CEREBRAL METABOLIC STUDIES ON THE HUMAN DURING TOTAL CEREBRAL ARTERIAL OCCLUSION AND HYPOTHERMIA

THE EFFECT ON CEREBRAL RESPIRATORY QUOTIENT*

JOHN E. ADAMS, M.D.
Division of Neurological Surgery, University of California School of Medicine, San Francisco, California

(Received for publication April 14, 1960)

Hypothermia and occlusion of the arterial supply to the brain have become an established method in some centers to aid the neurological surgeon in a direct attack on intracranial aneurysms and other vascular anomalies. Hypothermia, because of the resultant decrease in cerebral metabolism, allows a longer period of partial or complete interruption of the cerebral circulation than is possible at normal temperatures. Rosomoff and Holaday have shown that for every 1°C drop in temperature, utilization of oxygen by the brain is reduced by an increment of 6 per cent of the metabolic requirement at 37°C. On the basis of these data, it can be calculated that at the hypothermic temperatures commonly employed in intracranial vascular surgery (28°C to 30°C.) cerebral metabolism is reduced by approximately 50 per cent. Therefore, if the normal metabolic pathways are preserved at these temperatures and total ischemia is produced by occlusion of the vessels of the neck, it would be possible theoretically to occlude the vessels safely for periods not longer than approximately twice the safe period of occlusion at normal temperatures of the brain. Yet it has been observed empirically that total occlusion of the arterial inflow for as long as 10 to 12 minutes has been accomplished without obvious detriment to cerebral function. This observation raises the possibility that under these conditions, in addition to a reduction of its metabolic demands, the energy requirements of the brain may not be dependent solely upon exogenous substrates.

This investigation originally was undertaken to study the period of safe occlusion at various temperatures of the brain, since the length of time the vessels of the neck have been occluded usually has been dictated by empirical results and by the exigencies of the surgical problem at hand.

METHOD

Studies were carried out in 9 patients undergoing a direct attack upon an intracranial aneurysm in which total-body hypothermia and complete occlusion of the arterial supply to the brain were used. Hypothermic temperatures of 28°C to 30°C were obtained by first immersing the patient in an ice tub and subsequently transferring him to a Therm-O-Rite blanket. The left subclavian, left common carotid, and the innominate arteries were isolated according to a technique described previously. A polyethylene catheter was introduced into the right jugular vein and passed distally according to a predetermined measurement so that the tip lay at the jugular bulb. Simultaneous arterial specimens were obtained from an inlying catheter in the femoral artery. In most instances 4 observations were obtained. The initial sampling was done at varying temperatures some time prior to the arterial occlusion (basal sample). The second sampling was done immediately prior to the arterial occlusion, the third immediately upon release of the occlusion, and the fourth 3 to 5
minutes following the release of the arterial occlusion. Because of technical difficulties, such as clotting in the tubing, it was not possible to obtain all the specimens from each patient.

Blood-oxygen and carbon-dioxide analyses were made in duplicate by the manometric method of Van Slyke and Neill, as modified by Kety and Schmidt. Glucose was determined by the iodimetric titration method of Somogyi, and lactic acid by a modification of the method of Miller and Muntz.

RESULTS

The necessary assumption has been made that after circulation to the brain has been interrupted for prolonged periods, the composition of the first blood to flow through the brain upon release of the occlusion should be a reflection of the metabolic changes that have occurred in the intracellular fluids during the period of occlusion. The blood obtained from the jugular-bulb samples can be assumed to be representative of mixed cerebral venous blood. Similar techniques have been applied in the study of renal physiology. The values for oxygen and carbon dioxide are shown in Table 1. The low values of arterial oxygen saturation in these patients is indicative of their acutely ill state and their reduced hemoglobin concentration. The arterial oxygen saturation remained relatively constant during the period of sampling, since all the patients had their respiration controlled by the anesthesiologist. The arteriovenous differences for both oxygen and carbon dioxide were lowered appropriately as the temperatures of the brain decreased (pre-occlusion sample). The immediate post-occlusion specimens demonstrated a significant lowering of the jugular venous oxygen content and a rise in jugular carbon-dioxide content.

Arteriovenous differences are difficult to interpret in the immediate post-occlusion samples since the brain has been deprived of blood during the period of occlusion. It has been assumed that the first venous samples obtained after occlusion represented a composite of metabolic events occurring during the occlusion plus those occurring during the first passage of blood through the brain after the circulation had been restored. Obviously the arteriovenous differences are important only in the latter phase. There was, however, a significant rise in the respiratory quotient from the basal and pre-occlusion values to the immediate post-occlusion value, which then returned to normal in the specimens obtained 3 to 5 minutes after occlusion.

In Table 2 the length of occlusion is given for each study, as well as the respiratory quotient, and the arteriovenous differences for both glucose and lactate. Although the data are not firm, it would appear that the longer the period of occlusion the greater the rise in respiratory quotient. This is demonstrated graphically in Fig. 1. The plasma-glucose values in all patients were elevated, and reached levels as high as 200 to 300 mg. per cent. This undoubtedly was ascribable in part to the direct effect of hypothermia, and to the fact that most of the patients had received an intravenous infusion of glucose during the initial stages of the operative procedure. The data for arteriovenous glucose levels are widely scattered and the chemical determinations are not accurate because of the high plasma values. Nevertheless, the arteriovenous differences for glucose show a decrease in the post-occlusion specimen and in one instance an actual release of glucose by the brain. The arterial lactic-acid levels were also extremely elevated, ranging from 10 mg. per cent to 85 mg. per cent, a finding that was reported previously by us and by others. The arteriovenous differences indi-