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Effect of Head Turning on Blood Flow in Lateral Sinuses of Nonhuman Primates

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The pattern of blood flow leaving the cranium via the lateral sinuses and internal jugular veins is significantly altered by head rotation. This effect is documented in the baboon and macaque monkey by Doppler flow recording and by angiography. This phenomenon may affect the validity of cerebral blood flow data determined by venous sampling and may have significance in angiographic interpretation and in the clinical course of patients with a hypoplastic or occluded lateral sinus or internal jugular vein.

It has been generally assumed that a relatively fixed proportion of the total cerebral blood effluent leaves the cranium via the right and left lateral sinuses. However, using a monkey to study the effects of a variety of factors on cerebral blood flow, one of us (L. G. D.) incidentally noted a shifting pattern from one lateral sinus to the other one with head turning. Using chronically implanted Doppler flow meters on the lateral sinuses and angiography, we tried to determine the effect of head turning on flow in the lateral sinuses in several nonhuman primate specimens. Our findings are reported, and some potentially important diagnostic and therapeutic implications are discussed briefly.

Materials and Methods

Doppler flow meters were implanted on the lateral sinuses of a baboon weighing about 28 kg and six macaque (*Macaca fascicularis*) monkeys weighing 5–6 kg. Continuous, calibrated, simultaneous, separate recordings of blood flow through both lateral sinuses as well as recordings of the summed total cerebral blood flow through both lateral sinuses were obtained. In order to maintain conditions as natural as possible, without use of general anesthesia, all of the Doppler flow recordings were collected while the animals were sitting in a chair, completely awake, and performing spontaneous, voluntary head-turning movements. The technical details are described more fully elsewhere [1].

Two of the macaque monkeys subjected to angiography had clear plastic catheters (ID, 0.040 inch [1.02 mm]; OD, 0.070 inch [1.79 mm]) chronically implanted in the left atrium and in the aorta by open thoracotomy. The aortic catheters were introduced into the proximal descending aorta without fluoroscopic guidance. Although we intended to place the catheter tip in the ascending aorta in both cases, angiography demonstrated the tip to be located in the left subclavian artery in one of the animals. Therefore, cerebral angiography was done by injecting contrast material into the ascending aorta in one animal and into the left atrium in the other one.

In both cases, we injected 5 ml of Renografin-76 over 1 sec on three separate occasions for serial frontal filming of the head and neck in an occipital projection with the animals supine and the head in the neutral position, and with the head turned about 45° to the right and left. For convenience of filming, using an anteroposterior film changer and overhead x-ray tube combination, appropriate head turning relative to body orientation was actually achieved by a combination of head and body rotations in opposite directions. Magnification and subtraction were used. The angiograms were obtained with the aid of intramuscularly administered ketamine and Xylocaine anesthesia. All catheters and flow meter leads were chronically buried subcutaneously in the interscapular region but externalized for recordings and angiographic procedures.

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Results

Technically satisfactory flow recordings were obtained repeatedly from the baboon and from four of the six macaque monkeys. There was an essentially reciprocal relation in the flow of blood in the right and left lateral sinuses with head turning. This effect was easily reproducible both with respect to different animals and in the same animal with time and was noted throughout head-turning periods lasting for about a minute (fig. 1). The effect was also reproduced with head turning of a short duration (fig. 2). Relative blood flow changes rather than absolute changes measured in milliliters/minute were obtained. The magnitude of the changes varied depending on the degree of head turning, which at its maximum produced complete or nearly complete cessation of flow in one or the other lateral sinus (fig. 2). The summed or total cerebral blood flow through the right and left lateral sinuses remained remarkably constant throughout the periods of recordings, regardless of head position (fig. 2). Angiography demonstrated a less striking but similarly shifting pattern of blood flow in response to about 45° head turning (fig. 3).

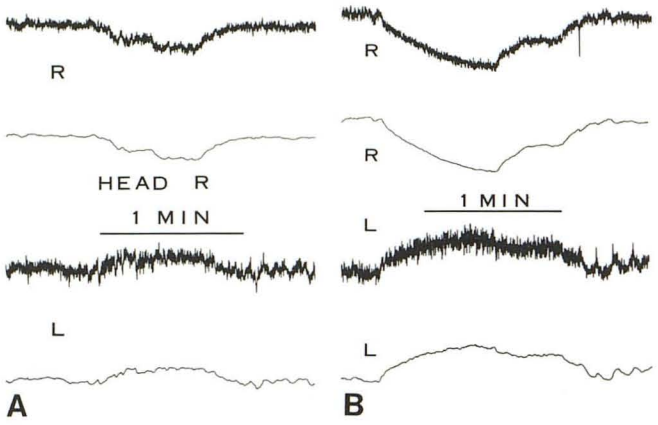

Fig. 1.—Lateral sinus flow recordings in baboon, head turning to right. **A**, Top two tracings represent relative blood flow in right lateral sinus with sensitive (*upper*) and dampened (*lower*) recordings before, during, and after spontaneous head turning to right for about 1 min. Bottom two tracings represent similar simultaneous flow recordings from left lateral sinus before, during, and after same episode of head turning to right. Upward displacement of curve indicates relative increase in flow and vice versa. **B**, Similar effect of head turning on separate occasion in same animal. Essentially reciprocal relation of flow through right and left lateral sinuses on both occasions (cf. **A**). Slight differences in appearance of recordings between **A** and **B** can be explained by different degrees of head turning.

Discussion

The vertebral venous system (meningorachidian plexus) has abundant anastomoses with the venous sinuses of the base of the skull and the internal jugular veins in the region of the foramen magnum. Dilenge and Perey [2] found this system to be the major outflow tract of the cerebral circulation in both the rhesus monkey and man when the body was in the upright position, whereas the internal jugular veins served as the major drainage route when the body was in the decubitus position. They postulated that this shifting phenomenon of venous drainage reflects postural variations in the intracranial and intraspinal cerebrospinal fluid pressures. No postural (supine versus upright) blood flow changes of this nature can account for the laterality of blood flow changes that were observed in association with head turning in the present investigation. The flow meters were placed on the lateral sinuses and reflected essentially the entire cerebral venous outflow rather than just the effluent through the internal jugular veins.

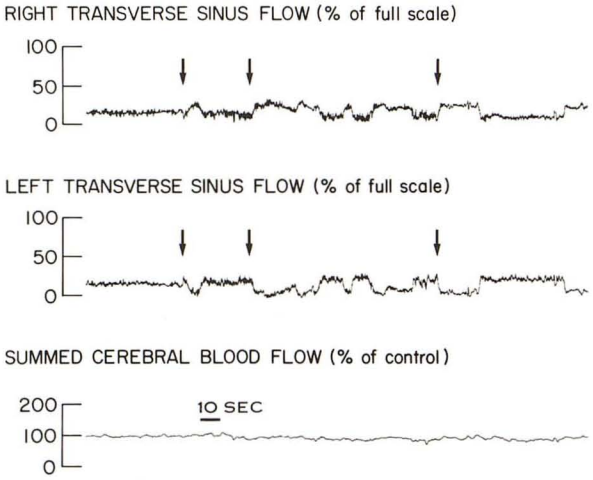

Fig. 2.—Simultaneous blood flow recordings from right and left lateral sinuses and summed flow through sinuses in macaque monkey. Although percentage scale is arbitrary and adjustable, zero value is reliable indicator of no flow. Note reciprocal relation of flow in right and left lateral sinuses with head turning lasting only a few seconds. *Arrows* in top two tracings denote onset of head turning on three occasions. Other short episodes of head turning during illustrated recording demonstrate similar blood flow changes in right and left lateral sinuses. Bottom tracing shows no significant alteration in summed cerebral blood flow over summed control blood flow before head turning.

Watson [3] noted the effect of head rotation on internal jugular vein blood flow during cardiac catheterizations in 60 infants and children who had various congenital cardiac anomalies. Flow was observed fluoroscopically by injecting contrast material through a transfemoral catheter advanced into one or both internal jugular veins. Rotation of the head to almost 90° caused complete occlusion of the ipsilateral vein in all 16 children who were anesthetized and in 25 of the other 44 who were examined with or without sedation. In 24 of the 41 children with venous obstruction during head rotation, only 75° rotation was needed, and in 15 of them only 60° was required. These observations are consistent with the results of our present investigation, which showed *decreased* blood flow in the lateral sinus toward which the head was turned.

Watson [3] stated that flow in a catheterized and injected internal jugular vein was not affected by contralateral rotation of the head. This statement is in apparent conflict with the results of our investigation, which showed *increased* blood flow in the ipsilateral lateral sinus and internal jugular vein with contralateral head turning. Watson's investigation did not lend itself well to detection of this phenomenon.

Watson [3] also observed a narrowing in the middle third of the internal jugular vein in response to ipsilateral rotation of 45° or more, presumably due to soft tissues related to

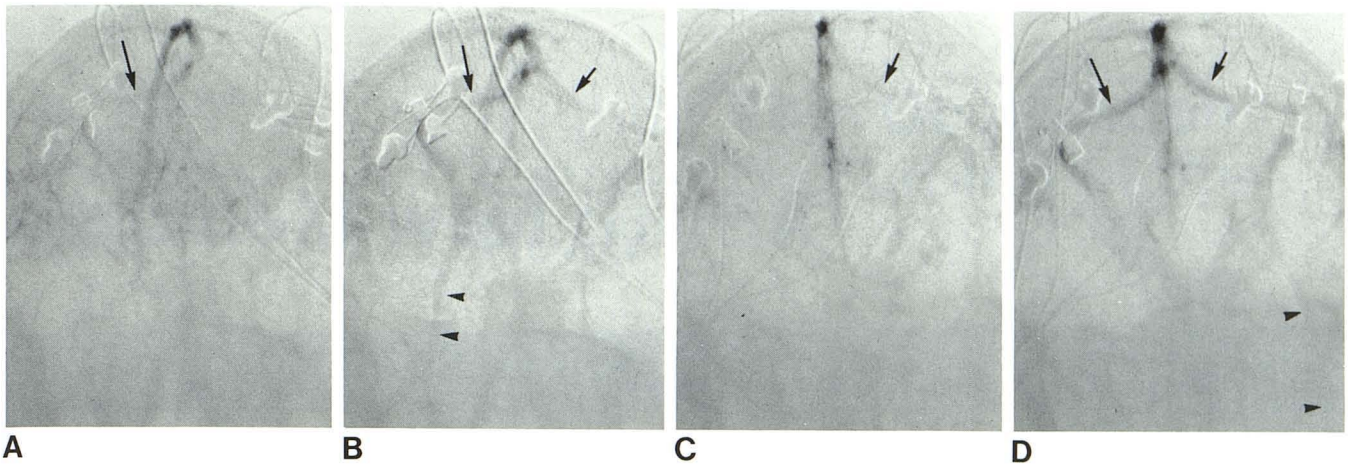

Fig. 3.—Head and neck angiograms in macaque monkey after intraatrial injection of contrast medium. Head was maintained fairly straight anteroposteriorly, and body was rotated in relation to head. **A** and **B**, During head rotation to left relative to body position. **B** was exposed 1 sec after **A**. Dominant flow through right lateral sinus and internal jugular vein demonstrated by only right lateral sinus opacification in **A** (*arrow*), only right internal jugular vein opacification in **B** (*arrowheads*), and slightly more dense opacification of lateral sinus on right (*long arrow*) than left (*short arrow*) in **B**. **C** and **D**, **D** was exposed 1 sec after **C**. These films, obtained during head rotation to right relative to body position, show dominant flow through left lateral sinus and internal jugular vein. Although intensity of opacification of lateral sinuses in **D** is not noticeably different on right (*long arrow*) versus left (*short arrow*), overall pattern of flow is different in **C** and **D** as compared and contrasted with pattern in **A** and **B**. Note opacification of only left lateral sinus (*arrow*) in **C** and definite opacification of only left internal jugular vein (*arrowheads*) and no visualization of right internal jugular vein in **D**.

the sternocleidomastoid muscle. Withdrawal of the catheter just after an injection of contrast material did not affect the obstruction. It is of interest that changes in cervical venous hums caused by rotation of the head are well known. No blood flow measurements were made in the internal jugular veins in the present investigation. However, significant flow changes in the internal jugular veins undoubtedly can occur in response to head turning, as demonstrated by flow recordings from the lateral sinuses in our present study as well as by flow changes observed angiographically in the internal jugular veins by Watson [3] and by us. Furthermore, it seems logical to conclude that the changes in lateral sinus flow observed in our study almost certainly are secondary to altered patterns of blood flow in the neck and/or area of the foramen magnum.

On the basis of our findings and those of Watson [3], one may speculate regarding some potentially important diagnostic and therapeutic implications. Determination of cerebral flood flow or other blood flow-dependent data such as venous oxygen saturation by sampling from only one internal jugular vein may give misleading information during head turning, which may alter not only flow rate but the ratio of venous return from intra- and extracranial origins. Head turning during angiography could lead also to a mistaken diagnosis of lateral sinus occlusion. On the other hand, head turning might be used effectively in deliberately attempting to direct flow into one or the other lateral sinus. If one lateral or sigmoid sinus or internal jugular vein is congenitally hypoplastic, thrombosed, or surgically occluded, prolonged head turning toward the opposite side, as during sleep or an operation, might cause significant obstruction to the egress of blood from the brain. This could lead to an undesirable and even dangerous rise in intracranial pressure and may be the cause of some postoperative complications that have been difficult to explain in the past. A prolonged, adverse head position could even produce sufficient venous stasis to cause a lateral sinus thrombosis.

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