Regional Cerebral Blood Flow in Patients with Intracranial Tumors

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For many years a wealth of information concerning the vascular histopathology of brain tumors and their angiographic appearance has been available. The histological appearance of abundant proliferating thin-walled vessels might suggest that these vessels allow a high blood flow value and that they possess little capacity for normal active regulation of vessel diameter. Furthermore, cerebral tumors would seem to affect the function and the circulation of neighboring cerebral structures. With these circulatory aspects of cerebral tumors in mind it was decided to study some tumor cases, applying the newly developed regional cerebral blood flow (rCBF) technique based on \textsuperscript{133}Xenon clearance measurements, in order to gain more quantitative data than that obtainable by angiography. In preliminary studies by Cronqvist, et al., abnormally high rCBF values were commonly seen in the region of cerebral tumors. Their findings have been confirmed in the present study which, in addition, emphasizes certain grossly pathological CBF responses to changes in arterial carbon dioxide tension or arterial blood pressure in the focal and perifocal regions of the brain of patients suffering from cerebral tumors.

Method

The \textsuperscript{133}Xenon clearance method has been described previously.\textsuperscript{7,15,17,24,27,31} It will therefore be presented only briefly here. Sixteen extracranial scintillation detectors with NaI (TI) crystals were used to follow the washout clearance of the radioactive inert gas administered by rapid intraarterial injection. Each crystal measured 11.5 mm in diameter and 5 mm in thickness, and the internal dimensions of the lead collimator were for each crystal 12 mm in diameter and 43 mm in length. The impulses coming from the probes, after discrimination, were stored on magnetic tape and subsequently replayed via a scaler and a ratemeter coupled to a writing potentiometer. The ratemeter and writer had a time constant of 1 sec.

A solution of 2 or 3 mCi of \textsuperscript{133}Xenon dissolved in 4 to 5 ml saline was injected over 1 to 2 sec through a polyethylene catheter into the internal carotid artery, and the clearance curves in the control state were followed for 10 min (Fig. 1). A maximal counting rate of about 25,000 counts/min was reached in most channels. From these 16 linear curves, the average blood flow of each region was calculated by the equation:

\[
rCBF(10) = \frac{\lambda \cdot \Delta H \cdot 100}{\Delta A} \text{ml/100 g/min},
\]

where \(\lambda\) is the partition coefficient of \textsuperscript{133}Xenon between the blood and average brain tissue (a value of 1.15 being usually used in nonanemic subjects); \(\Delta H\) is the difference between the maximal height of the curve at the beginning and at 10 min (the maximal impulse counting rate in counts per min minus that after 10 min of clearance); 100 is a constant that converts the flow value into the unit of flow per min for 100 g of tissue; and \(\Delta A\) is the total area under the linear clearance curve for the 10 min of clearance. This value is read directly from the scaler as the sum of all of the impulses during the 10-min examination period minus the background counting rate.

To examine the normal and pathological responses of the cerebral circulation to various artificially induced stimuli, the following so-called "functional tests" have been used: hypocapnia induced by voluntary hyperven-
tillation; hypercapnia induced by inhalation of 8% CO₂ in air; hypertension induced by intravenous infusion of either Angiotensin or Aramine; hypotension induced by injecting Prozil or Ansolysen.

During the functional tests, clearance curves were logarithmically recorded for 2 min. The flow in each region was estimated from the initial slope of the clearance curve (Fig. 1),

\[ r\text{CBF}_{(\text{initial})} = 100 \cdot \lambda_g \cdot 2.30 \cdot \frac{D}{100 \text{ g/min}} \]

where \( \lambda_g \) is the partition coefficient of \(^{133}\)Xenon between blood and gray matter of the brain, a value selected since the initial slope is normally dominated by the blood flow of the gray matter. A standard value of 0.88 is used, as then the entire constant \( 100 \cdot \lambda_g \cdot 2.30 \) becomes simply 200. The 2.30 value is approximately equal to \( \log_10 \) 10; it is the factor that converts decade logarithmic values (\( \log_{10} \)) to natural logarithm (\( \log_e \)) as follows:

\[ \log_e x \approx 2.30 \cdot \log_{10} x. \]

In Eq. 2, \( D \) is the numerical value of the slope of the curve in the first minute.

The logarithmical clearance curve of the normal brain tissue in the first 2 min is always practically monoexponential during eucapnia. After the first 2 min the slope decreases, and typically the normal curve followed logarithmically for 10 min can be described by two exponential functions. This decrease in the initial slope after 2 min occurs earlier, after only 1.5 or even after only 1.0 min at very high flow value (CBF > 70 ml/100 g/min). This normal phenomenon is due to the more rapid desaturation of the fast component at the high flow level and called “curve transformation.” In practice it is usually not difficult to distinguish curve transformation from pathological multieponential 2-min curves, as the latter occur at any flow level and tend to have a much more pronounced and more early bending.

In the temporal region a very fast component is seen at the start of the clearance curve due to Xenon passing rapidly through this region within the large cerebral arteries to reach cerebral tissue in other parts of the brain (Fig. 2). This shunt-like peak is here called the “carotid peak” to emphasize its origin and location.

**Normal Cerebrovascular Regulation**

In attempting to understand the alterations in rCBF which one observes with intracranial neoplasms when applying the above mentioned functional tests, it is necessary to have a basic understanding of the normal cerebrovascular regulation. A brief summary of the normal responses of the cerebral vessels is therefore given here.