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CT Prognostic Criteria of Survival after Malignant Glioma Surgery

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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 one was of mixed race 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.

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.
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 $01 (= 96 \text{ mm})$. 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 $01 (= 140 \text{ mm})$. 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 defined as residual tumor burden (mass size $02) (= 45 \text{ mm})$.

Fig. 2.—Parietal glioma. A, Contrast-enhanced scan at $2\frac{1}{2}$ weeks postsurgery. Residual tumor burden (mass size $02) = 110 \text{ mm}$. B, Postirradiation scan. Residual tumor burden (mass size $03) = 100 \text{ mm}$. Associated edema is also reduced.

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

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.

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 $\rho = -0.48 (p < 0.01)$; 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 ($r = -0.49; p < 0.01$).
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.

**REFERENCES**