists not only in an anaesthesia but also in an artificial supine position of the animal. Cutting off the spinal cord at the level T7-8 results in a marked and significant decrease of the blood flow of muscles and the paw in the paraplegic area but also of kidney and gut. The blood supply of the lung, however, is significantly increased. As measurements were performed immediately after the interruption of the spinal cord the decrease of the blood flow in the paraplegic area as well as in main organs of the rat can be explained by the shock situation. Also the findings in the lung have a clinical correlate. It is often observed that in the acute phase of spinal lesions patients show a lung oedema or an over-perfused lung in X-ray pictures. This is explained by a centralisation of blood volume as normally found in shock.

FIG. 2

Blood supply during control conditions, in anaesthesia and after paraplegia was measured with radioactively labelled microspheres.

These changes of blood supply due to cutting off the spinal cord is not accompanied by changes of the cardiac output. As far as the microsphere method is reliable to determine cardiac output in rats, this parameter was not influenced by the spinal cord manipulation.

With these changes of the blood supply in different organs and with the knowledge that cardiac output is essentially unchanged, one can speculate that the reduction is caused by a decrease of the circulating blood volume. Therefore a second experiment was performed under similar conditions, in which the circulating blood volume was calculated with chromium-51 labelled autologous erythrocytes. For this measurement it is necessary to wait for the postmix sample until the injected chromium-labelled erythrocytes are completely mixed with the circulating blood. From former investigations it was known that the mixing time can be very much delayed, for example in haemorrhagic shock in rats (Seifert & Messmer, 1971).

In Table I the mixing time of chromium-51 labelled erythrocytes in control animals is compared with the mixing time under the condition of haemorrhagic shock and the condition after cutting off the spinal cord. Complete mixing of autologous erythrocytes is delayed after injury of the spinal cord and this delay is comparable to that in haemorrhagic shock. Under both conditions the indicator is mixed within 5–8 minutes, compared to control animals, in which only 10

TABLE I

Blood volume and mixing time of chromium-51 labelled erythrocytes in rats during control conditions, after spinal cord injury and after haemorrhagic shock.

	Control (<i>n</i> = 9)	Paraplegia (<i>n</i> = 7)	Haemorrhagic shock (<i>n</i> = 5)
Mixing time (min.)	0, 2	8	5-8
Blood volume (ml/kg)	69 ± 2.6	51 ± 3.5	53 ± 4.2

seconds are needed. Whereas no significant differences can be observed between the blood volume of paraplegic rats and rats in haemorrhagic shock, a marked difference can be detected between the values of both those groups and the control animals.

If also the blood pressure is taken into consideration, which decreases after cutting off the spinal cord to about 70 per cent of the initial value, all measured circulatory parameters indicate that not only the clinical symptoms but also circulatory parameters after acute paraplegia can be compared to a shock situation observed after blood loss. These observations indicate that symptoms of spinal shock in the acute phase of spinal cord injury are mixed up with symptoms which are characteristic for a blood loss situation. Since the initial cause for both kinds of shock symptoms is the injury of the spinal cord, the circulatory disturbances like blood flow changes, delay of mixing time and decrease of the circulating blood volume should be included in the conception of the spinal shock, because variations of the mentioned parameters should have therapeutical consequences.

Summary

Blood flow, cardiac output, blood pressure, indicator mixing time and blood volume were measured in rats before and after spinal cord injury. After cutting off the spinal cord blood flow decreases markedly in the paraplegic area but also in the main organs of the animals. Only the blood supply of the lung increases by this manipulation. As blood volume and the blood pressure is decreased and the indicator mixing time delayed the situation of the spinal cord injury can be compared with the situation after acute blood loss. Therefore it is proposed to include circulatory disturbances into the conception of the acute spinal shock situation.

RÉSUMÉ

Avant et après l'interruption de la chord spinale la circulation du sang était déterminé chez le rats dans les organes différentiels. Après la dissection de la chord spinale la circulation de sang baisse dans l'areal paraplégique mais aussi dans les organes nécessaires des animaux. Seulement dans le pulmon le supplement du sang augmente après dissection de la chord spinale. Puisque le volume du sang et la tension sont baissé et le temps du melangement d'indicateur est retardé on peut comparer la situation après la dissection de la chord spinale avec la situation après une hemorrhagie. C'est pourquoi on recommande que le changement de la circulation soit inclué dans le terminus du choc spinale.

ZUSAMMENFASSUNG

Vor und nach der Durchtrennung des Rückenmarks wurde bei Ratten die Durchblutung in verschiedenen Organen, Herzzeitvolumen, Blutdruck, Indikator durchmischung und Blutvolumen gemessen. Nach der Verletzung des Rückenmarks erniedrigt sich die Durchblutung im gelähmten Bereich aber auch in den lebenswichtigen Organen der Tiere. Nur in der Lunge steigt die Blutversorgung nach der Verletzung des Rückenmarkes an. Da das Blutvolumen und der Blutdruck erniedrigt sind und die Indikator durchmischungszeit verzögert kann man die Situation nach Durchtrennung des Rückenmarkes mit der Situation nach akutem Blutverlust vergleichen. Deshalb wird vorgeschlagen, die Kreislaufveränderung in den Begriff des akuten spinalen Schocks mitaufzunehmen.

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