The Pattern of Location of Cerebral Metastatic Tumors*

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This study concerns the pattern of location of metastatic tumors within the cerebrum, excluding structures of the cerebellum and brain stem. Some consideration also will be given as to the reasons why emboli of tumor, as well as other emboli, have a tendency to lodge repeatedly in a certain area of the brain.

One of the most extensive studies of metastatic brain tumors was made by Courville, who used a series of 40,000 autopsies at the Los Angeles County Hospital. A total of 221 cases of metastatic brain tumors were reviewed post mortem by him in that series. The parieto-occipital area was described as the region of highest incidence where such metastatic tumors occurred. Previous reports relative to the site of predilection of cerebral metastatic tumors have been confined as a rule to the specific lobes of the brain involved.

Materials and Methods

A new method was used in this study. It consisted of plotting the centers and the outlines of the tumors as accurately as possible on a drawing of the brain. Excellent localization of these tumors was made possible by use of the radioactive mercury$^{203}$ brain scan. Operative findings and autopsy reports were reviewed whenever possible as a further check on the site and the size of the tumors.

Fig. 1 shows a radioactive mercury$^{203}$ brain scan with the skull traced in position from the routine roentgenogram of the skull. The outline of the metastatic tumor demonstrates itself quite clearly. Fig. 2 constitutes a tracing of the outline and the center of the tumor in a drawing of the skull and brain, as well as it could be shown from the scan and from operative findings.

Thirty-two consecutive cases of metastatic cerebral tumors encountered from December 1960 to March 1963 were taken as a sample. The centers of these metastatic lesions as projected directly lateralward on a drawing of the brain are shown in Fig. 3.

Twenty-seven consecutive cases of glioblastoma multiforme, which occurred over the same period of time, were also taken for comparison. The centers of these primary tumors were plotted in Fig. 4.†

Another method then was used to show further the predilection of metastatic tumors for a certain area of the brain. The procedure

† Only the locations of the tumors as projected on a single left lateral view of the brain were considered for this study. However, the locations were also plotted on a frontal view of the brain when developing the data. Of the metastatic tumors 20 were located in the right hemisphere and 12 in the left hemisphere. Fourteen of the primary tumors were located in the right hemisphere and 13 in the left hemisphere.

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Fig. 1. Radioactive mercury (Hg$^{203}$) brain scan of a patient with a single metastatic cerebral tumor. The outline of the skull is obtained from the routine roentgenograms of the skull.
used by meteorologists to plot charts of thickness for use in weather forecasting was borrowed and applied here. The outlines of all 32 metastatic tumors then were traced carefully on a single drawing of the brain. Lines then were drawn through the intersections of the outlines of the tumors to make a chart of thickness or a map of contours. This is shown in Fig. 5, and indicates the per cent of the tumors that overlapped certain areas of the brain. The area of the brain within the inner line of contour was involved by over 50 per cent of the metastatic tumors in this series.

Results

The results of this study as seen from the diagrams indicate a definite predilection for metastatic cerebral tumors to locate along the posterior aspect of the Sylvian fissure in the region of the junction of the temporal, parietal, and occipital lobes. The primary brain tumors showed no such tendency, and these tumors appeared to be distributed more evenly with respect to volume of brain.

The area of the brain with the highest incidence of involvement by metastatic tumor as shown by the overlap method is found in the region deep to area 39 of Brodmann. This region of the brain receives its blood supply from the angular branch of the middle cerebral artery. All the metastatic tumors within this series were found to be located within the distribution of the middle cerebral artery.

Comment

It is interesting to speculate as to why one region of the cerebrum, more than another, should demonstrate an increased involvement with metastatic tumors. We believe this can be explained on the basis of principles of arterial blood flow.

Coman et al., showed by injecting tumor cells into the left side of the heart of experimental animals that the relative number of tumors arising in various tissues depended upon the actual number of emboli lodging in the capillaries of such tissues. With metastatic cerebral tumors, relatively more neoplastic emboli apparently are arriving in the capillary bed just posterior to the Sylvian fissure than in other regions of the brain. This is the region supplied by the terminal branches of the middle cerebral artery.
One explanation for why the emboli of tumor would be more likely to pass into the terminal branches of the middle cerebral artery can be given by using fluid-flow principles applied to blood flow in arteries. First it must be proved that emboli in arterial blood flow have a tendency to be located near the axis of the lumen of the artery. Laminar or smooth flow probably does exist during much of the cycle of flow, especially in the medium and small arteries, despite the pulsatile nature of the flow and the elasticity of the arteries. In this type of flow, the maximum velocity occurs at the center of the tube with the rate of flow tapering off to zero at the wall of the tube. This profile of velocity is represented by a parabola. A particle or embolus caught in such a pattern of flow is directed toward the axis of the lumen of the tube. The reason for this phenomenon can be explained by the application of Bernoulli’s theorem. This principle applies in the familiar aspirator which is used on a water faucet to produce suction in the chemistry laboratory. It can be represented by the formula:

\[ p_1 + \frac{1}{2} \rho v_1^2 = p_2 + \frac{1}{2} \rho v_2^2. \]

In this formula, \( p \) represents pressure, \( v \), velocity, and \( \rho \), density. During the flow of a fluid in one direction, the lateral pressure exerted varies inversely with the square of the velocity of flow. As indicated, the velocity of flow is greatest near the axis of the lumen of the tube and less near the wall; and therefore the pressure on a particle in this pattern of flow would be greatest on the side of the particle nearest to the wall of the tube. This difference in pressure results in a force on the particle toward the axis of the lumen as well as a rotary force. This force would be relatively more significant on a large particle such as an embolus than it would be on a smaller particle such as a blood cell. Actually, the same principles would hold for turbulent flow; but the forces would apply only near the wall and not near the axis of the lumen where the profile of velocity is blunted.

The tendency for particles to be directed toward the axis of the lumen of a tube during flow of fluid is supported by experimental work reported in the chemical engineering literature. Newitt et al. have demonstrated conclusively with the use of high-speed photography the tendency of particles within a mixture to streamline along the axis of a tube.

A reason can therefore be given why neoplastic emboli would tend to lodge in the distribution of the terminal branches of the middle cerebral artery (Fig. 6). Emboli located near the axis of the lumen of the internal carotid artery most likely would pass the smaller branches such as the posterior communicating, and the anterior cerebral arteries, and would continue into the larger middle cerebral artery. The emboli also would be likely to miss the smaller side branches of the middle cerebral artery and would continue into the terminal branches of the artery before lodging in the capillaries.

The same principles apply to other emboli

![Fig. 5. This diagram represents the per cent of the metastatic tumors that overlapped the above areas of the brain.](image)

![Fig. 6. Schematic drawing of emboli and blood in cerebral circulation.](image)
as well as to emboli of tumor. Many of the metastatic brain abscesses seen at this center in recent years also have been observed to have been located in the parietal region: in the region of high incidence of metastatic neoplasms. This tendency for location in the parietal region applies to abscesses seen frequently in cases of congenital heart disease and lung abscess, but does not apply to those caused by direct extension through the dura mater. The principles also could apply to other organs. The early metastatic lesions of the lung often are found in the periphery of the pulmonary field rather than near the hilum. The neoplastic emboli in such instances could be traveling to the terminal branches of the pulmonary arteries.

Summary

Thirty-two consecutive cases of metastatic cerebral tumor were reviewed and these tumors were plotted as accurately as possible on a drawing of the brain. A definite site of predilection for these tumors was found posterior to the Sylvian fissure near the junction of the temporal, parietal, and occipital lobes. This region of the brain receives its blood supply from the terminal branches of the middle cerebral artery. No such predilection was found in a series of primary tumors which appeared to be located more evenly with respect to volume of brain. A possible reason for this discrepancy was explained in detail using principles of flow of fluid as applied to blood flow in arteries.

References