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Vascular Velocity Measurements in the Central Nervous System

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During the past four years, we have been interested in changes of circulation patterns of the human brain. Much has been written concerning the angiographic appearance of the circulation, and still more information has been compiled concerning flow measurements as determined by the Fick principle. Because of finite periods of observation, the serial angiograms have given but a fleeting animated indication of the cerebral circulation, while measurements, as noted by the Fick principle, do not always reflect the cerebral flow or the true clinical appearance of the patient.

The important arterial inputs and venous outputs of the brain can be measured by external collimated detectors.

INSTRUMENTATION AND TECHNIQUE

For this study, we have used a two chanel system consisting of dual scintillation probes (Nuclear-Chicago DS8), connected to rate meters (Nuclear-Chicago 8350). The pulses are fed just prior to the binary dividing network through a cathode follower to an Ampex No. 354 Tape Deck. Here the pulses are stored and later are processed through the rate meters to a Heiland 1508 oscillograph. After completion of standard angiography, 0.2 cc of radioactive albumin is injected and monitored by probes over the distal carotid artery in the cervical area.

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The output is observed with another probe over the inion. More complete details have been described (1–3).

More recently, this system has been used for velocity measurements by repositioning the probes. The initial measurements are performed as previously described. However, the next series of observations is made over the sagittal sinus between two measured points. The final tracing is made by positioning the two probes on 3 cm centers over the carotid jugular areas of the neck.

OBSERVATIONS

In the normal cerebral circulation, it is possible to detect a radioactive bolus of radioactive albumin after it has been injected through a carotid puncture site (Fig. 1). Here one notes the original spike of activity, and because the activity returns in the adjacent jugular vein, there is a reappearance of the activity. If a probe is placed over the torcula or confluence of the sinuses, there is a passage of the material beneath the probe on its way to the jugular vein. One may readily measure the arteriovenous transit times and note prolongation of this time in certain conditions.

We have extended these measurements to the other portions of the venous channels because we have been interested to know if various portions of this system have different velocities. As predicted, there is a velocity gradient between arterial input and venous output. In the patient considered within the normal range of blood pressure and without intracranial lesions, there is a linear relationship (Fig. 2) between the major arterial input, the sinuses, and the jugular vein, when velocities are plotted versus time of occurrence of the event. A hypertensive patient (Fig. 3) having a pulse rate of 82 and a blood pressure of 190/120 mm mercury, was noted to have a more acute velocity gradient. It was felt this individual had severe arteriosclerosis with narrowing of the vessels, in addition to his hypertension.

In addition, if one observes velocity measurements with patients harboring hemisphere lesions (Fig. 4), one is immediately concerned about the apparent asynchronism of the cerebral circulation and the "apparent wandering" of the sagittal sinus velocity. Gradually, the anterior sagittal sinus peak coincides in time to the torcular peak and may migrate to the opposite side of the graph so that one thinks in terms of a "negative" velocity. This may be nothing more than an expression of a deviation of the circulation to one of the venous shunts. In this instance, (Fig. 5) the material arrives via the deep venous circulation at the torcula before the venous circulation of the sinus.

Other tracings (Fig. 6) are more difficult to interpret, but can be correlated when the tracings are matched with the angiograms. In this instance, the tracing is contaminated by circulation in branches of the external carotid. Later, the torcula tracing is elevated because of a prolonged discharge through the torcula. Measuring over the midline yields a tracing showing a prolonged plateau of four seconds over the anterior sinus. In this instance, a prefrontal vein empties for a prolonged period. As noted in the angiogram, there was absence of parietal lobe filling and poor sinus emptying to the torcula. At first there was a torcula response

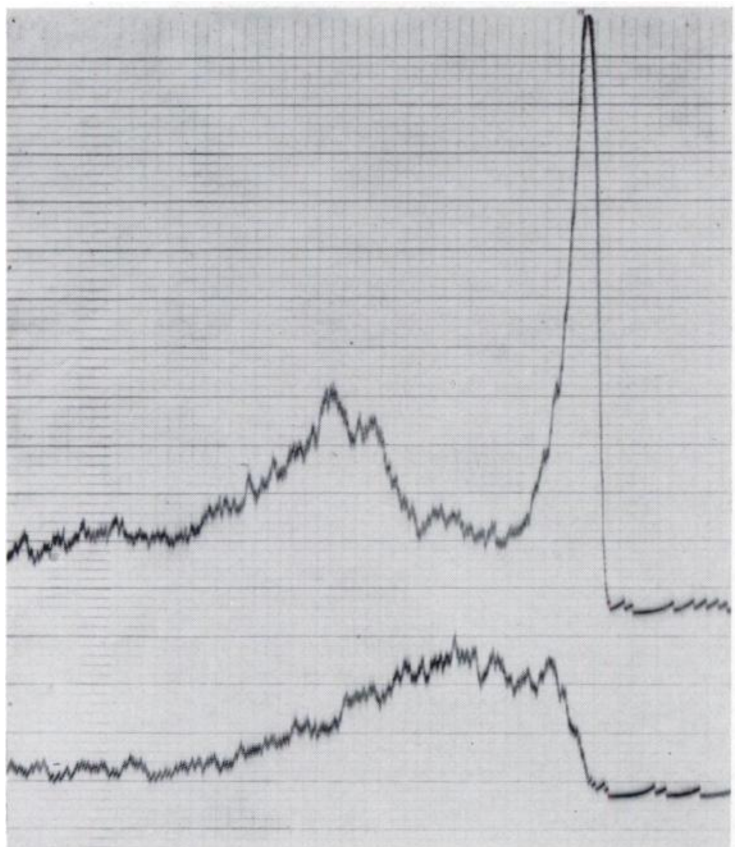

Fig. 1. Normal Circulation. Vertical lines 1 sec time intervals. (From BELL, R. L., *J. Nuclear Med.* 5:9, 1964)

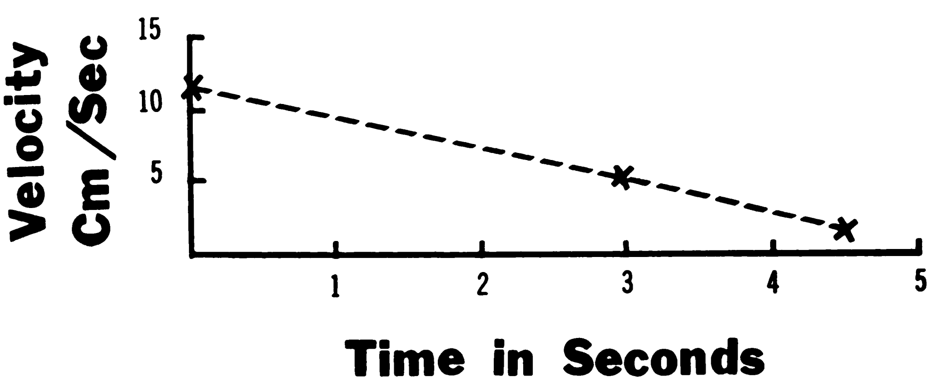

Fig. 2. Velocity measurements in normotensive patient.

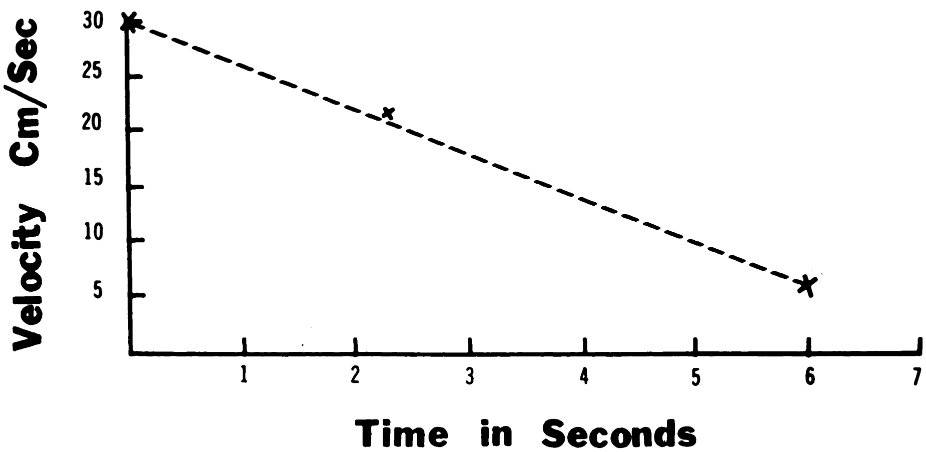

Fig. 3. Velocity measurements in hypertensive patient.

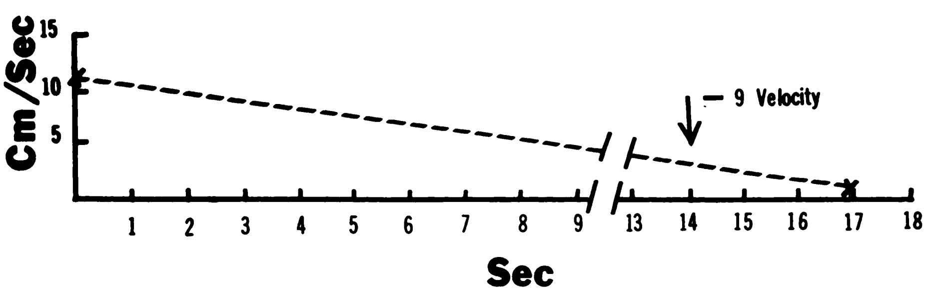

Fig. 4. Impairment of sagittal sinus velocity in presence of cerebral swelling.

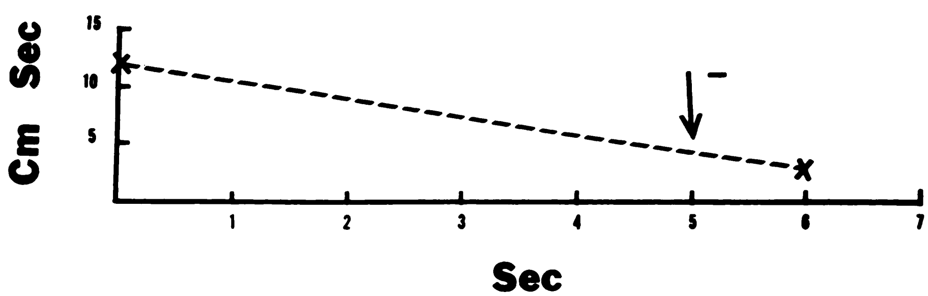

Fig. 5. Decreased velocity along sagittal sinus in patient having a vascular shunt through a tumor.

because of the external carotid circulation, and later there was a second response because of sagittal sinus material and drainage from the deep vein of Galen. Tracings from the jugular vein showed marked irregularity with peaks of activity related to turbulence generated by respiratory excursions and irregular contributions from the intracranial circulation by way of shunts in the tumor or the shunts between the main venous pathways.

DISCUSSION

The cerebral circulation has a contribution from a number of arterial sources and drains via numerous veins and sinuses. The velocity gradients are orderly except when disturbed by intracranial pressure or processes which tend to alter cerebral circulation. There are a number of shunts which may operate and account for abnormalities in the measurements.

In order to explore the unknown more fully, the techniques used must become more dynamic and functional. For this reason, we would advocate that the newer method should be applied to both carotid arteries and jugular output simultaneously, and that other points be selected for velocity measurements. As can be seen by these measurements, other techniques which view the head as

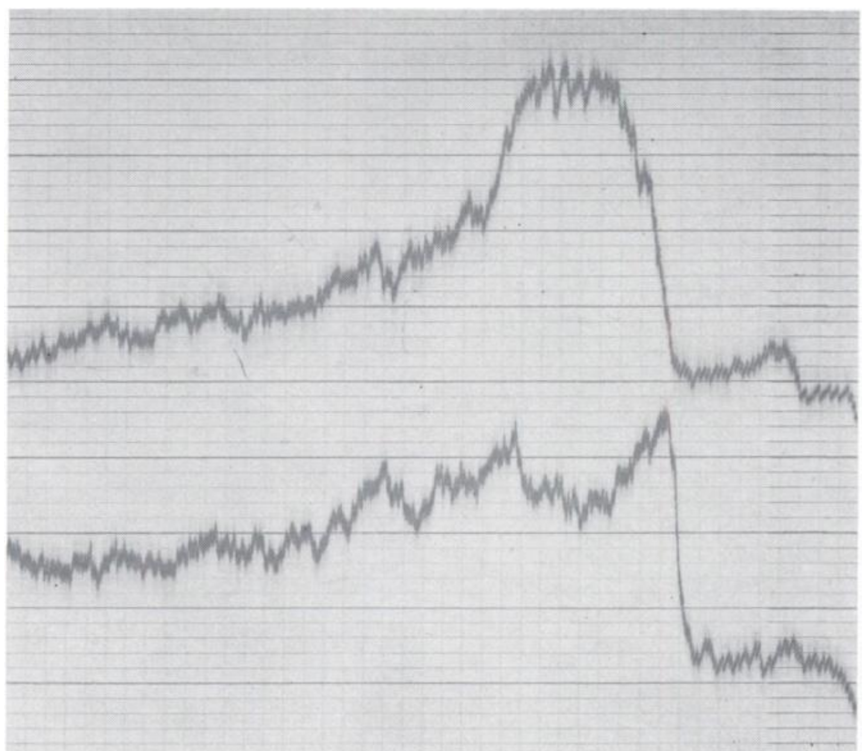

Fig. 6. Example of complex curve obtained from patient harboring large left hemisphere tumor. Top tracing obtained over anterior sagittal sinus. Lower tracing from inion. Vertical lines are 1 sec.

a whole tend to integrate the data and may well show total uptake or total cerebral flow, but do not consider the wide variations in the pattern of flow within the central nervous system. In the future, we hope to add other channels to monitor points simultaneously and to calculate circulation through certain channels.

CONCLUSIONS

Through the evaluation of tracings dealing with passage of a radioactive bolus through the circulation, it is possible to derive velocity measurements for certain segments of the cerebral circulation. These observations can be verified and amplified by simultaneous angiography. The normal circulation has a velocity gradient which is predictable, however, in those harboring a central nervous system disease, there may be shunts or impedances which block this normal gradient.

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