PHYSIOLOGIC EFFECTS FROM THE INTRODUCTION OF BLOOD AND OTHER SUBSTANCES INTO THE SUBARACHNOID SPACE OF DOGS*

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Solutions of normal saline, injected under pressure into the subarachnoid space, escape into the orbital tissues, producing proptosis and subconjunctival edema. When normal saline is injected at pressures in excess of 100 mm. Hg, drainage from the nostrils is often apparent. Solutions of dextran, plasma protein and colloidal gold also pass readily from the subarachnoid space, although more slowly than does normal saline. If erythrocytes or carbon particles from India ink are injected within the subarachnoid space in advance of an injection of normal saline, the flow of saline out of the subarachnoid space is blocked, and hence the flow of saline into the subarachnoid space also is impeded. Openings that can be blocked by erythrocytes or carbon particles are present about the optic nerves and about the olfactory nerves. In addition, spaces that permit the passage of fluid and particles have been demonstrated about the spinal nerves, and probably are present around other cranial nerves.

The arachnoid villi, whose importance was emphasized by Weed, have been shown experimentally by Welch and Pollay to permit perfusion of liquids and particles into the venous system in the monkey. Arachnoid villi in other species probably function in the same way. Simmonds recovered erythrocytes labeled with Fe¹⁰⁹ in the systemic circulation after their injection into the subarachnoid space of rabbits. Adams and Prawirohardjo recovered Cr⁶⁷ labeled erythrocytes, and Bradford and Johnson recovered Fe⁵⁹ labeled erythrocytes from the systemic circulation of dogs after their introduction into the subarachnoid space.

The brain and spinal cord become highly radioactive when radioactive colloidal gold is perfused into the subarachnoid space. The possibility of fluid and particles reaching the circulation of the brain or spinal cord by communication between the cerebrospinal-fluid spaces and the perivascular spaces must be kept in mind.

In this study there is little evidence to show which of the routes is followed by the bulk of a solution injected or just where the erythrocytes or carbon particles obstruct the flow of fluid from the subarachnoid space. However, it seems likely that all routes must be affected, since the degree of blocking of the passage of saline introduced into the subarachnoid space becomes quite high.

METHOD

Dogs weighing 14 kg. or more were anesthetized by intravenous injection of 30 mg./kg. of pentobarbital sodium. A lumbar laminectomy was performed and a polyethylene tube was introduced about 5 cm. cephalad into the lumbar subarachnoid space. Tight closure was made by tying the dura mater and the enclosed spinal cord and cauda equina firmly about the polyethylene catheter. A "T" connector was used so that 1 connection could be made to a pressure transducer and 1 to a container for injections by gravity or to a syringe for direct injections. In some of the more recent experiments 2 polyethylene tubes were tied into the subarachnoid space, 1 for pressure recordings and 1 for injections. Blood pressure was taken by cannulating the femoral artery and connecting it to a pressure transducer. For shunting procedures requiring blood at arterial pressure the other femoral artery was cannulated and poly-
ethylene tubing was used to make appropriate connections. Before a shunt was connected, the dog was heparinized with 2 mg. heparin/kg. Routine recording was done with a physiograph having channels for blood pressure, cerebrospinal-fluid pressure, respiration and time signal. Sixty-eight dogs, 2 cats and 2 rabbits were used in the experiments reported here.

OBSERVATIONS

Subarachnoid Injection of Normal Saline. The flow of normal saline into the subarachnoid space by gravity at approximately 135 mm. Hg pressure is variable, but usually quite free. The average rate is from 0.5 to 1.0 cc. per kg. of body weight per min. Occasional dogs will have much slower flow than others. The usual 20 kg. dog would accept 60 cc. of normal saline at 135 mm. Hg pressure in from 3 to 6 min. If the pressure is halved, the same amount of saline requires slightly less than 4 times as long to run in. If normal saline only is injected, succeeding 60 cc. quantities flow in the same or slightly less time. Edema can be noted in the orbital tissue after injection of 20 cc., and proptosis is apparent after 100 cc. or more. As a rule, vital functions are not altered appreciably by injections at a pressure of 135 mm. Hg lasting up to 12 min. Injections of from 30 to 50 cc. of normal saline by syringe at pressures of from 300 to 400 mm. Hg in 1 to 2 min. usually can be made. A marked rise in blood pressure occurs and occasional arrest of respiration, but the cerebrospinal-fluid pressure usually has returned to tolerated limits before any deterioration of the condition of the dog occurs. With a short rest between injections, many injections can be made without deterioration.

Two cats and 2 rabbits were tested with subarachnoid injections of saline. The rate of absorption, the collection of saline in orbital tissues and the dripping from the nostrils quite parallel the reactions observed in dogs.

In 3 dogs a catheter was tied into the lower end of the subarachnoid space at the 1st thoracic vertebra. Saline was accepted by this portion of the subarachnoid space with no access to the intracranial subarachnoid space. Absorption was quite slow, less than 10 per cent of that of the cranial subarachnoid space for pressures of from 200 to 400 mm. Hg and even slower for pressures of 100 mm. Hg or less.

Subarachnoid Injection of Blood. In his study of intracranial hematoma, Kabuki injected 1 cc. per kg. of autogenous blood into the subdural and epidural spaces of dogs without mortality. Mullan et al. injected blood into the subarachnoid and subdural spaces of dogs, finding the lethal dose under most circumstances between 1 and 2 cc./kg. If injected over a period of 45 min., a larger amount of blood was tolerated than if more rapid injection was made. Our findings upon injection of blood into the subarachnoid space were quite similar. It also was observed that saline, injected after blood in the amount of 1 cc./kg. or more, rapidly raised subarachnoid pressure. In fact, after the injection of blood, saline encountered as much resistance as would additional blood. Saline, injected after considerable blood had already been injected, was as lethal as further injection of blood. This effect was observed also in injections by gravity. Because of the free flow of saline from the subarachnoid space when injected by gravity at 6 feet (135 mm. Hg) the effective pressure was reduced. However, when flow was stopped by injection of blood preceding saline, further saline at the pressure of gravity at 6 feet caused more deleterious effects on vital functions. At one time it was thought that blood in the subarachnoid space had some specific lethal effect, but evidence gradually was accumulated that it was the almost complete arrest of flow from the subarachnoid space that produced the more formidable signs when additional saline was introduced by gravity or by injection.

After the injection of blood, if saline, in amounts just tolerated, is forced into the subarachnoid space, perhaps 60 cc. in the course of 1 hour, its passage through the subarachnoid space becomes easier, and subsequently moderately large quantities of saline can be injected in only a few minutes. Under such circumstances the subarachnoid space can be washed almost free from erythrocytes. During the "washing process"