AJNR

CT prognostic criteria of survival after malignant glioma surgery.

J Andreou, A E George, A Wise, M de Leon, I I Kricheff, J Ransohoff and S H Foo

AJNR Am J Neuroradiol 1983, 4 (3) 488-490
http://www.ajnr.org/content/4/3/488

CT Prognostic Criteria of Survival after Malignant Glioma Surgery

John Andreou,[1] Ajax E. George,[1] Arlene Wise,[2] Mony de Leon,[3] Irvin I. Kricheff,[1] Joseph Ransohoff,[2] and Sun-Hoo Foo[4]

The serial pre- and postoperative computed tomographic (CT) scans of 115 patients entered in the Cooperative Brain Tumor Study between 1975 and 1982 were analyzed in order to define CT prognostic criteria and to test the hypothesis that radical glioma surgery prolongs patient survival. The CT parameters of mass size, associated edema, and intensity of enhancement were quantitated on all scans. Clinical parameters evaluated included gender, age, length of survival, and useful (Karnofsky > 30) survival. Data analyses indicated postoperative residual tumor burden was inversely related to length of survival ($p < 0.01$). Postoperative associated edema and intensity of image enhancement were also of prognostic value and showed an inverse relation to survival. Younger patients proved more likely than older patients to attain long-term survival. Residual tumor burden of less than 45 mm diameter on postoperative CT scans was associated with 70% chance of long-term survival. These findings support the radical surgical management of glioma.

Current surgical practice advocates maximal glioma resection followed by radiation and chemotherapy [1, 2]. The contribution of radical versus conservative surgical treatment to length and quality of patient survival has not been conclusively established. We analyzed the serial pre- and postoperative computed tomographic (CT) scans of patients who participated in the Cooperative Brain Tumor Study between 1975 and 1982 in order to define CT prognostic criteria and to test the hypothesis that radical surgery of malignant glioma increases length as well as quality of survival.

Materials and Methods

One hundred fifteen cases treated between 1975 and 1982 were reviewed. Seventy-four patients were men (age range, 30–76 years; mean, 55.3) and 41 were women (age range, 22–72 years; mean, 54.3). One hundred nine patients were white, four were black, and two were oriental. The pathologic diagnosis in all cases was astrocytoma, grade III or grade IV according to the classification of Kernohan et al. [3]. Sixty-eight tumors were located in the right hemisphere, 44 were in the left hemisphere, and three were bilateral. Thirty-two were frontal, 27 parietal, 13 occipital, 40 temporal, and three were deeply located. Thirty-four lesions demonstrated deep extension.

All surgeries were performed under the operating microscope with the aid of the Sonic dissector (Cavitron). Perioperative steroids were used in all cases. The objective of the surgery was gross total removal whenever feasible. Whole brain radiation was administered with opposing parallel fields in a total dose equivalent to 6,000 rads (60 Gy). Chemotherapy comprised or included carmustine (BCNU) in most cases.

Serial CT scans were obtained according to the following protocol: The preoperative scan (designated 01) was obtained an average of 13.4 days before surgery (range, 1–230 days). The first postoperative scan (designated 02) was obtained an average of 19.1 days after surgery (range, 1–251 days). The postirradiation scan (designated 03) was obtained an average of 82.7 days after surgery (range, 10–178 days). Additional scans were then obtained at 2 month intervals until the patient's death.

Clinical Parameters

Clinical parameters evaluated were gender, age, race, tumor grade and location, type of chemotherapy, Karnofsky score [4], survival, and useful survival. Survival was defined as the period between surgery and the patient's death. Useful survival, an indicator of quality of survival, was defined somewhat arbitrarily as the length of time between surgery and the point at which the patient's Karnofsky score reached 30.

CT Parameters

CT features quantitated were mass size, extent of edema, and intensity of enhancement. Mass size was quantitated on the slice showing the largest amount of tumor by measuring the two largest perpendicular diameters of the ring enhancement, summing them, and correcting for minification. Thus, for example, the preoperative (01) tumor mass size in a case of frontal glioma is determined to be 96 mm (fig. 1A), while the postoperative (02) residual tumor burden in the same case is 45 mm (fig. 1C). Edema was similarly measured (fig. 1B) by summing the two largest perpendicular diameters of peritumoral radiolucency and correcting for minification. This measurement therefore encompassed the ring lesion. Intensity of enhancement was subjectively rated on a four point scale as either none, mild, moderate, or intense. A more precise measure was not performed because of variations in scanning equipment, injection

This work was supported in part by Brain Tumor Study Group grant N01-CM-17473.

[1] Department of Radiology (Neuroradiology), New York University Medical Center, 550 First Ave., New York, NY 10016. Address reprint requests to A. E. George.
[2] Department of Neurosurgery, New York University Medical Center, New York, NY 10016.
[3] Department of Psychiatry, New York University Medical Center, New York, NY 10016.
[4] Department of Neurology, New York University Medical Center, New York, NY 10016.

AJNR 4:488–490, May/June 1983 0195–6108/83/0403–0488 $00.00

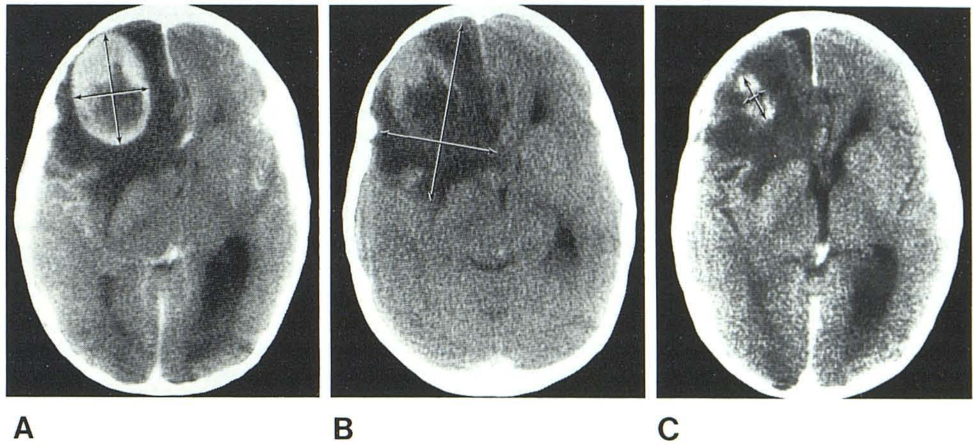

Fig. 1.—Frontal glioma. **A,** Preoperative contrast scan with ring enhancement. Sum of two largest perpendicular diameters (*arrows*) with correction for minification yields CT parameter defined as mass size 01 (= 96 mm). **B,** Preoperative scan without contrast enhancement. Sum of two largest perpendicular diameters (*arrows*) with correction for minification yields CT parameter defined as extent of edema 01 (= 140 mm). **C,** Postoperative contrast-enhanced scan after frontal craniotomy and glioma resection. Sum of two largest perpendicular diameters (*arrows*) with correction for minification yields CT parameter described as residual tumor burden (mass size 02) (= 45 m).

times, and body weight relative to amount of contrast medium administered.

Typically, both residual tumor burden and associated edema are reduced on the first postoperative scan and further reduced on the postirradiation (03) scan. The parietal glioma in figure 2 shows further reduction in ring diameter on the postirradiation scan (fig. 2B) as compared with the first postoperative scan (fig. 2A). Associated edema is also reduced.

An example of total resection (i.e., residual tumor burden = 0) is shown in figure 3. The large occipital glioma in the preoperative scan (fig. 3A) is intensely enhancing and associated with extensive edema. On the postoperative scan obtained 21 days after surgery (fig. 3B), residual mass effect is minimal and associated edema is slight. The ring seen on the preoperative scan has been entirely excised.

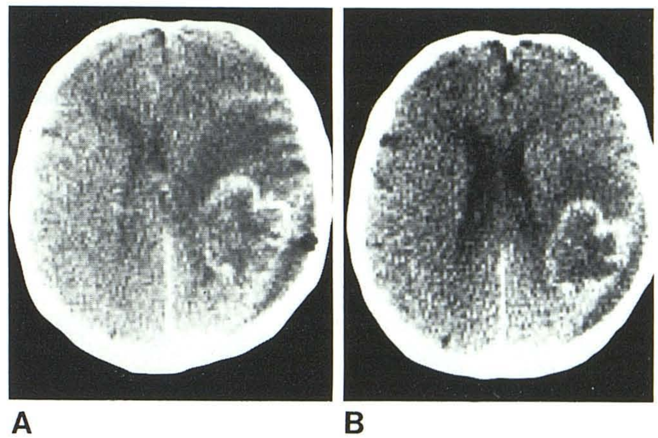

Fig. 2.—Parietal glioma. **A,** Contrast-enhanced scan at 2½ weeks postsurgery. Residual tumor burden (mass size 02) = 110 mm. **B,** Postirradiation scan. Residual tumor burden (mass size 03) = 100 mm. Associated edema is also reduced.

Data Analysis

Pearson product correlations were derived between length of survival and the CT parameters and length of survival and other clinical parameters, respectively. In addition, Student *t*-tests were performed to compare serial CT mass size in the long-term survival (>700 days) and short-term survival (<700 days) groups.

Results

Tumor Burden versus Survival

Results for absolute survival and useful survival were very similar. All results presented below refer to useful survival.

The Pearson product correlations between CT parameters and useful survival for 98 patients are shown in Table 1. Preoperative (01) mass size is not significantly related to the length of survival. Residual tumor burden after surgery (mass size 02) is inversely related to length of survival with a correlation coefficient of −0.48 ($p < 0.01$); thus, the size of residual tumor burden, not the size of the tumor before surgery, defines the chances of survival. Tumor size on the postirradiation scan (mass size 03) is also inversely related to length of survival ($r = -0.50$; $p < 0.01$). The other two CT parameters, extent of associated edema and intensity of enhancement, are also related to postoperative longevity. Postoperative edema is only weakly associated with length of survival, apparently reflecting the confounding influence of this parameter. On the postirradiation scan, however, the amount of persistent edema is more strongly related to length of survival ($r = -0.49$; $p < 0.01$).

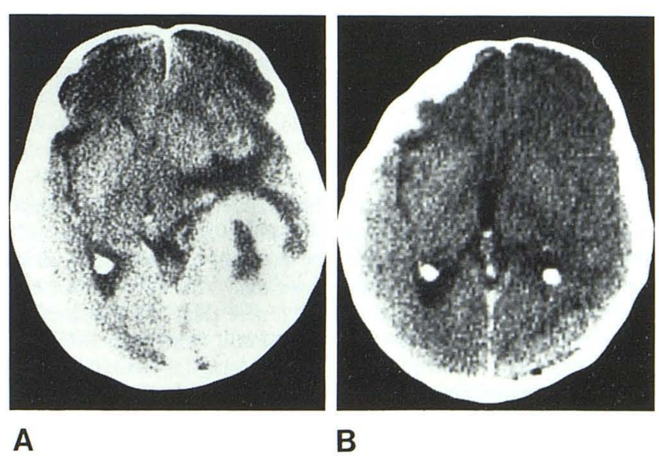

Fig. 3.—Occipital glioma. **A,** Preoperative contrast-enhanced scan. Mass size 01 = 129 mm. Extensive peritumoral edema. **B,** Contrast-enhanced scan at 21 days postsurgery. Residual tumor burden (mass size 02) is minimal and associated edema is slight.

TABLE 1: **Pearson Product Correlations between CT Parameters and Useful Survival (n = 98)**

Scan Time	CT Parameter: Mass Size	Extent of Edema	Intensity of Enhancement
Preoperative (01)	NS	NS	−0.36*
Postoperative (02)	−0.48*	−0.31†	−0.45*
Postirradiation (03)	−0.50*	−0.49*	−0.54*

Note.—Useful survival is defined as the length of time between malignant glioma surgery and the point at which the patient's Karnofsky score reaches 30. NS = not significant.
* $p < 0.01$.
† $p < 0.05$.

TABLE 2: **Comparison of Serial CT Mass Size in Long- and Short-Term Survivors of Malignant Glioma Surgery**

Scan Time: Survival Group	Mean Mass Size (mm)	SD	t value	Degree of Freedom	Two-Tail Probability
Preoperative (01):					
L (n = 19)	70.1	17.5	−1.70	91	0.093
S (n = 77)	83.4	30.2			
Postoperative (02):					
L (n = 18)	25.7	21.5	−4.84	95	0.000
S (n = 79)	60.7	28.8			
Postirradiation (03):					
L (n = 19)	16.2	22.0	−5.33	95	0.000
S (n = 78)	62.3	36.0			

Note.—L = long-term (survival > 700 days after surgery); S = short-term (survival < 700 days after surgery); SD = standard deviation.

Not only postoperative and postirradiation but also preoperative intensity of enhancement is inversely related to length of survival. This correlation apparently reflects the reduced chance of survival in patients with intensely enhancing (i.e., highly malignant [5]) lesions.

A discriminant analysis determined that postoperative residual tumor burden of 45 mm or less (fig. 1C) was associated with a 70% chance of long-term (>700 days) survival; and postirradiation residual tumor burden of less than 30 mm was associated with a 78% chance of long-term survival.

CT Mass Size in Survival Groups

Results of Student t-tests comparing serial CT mass size in long- and short-term survival groups are shown in table 2. Preoperative (01) mass size was not significantly different between long-term survivors and those who survived less than 700 days. However, postoperative residual tumor burden (mass size 02) was significantly different between the two groups and more than twice as large in the short-term survivors than in the long-term survivors. An even greater difference was demonstrated for mean postirradiation residual tumor size, which was nearly four times as large in short-term survivors than in long-term survivors.

TABLE 3: **Significant Pearson Product Correlations between Clinical Parameters and Useful Survival (n = 99)**

Clinical Parameter	Correlation
Age	−0.30*
Karnofsky score:	
Preoperative (01)	0.19†
Postoperative (02)	0.43*
Postirradiation (03)	0.54*

Note—Useful survival is defined as the length of time between malignant glioma surgery and the point at which the patient's Karnofsky score reaches 30.
* $p < 0.01$.
† $p < 0.05$.

Clinical Parameters versus Survival

The Pearson product correlations between selected clinical parameters and useful survival for 99 patients are shown in table 3. A significant correlation was found between survival and age (r = −0.30; $p < 0.01$). Thus, as has been demonstrated previously by others, younger patients were more likely to attain long-term survival. The gender of the patient and location of the tumor were not related to survival statistics. The Karnofsky scores before and after surgery and after radiation therapy were all significantly related to survival, although preoperative (01) Karnofsky scores showed a correlation coefficient of only 0.19 ($p < 0.05$).

Summary

This study demonstrates that postoperative residual tumor burden is inversely related ($p < 0.01$) to length of survival and useful (Karnofsky > 30) survival. Residual tumor burden is defined by the first postoperative CT scan, obtained an average of 19 days after surgery, despite the potentially confounding presence of postoperative changes. The intensity of postoperative CT image enhancement and extent of postoperative edema on CT are also inversely related to length of useful survival ($p < 0.01$). Postoperative residual tumor burden of less than 45 mm is associated with 70% chance of useful long-term survival, and postirradiation residual tumor burden of less than 30 mm is associated with 78% chance of useful long survival. These findings strongly support the radical surgical management of glioma and indicate that postoperative as well as preoperative CT findings are useful prognostic criteria.

REFERENCES

1. Lieberman AN, Foo SH, Ransohoff J, et al. Long term survival among patients with malignant brain tumors. *Neurosurgery* **1982**;10:450–453
2. Ransohoff J. Surgical management of malignant brain tumors. *Natl Cancer Inst Moncgr* **1977**;46:145–150
3. Kernohan JW, Mabon RF, Svien GT, et al. Symposium on new and simplified concept of gliomas. *Mayo Clin Proc* **1949**;24:71–75
4. Lieberman A, Ransohoff J. Treatment of primary brain tumors. *Med Clin North Am* **1979**;63:835–848
5. Butler AR, Horii SC, Kricheff II, Shannon MB, Budzilovich GN. Computed tomography in astrocytomas. *Radiology* **1978**;129:433–439