Adding Chloroquine to Conventional Treatment for Glioblastoma Multiforme

A Randomized, Double-Blind, Placebo-Controlled Trial

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Background: Malignant cell clones resistant to chemotherapy and radiotherapy frequently lead to treatment failure in patients with glioblastoma multiforme. Preliminary studies suggest that adding chloroquine to conventional therapy may improve treatment outcomes.

Objective: To examine the effect of adding chloroquine to conventional therapy for glioblastoma multiforme.

Design: Randomized, double-blind, placebo-controlled trial.

Setting: National Institute of Neurology and Neurosurgery of Mexico.

Patients: 30 patients with surgically confirmed glioblastoma confined to 1 cerebral hemisphere, with a Karnofsky performance score greater than 70, no comorbid disease, and age younger than 60 years.

Interventions: Oral chloroquine at 150 mg/d for 12 months beginning on postoperative day 5 or placebo. All patients received conventional chemotherapy and radiotherapy.

Measurements: Primary outcome was survival after surgery; surviving patients were followed up to October 2005. Periodic evaluation using the Karnofsky scale and imaging studies, as well as hematologic tests and ophthalmologic examinations, was done in all patients.

Results: Median survival after surgery was 24 months for chloroquine-treated patients and 11 months for controls. At the end of the observation period, 6 patients treated with chloroquine had survived 59, 45, 30, 27, 27, and 20 months, respectively; 3 patients from the control group had survived 32, 25, and 22 months, respectively. Although not statistically significantly different, the rate of death with time was approximately half as large in patients receiving chloroquine as in patients receiving placebo (hazard ratio, 0.52 [95% CI, 0.21 to 1.26]; $P = 0.139$).

Limitations: The observed advantage of chloroquine may be due to chance; differences in pretreatment characteristics and conventional treatment regimens could not be adjusted for because of the small sample size.

Conclusions: Chloroquine may improve mid-term survival when given in addition to conventional therapy for glioblastoma multiforme. These results suggest that larger, more definitive studies of chloroquine as adjuvant therapy for glioblastoma are warranted.

Despite numerous advances in the diagnosis of glioblastoma multiforme, there have been relatively few advances in therapy, and the prognosis of patients with this disorder has not changed considerably during the past decades. Recent studies have shown that median survival after aggressive treatment combining surgery, radiotherapy, and chemotherapy is approximately 1 year (1–4). Even the most sophisticated approaches, such as stereotactic radiosurgery, have failed to improve survival or quality of life (5). There are 2 main reasons that explain the high rate of therapeutic failure: the infiltrative nature of glioblastoma multiforme and the presence of cancer cells resistant to radiotherapy and chemotherapy. The latter might be due to the unrestricted growth of resistant cell clones within the original tumor, which replace those cells initially susceptible, or to the emergence of new mutant cell clones resistant to the treatment. This phenomenon could be prompted by the high rate of mutagenesis of malignant glial cells, which is increased by both ionizing radiation and antineoplastic drugs (1, 2, 4, 6).

Antimalarial drugs, particularly chloroquine and quinacrine, are strong DNA-intercalating agents and are lysosomotropic; both actions in eukaryotic cells modify several cell functions. In cells with a high mitotic rate, such as cancer cells, chloroquine and quinacrine are antimutagenic (7, 8); however, they are not cytotoxic or antimitotic and do not exhibit a substantial antineoplastic effect (9). In cultured glioma cells and in malignant glioma in rats, we have shown that these substances have a strong potentiating effect on the antineoplastic action of carmustine and maintain the long-term susceptibility of malignant glioma cells to chemotherapy (10). On the basis of these experimental findings, we conducted a preliminary, open-label trial on patients with glioblastoma multiforme by administering chloroquine in addition to surgery and to the standard courses of radiotherapy and chemotherapy; when compared with concurrent controls, survival was statistically significantly longer in chloroquine-treated patients (6). After that initial experience, we conducted the present

Context

The median survival for patients with glioblastoma multiforme is 1 year despite aggressive treatment. Chloroquine interferes with cellular mechanisms that might cause treatment resistance.

Content

In this single-center, randomized, double-blind, placebo-controlled trial, 30 patients receiving surgery, chemotherapy, and radiotherapy for glioblastoma multiforme were randomly assigned to receive chloroquine or placebo for 12 months. Median survival was 24 months for patients who received chloroquine and 11 months for patients who received placebo. No patient stopped therapy because of toxicity.

Limitations

The number of patients was small, and the difference in survival was not statistically significant ($P = 0.139$).

Implications

Chloroquine, in conjunction with other treatments, may prolong survival in patients with glioblastoma multiforme. Larger clinical trials are needed.

—The Editors

double-blind, placebo-controlled study of chloroquine as adjuvant therapy for patients with glioblastoma multiforme.

METHODS

Patient Recruitment, Enrollment, and Follow-up

During a 40-month period (October 2000 to January 2004), 120 patients with clinical suspicion of a malignant brain tumor were screened at the National Institute of Neurology and Neurosurgery of Mexico. Of these patients, 30 participated in the present study. All patients fulfilled the following inclusion criteria: glioblastoma multiforme, which was confirmed by 2 independent pathologists on the histologic specimen obtained at surgery; fair clinical neurologic status with a Karnofsky performance score of 70 or higher at the time of diagnosis; absence of associated severe disorders, such as diabetes and hypertension; evidence on magnetic resonance imaging (MRI) scans that the tumor was restricted to 1 hemisphere of the brain; and age younger than 60 years.

Intervention

All patients participating in the study received the same conventional scheme of chemotherapy and radiotherapy: extensive tumor ablation by surgery; 4 courses of carmustine at 200 mg/m^2, one given every 5 weeks and the first given 8 weeks after surgery; and radiotherapy that began 3 weeks after surgery, for a total radiation dose of 60 Gy (6000 rads) separated in 30 to 32 courses with daily fractionated doses. All patients and their legal guardians signed the informed consent document, clearly stating their willingness to participate in a randomized, double-blind, placebo-controlled trial. Chloroquine tablets (Aralen, Sanofi-Synthelabo, Mexico City, Mexico), 150 mg, were commercially purchased, and identical placebo tablets were formulated; treatments were randomly distributed into 15 chloroquine and 15 placebo sets (each set was designed for 1-year treatment) and were coded at the laboratory of an independent investigator at another institution. We received the 30 sets coded and numbered, and they were administered in sequential order as the patients entered the trial. The study monitor sealed and kept the code until the end of the study. Therefore, the participants, those administering the treatment, and those assessing the outcomes were blinded to group assignment.

Chloroquine was administered at 150 mg/d, starting on day 5 after surgery, and was continued for 12 months; in a nontrial setting, chemotherapy and radiotherapy would have been completed before 12 months had passed. The dose of chloroquine used in this study was selected on the basis of several pharmacologic studies on toxicity, long-term administration, and antimalarial effectiveness (6, 7); it is also identical to the dose used in our preliminary study (6). The assignment of treatments was decodified in January 2005, when all patients had had surgery at least 1 year previously, and the follow-up continued until October 2005. Our institutional review board of research and the institutional board of ethics both approved the study. This study complied with the Consolidated Standards for Reporting Trials (CONSORT) items for a randomized trial (11).

Primary and Secondary Outcomes

Clinical evaluation after hospital discharge was done every 2 weeks, and MRI studies were done every 2 months. Tumor size was measured on the MRI scan taken before surgery; the largest diameter of the tumor on the axial planes was considered as a single value. Primary outcome was survival after surgery. Karnofsky score was determined at the time of diagnosis, 1 month after surgery, and 5 months after surgery. Signs of systemic toxicity induced by the therapy were studied monthly by routine analysis of peripheral blood, which included hematic biometry, blood chemistry, and hepatic tests. In addition, potential signs of drug toxicity in the retina as a result of chloroquine treatment were monitored monthly by ophthalmoscopic evaluation in all patients.

Statistical Analysis

Kaplan–Meier survival curves were plotted. Survival times in the 2 groups were compared by using the hazard ratio and 95% CI from a bivariate Cox regression. Statistical significance was assessed with the log-rank test. Other statistical comparisons were made by using the unpaired t-test and the Fisher exact test (SPSS, version 10.0, SPSS Inc., Chicago, Illinois).

Table. **Characteristics of Patients with Glioblastoma Multiforme**

Variable	Chloroquine Group (n = 15)	Placebo Group (n = 15)
Mean age (SD), y	40.8 (11.8)	46.1 (12.7)
Men/women, n/n	9/6	8/7
Mean tumor diameter before surgery (SD), mm	49.1 (13.8)	44.5 (9.0)
Mean duration of symptoms before surgery (SD), mo	5.5 (6.6)	3.7 (4.4)
Mean preoperative Karnofsky score (SD)	81.3 (9.9)	82.7 (11.6)
Mean 1-month postoperative Karnofsky score (SD)	81.3 (12.8)	82.7 (11.6)
Mean 5-month postoperative Karnofsky score (SD)	84.2 (10.7)	83.3 (13.1)
Conventional radiotherapy, n (%)	15 (100)	15 (100)
Conventional chemotherapy, n (%)	15 (100)	15 (100)
Clinical signs before surgery, n (%)		
Headache	12 (80)	10 (67)
Seizures	8 (53)	7 (47)
Nausea	7 (47)	7 (47)
Vomiting	6 (40)	5 (33)
Mental disturbances	4 (27)	3 (20)
Papilledema	5 (33)	3 (20)
Paresis	2 (13)	7 (47)
Diplopia	0	2 (13)
Hypoesthesia	1 (7)	0

Role of the Funding Source

RESULTS

Patient Characteristics and Follow-up

In the chloroquine group, the duration of symptoms and the diameter of the tumor were greater but the average age of the patients was slightly lower than in the placebo group; otherwise, the characteristics of patients were similar in the 2 groups (**Table**). Maximum, minimum, and median follow-ups were 59, 5, and 15 months, respectively. Radiotherapy or chemotherapy was not stopped in any surviving patient during the study period.

Survival

Median survival over the entire study period was 24 months for the patients in the chloroquine-treated group and 11 months for controls. At the end of the observation period, 6 patients (40%) from the chloroquine-treated group and 3 patients from the control group (20%) were still alive (**Figure 1**).

Secondary Outcomes

In October 2005, 6 patients from the chloroquine-treated group were alive. Of these, 1 had survived 59 months after surgery (**Figure 2**); 1 patient each had survived 45, 30, and 20 months, respectively, and 2 additional patients had survived 27 months. The patients from the control group had survived 32, 25, and 22 months, respectively. Although not statistically significantly different, the rate of death over time was approximately half as large in patients receiving chloroquine as in patients receiving placebo (hazard ratio, 0.52 [95% CI, 0.21 to 1.26]; $P = 0.139$). The observed data are consistent with proportional hazards assumption ($P = 0.92$).

Adverse Events

During the trial, no signs of retinopathy related to chloroquine toxicity were found in any patient. Follow-up hematologic results were similar between chloroquine-treated patients and control patients (results not shown); however, at the analysis done 8 months after the beginning of treatment, mean values of leukocytes and platelets were lower in patients from the chloroquine-treated group (7.5×10^9 cells/L vs. 9.9×10^9 cells/L [$P = 0.072$] and 170×10^9 cells/L vs. 219×10^9 cells/L [$P = 0.055$], respectively). These variables were again similar 1 month later. No other secondary reactions attributable to the treatment were detected during the trial. Nonetheless, no patients stopped receiving chemotherapy or radiotherapy or were excluded from the experimental blinded therapy because of treatment-related adverse reactions. No patient from either group discontinued treatment or was lost to follow-up. According to the common toxicity criteria from the National Cancer Institute (12), toxicity by chloroquine in this trial was graded 0 to 1 (absent or minimal) in bone marrow cellularity. During follow-up, 2 patients from the chloroquine-treated group (13%) and 4 patients from the control group (27%) had seizures that were adequately controlled with antiepileptic drugs; these events were considered secondary to the neoplasm rather than a complication of therapy in all patients.

Figure 1. Kaplan–Meier estimates of survival in 30 patients with glioblastoma multiforme who received chloroquine (*n* = 15) or placebo (*n* = 15) in addition to conventional therapy.
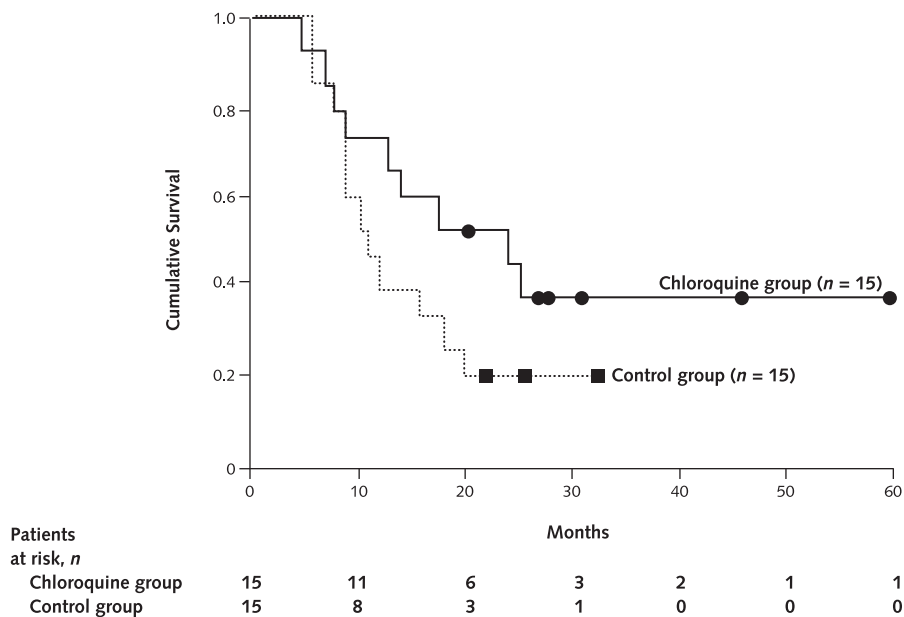
At the end of the observation period, 6 patients from the chloroquine-treated group and 3 patients from the control group survived.

DISCUSSION

The addition of chloroquine to the conventional therapeutic approach for glioblastoma multiforme may increase mid-term survival; however, this figure is higher in our study than that obtained recently with novel chemotherapeutic agents (13). The inclusion criteria and treatment of patients who participated in the current study were identical to those of the 18 patients in our preliminary open-label study of glioblastoma multiforme (6). The results of both studies were similar and support a mid-term beneficial effect of chloroquine in the treatment of this disorder. Chloroquine is not a cytotoxic substance, and a well-described, relevant antineoplastic effect does not exist. Therefore, we speculate that the mechanisms for this effect on therapy could involve either the enhancement of cytotoxicity induced by conventional treatments or the prevention of mutagenicity in neoplastic cells, which maintain their susceptibility to radiotherapy and chemotherapy by allowing them to elude the appearance of resistant cell clones.

Few other substances besides chloroquine have shown substantial effects on intracellular signaling events and cellular functions while lacking cytotoxicity; several studies of chloroquine have failed to show an effect on cell growth or clonogenic survival (14–16). Besides its well-known antiparasitic effects, chloroquine has incisive intracellular actions that have been widely used in experimental biology for the study of cellular functions (7, 17). In clinical medicine, the inhibition of tumor necrosis factor-α produced by chloroquine (which is highly dependent on phospho-

lipase A$_2$), together with other immunomodulating effects, has been used for many years to treat patients with chronic autoimmune disorders, such as systemic lupus erythematosus (18, 19).

Chloroquine exhibits an intense affinity for lysosomes ("lysosomotropism") within the cell metabolism that inhibit the enzymes phospholipase A$_2$, lysophospholipid acylhydrolase, and monoacylglycerol lipase; these enzymes release arachidonic acid from phospholipids (20–22). The consequence is inhibition of proteolytic processes in lysosomes and blockage of the metabolism of neoglycolipids (14, 23). Through these actions, several molecular signals at the interior of the cell are altered (21, 24–29). Chloroquine also has a strong DNA-intercalating activity (30, 31), which is independent of its lysosomotropism (32–34). Interaction of chloroquine with nucleic acids is incisive and initiates by a fast electrostatic attraction followed by a slow intercalation process (27); this intense binding produces structural perturbations in DNA that render it a poor substrate for endonucleolytic cleavage (8, 27). Chloroquine produces unwinding and relaxation of DNA supercoiling. In this process, 2 different events occur: direct DNA intercalation and inhibition of topoisomerase II, avoiding DNA fragmentation (32, 35, 36). In addition, DNA intercalators bind quadruplex DNA structures at the end of chromosomes inhibiting telomerase, an essential enzyme for the unlimited replicative potential of tumor cells (37). Of interest, despite its intense molecular activity on DNA, genotoxicity of chloroquine is minimal (16).

Figure 2. Magnetic resonance imaging scan of a patient with glioblastoma multiforme treated with chloroquine in addition to surgery, chemotherapy, and radiotherapy.
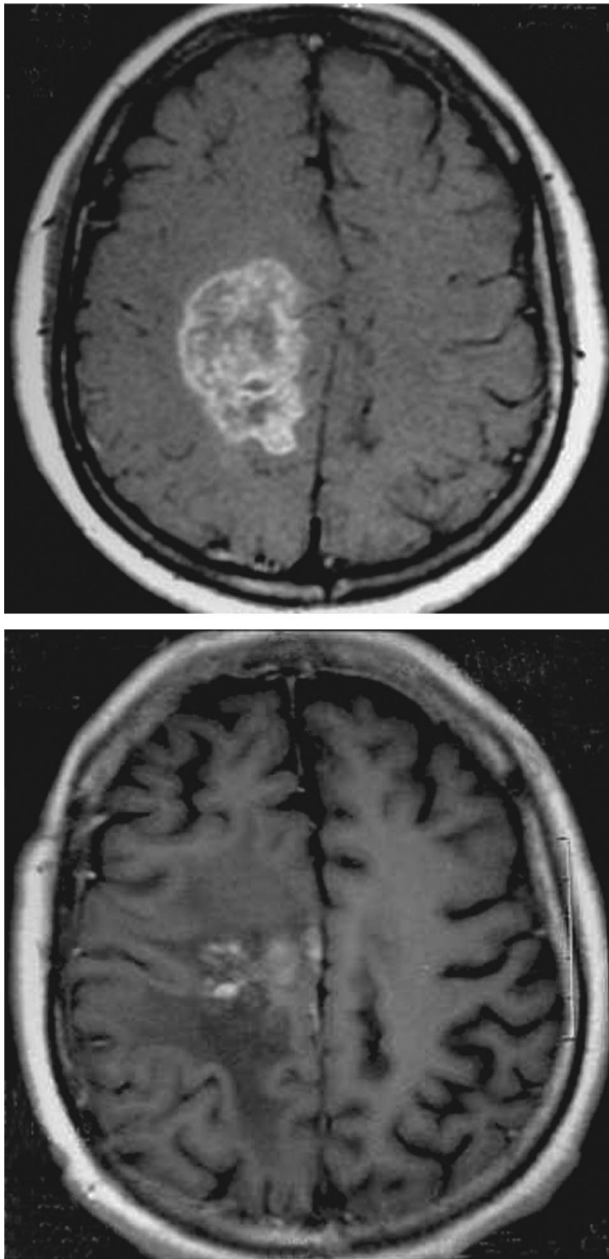
Top. A large mass is shown on the left hemisphere before treatment. **Bottom.** Forty-four months after the beginning of treatment, no evidence of tumor regrowth is seen. At this time, the patient's Karnofsky performance score was 100 (asymptomatic).

In vitro, chloroquine enters malignant glial cells, blocking the expression of antigenic proteins on their surface. Because of its curtailing action on DNA synthesis and DNA repair processes, chloroquine strongly potentiates the inhibitory effect of radiation on cell multiplication (38, 39). Although chloroquine alone is not cytotoxic, when associated with ionizing radiation, it produces severe ultrastructural lesions characterized by vacuolization of the endoplasmic reticulum, damage of mitochondria, and an increase of microtubules and microfilaments with subsequent alterations of the cytoskeleton in cultures of carcinoma and melanoma cells (38, 40).

It is also possible that additional intracellular actions of chloroquine may increase the susceptibility of malignant glioma cells to standard therapy. For example, some neoplastic drugs have extended permanence inside cancer cells because of elevation of endosomal and lysosomal pH that increases and maintains the concentration of lipophilic antineoplastic drugs, such as carmustine (21, 36, 41). A conspicuous effect of chloroquine, which has effectively reversed multidrug resistance of cancer cells, is preventing and delaying the outward cell transport of antineoplastic drugs, such as vincristine (36, 42). Finally, the addition of chloroquine to the culture medium of leukemic multidrug-resistant cells decreases resistance to vinblastine by 10- to 15-fold (15, 36, 43–47).

The addition of chloroquine to therapy for glioblastoma multiforme may increase survival at mid-term; however, the long-term prognosis continues to be poor. On the basis of these results, we suggest a large-scale, properly powered, randomized trial to clearly define a potential role for chloroquine in treatment of glioblastoma. Additional modifications to the regimen used in this study could improve our results. The daily dose of chloroquine was mild (150 mg). However, because the intracellular effects of chloroquine are dose-dependent (48), the dose could be selectively increased (for example, to 300 mg/d, which is still fairly well tolerated by humans) in subsequent trials during chemotherapy and radiotherapy; mutagenesis increases and therapy-induced damage of neoplastic cells is maximal at that time (38). Alternatively, chloroquine could be replaced with its analogue, quinacrine, which is more active than chloroquine in some of the cellular functions described previously (8, 10, 18, 42, 49).

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AD LIBITUM

Madrid March 11, 2004

How have you broken into my heart

All you who have gone?

Who never said goodbye,

Nor adios nor adieu

Nor any other farewell

To those you loved,

Nor said "Look after the children"

Or its equivalent in any language,

But simply went torn and shoeless

Into the heavens,

While those who sent you dreamed of Paradise.

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New Treatments for Malignant Gliomas: Careful Evaluation and Cautious Optimism Required

The treatment of patients with glioblastoma is a show-case for improved technology in many disciplines of medicine. Imaging technology has improved substantially, leading to more accurate and rapid diagnosis; better anatomic localization, which leads to improvements in neurosurgical results; and earlier detection of recurrent or relapsing disease. Surgical techniques have improved with better tumor delineation, which results in a higher percentage of patients having what seems to be complete tumor resection while maintaining or even improving neurologic function. Radiation therapy has also improved, beginning with the recognition that regional treatment is better than whole-brain radiation for most malignant primary brain tumors. Technological advances, such as conformal radiation and intensity-modulated radiation therapy, have resulted in more accurate delivery of treatment and therefore less collateral damage to normal neuronal structures. Many new chemotherapeutic agents have been developed and tested, and multicenter clinical trial groups have formed. However, until very recently, chemotherapy did not substantially improve outcomes when added to the other treatment methods.

Despite these advances in the process of care, patient outcomes have not changed very much. Even extensive surgical resection with documented removal of all visible tumor only prolongs survival by a few months. A study by Lacroix and colleagues (1) clearly showed that patients with glioblastoma who had greater than 98% resection fared better than patients whose tumors had less extensive resection (median survival, 13 months vs. 8.6 months). Although the outcome is better, patients having what the surgeon thinks is total resection have microscopic tumor infiltration into the surrounding brain, often detectable by obtaining a biopsy specimen several centimeters away. Similarly, radiation therapy clearly improves survival when compared with chemotherapy alone or with supportive care (2). However, with radiation after surgical resection, most studies show a median survival of only 12 months or less. Although radiotherapy is effective, some tumor cells survive irradiation. Chemotherapy has provided even less benefit. Most studies of the effect of administering chemotherapy after radiation have shown no statistically significant improvement in outcomes. Meta-analyses that combine these studies show a small benefit to chemotherapy (3–5). Recently, however, a large randomized clinical trial involving 573 patients showed that a regimen of chemotherapy and radiation was superior to radiation alone (6). In this study, patients received radiation alone or radiation with concurrent chemotherapy (temozolomide), then 6 months of temozolomide. The patients who received combination treatment had a median survival of 14.6 months

and a 2-year survival rate of 26%, compared with 12.1-month median survival and a 2-year survival rate of 10% in patients who received radiation alone.

These results have generated great interest in improving on this chemoradiation regimen. In this issue, the study by Sotelo and colleagues (7) examines the potential benefit of adding chloroquine to a treatment regimen consisting of radiation plus carmustine, a nitrosourea that has been used to treat brain tumors. The investigators performed a randomized, double-blind, placebo-controlled trial in 30 patients (15 in each arm) and found a large difference in median survival: 24 months for the patients in the experimental group versus 11 months for the patients receiving only carmustine and radiation.

These results seem quite striking, because patients in the experimental group survived twice as long as those treated with a conventional regimen. On the basis of these data, should chloroquine be added to chemoradiation for all patients with newly diagnosed glioblastoma? Should it become part of the standard of care? The authors do not claim that it should, but one could argue that the prognosis in patients with glioblastoma is so limited that a promising treatment should be seriously considered on the basis of 1 small trial.

Do we really have adequate proof that adding chloroquine enhances treatment? The small number of patients enrolled in Sotelo and colleagues' trial raises concern that the chloroquine and placebo groups differ in the frequency of prognostic factors that might influence outcome (statistically, 2 small random samples are more likely to differ than 2 large random samples). The investigators attempted to address this issue by comparing performance status and age, 2 well-established factors, in both groups. The patients in the experimental group were younger but had a slightly worse median performance status. However, additional factors exist, as shown by the recursive partitioning analysis performed by the Radiation Therapy Oncology Group on a large series of 1578 patients (8). This study confirmed the importance of age and performance status but also showed that additional factors, such as mental status and extent of tumor resection, permitted subclassification of patients into distinct prognostic groups. Sotelo and colleagues did not consider these additional factors.

Other prognostic factors, based on molecular tumor profiling, have only recently begun to be defined. For example, the extent of methylation of the promoter region of the *MGMT* gene, which codes for the protein that is associated with chemotherapy resistance, correlates with the outcome of brain tumor treatment with alkylating agents, such as temozolomide or carmustine (9, 10). Additional factors in tumor cells, such as the status of the *PTEN* gene,

a major factor in the activity of the Akt signal transduction pathway involved in tumor cell proliferation and resistance to apoptosis, may also have a major impact on outcome regardless of other clinical factors, such as age and performance status (11). Therefore, with a small patient sample, it is quite possible that patients with a good prognosis (methylated *MGMT* promoter, intact *PTEN* gene) were unevenly distributed between the 2 groups and that by chance, the experimental group "benefited" by this uneven distribution.

The trial done by Sotelo and colleagues is 1 of several small trials with promising results for patients with glioblastoma. In some of these small trials, an initially promising intervention has failed the test of a larger trial. For example, Valtonen and colleagues (12) tested bischloroethylnitrosourea (BCNU) embedded in a biodegradable polymer as treatment for patients with newly diagnosed glioblastoma. In this randomized, double-blind, controlled trial, all patients had surgical resection with implantation of a blank (no BCNU) or chemotherapy-containing polymer wafer. All patients then received radiation therapy. The study was stopped early after enrollment of 27 patients because of difficulty obtaining the experimental agent. Patients receiving the chemotherapy-containing polymer had a median survival of 53 weeks versus 40 weeks for those receiving placebo ($P = 0.008$). However, a subsequent study with the same design randomly assigned 240 patients with newly diagnosed brain tumors to either BCNU wafer or placebo (13). Survival with the BCNU intervention was better in the entire study sample. However, in the 201 patients with glioblastoma, the BCNU wafer did not show a statistically significant benefit over placebo. Similarly, a small phase II trial of preradiation chemotherapy using a 72-hour continuous infusion of cisplatin and BCNU looked very promising, with an objective response rate of 42% and median survival of 13 months (14). Again, the new regimen was not better than the standard regimen of radiation and adjuvant chemotherapy in a phase III trial (15). The clear lesson here, and in other fields of clinical medicine, is to avoid adopting new treatments on the basis of promising results in 1 or 2 small clinical trials.

Because of the sample size issue, the risk for uneven distribution of patients by prognostic category, and general caution about acting on the results of a small trial, it is not reasonable to endorse chloroquine as a standard of care. We should instead use the results of this trial to generate interest in studying this regimen more extensively. Given the cautions associated with Sotelo and colleagues' trial, perhaps it is too early to start a resource-intensive, appropriately powered phase III trial. Rather, the prudent next step would be a well-designed phase II trial with well-established historical controls (16). Stupp and colleagues (17) successfully utilized this strategy. Their initial phase II study of chemoradiation was promising and led to the successful phase III trial that provided level 1 evidence of the benefit of this regimen over the previous standard therapy (6).

Major advances in the treatment of brain tumors continue to be elusive. We should encourage the exploration of new therapies while taking a hopeful yet cautious approach to early promising results. We should also establish the infrastructure to support large clinical trials that can quickly determine the potential efficacy of a new regimen. Only through these shared efforts are we likely to get good evidence quickly about incremental improvements in treatment.

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Adding Chloroquine to Conventional Chemotherapy and Radiotherapy for Glioblastoma Multiforme

What is the problem and what is known about it so far?

Glioblastoma multiforme is a type of brain cancer that is difficult to treat. Even with aggressive treatment, including surgery, chemotherapy (cancer-fighting drugs), and radiotherapy (cancer-fighting radiation), most people with this disease only survive about 1 year after diagnosis. Glioblastoma multiforme is difficult to treat because the cancer cells develop genetic mutations that cause them to be resistant to treatment, which means that previously effective treatment no longer fights the cancer cells. Chloroquine is a drug that is most often used to treat malaria, an infection that is spread by mosquitoes in some parts of the world. Researchers have observed that chloroquine can make it more difficult for some cells to develop genetic mutations and have hypothesized that chloroquine might prevent glioblastoma cells from developing the mutations that cause them to become resistant to standard treatment. Early studies done in rats support this hypothesis.

Why did the researchers do this particular study?

To see whether adding chloroquine to standard treatment (chemotherapy and radiotherapy) for glioblastoma multiforme improves patient outcomes.

Who was studied?

30 patients with glioblastoma multiforme who received care at the National Institute of Neurology and Neurosurgery in Mexico. To be included in the study, patients had to be younger than 60 years of age, have glioblastoma that involved only 1 side of the brain, not have other major illnesses, and be well enough to care for themselves.

How was the study done?

From October 2000 through January 2004, the researchers randomly assigned patients who agreed to be in the study to receive either daily chloroquine, 150 mg, or a placebo pill that contained no active ingredient. The patients received chloroquine or placebo for 12 months beginning 5 days after surgery to remove the cancer. All 30 patients also received standard chemotherapy and radiotherapy. The researchers then followed patients to see who was still alive as of October 2005.

What did the researchers find?

As of October 2005, 6 of the 15 patients in the chloroquine group were alive compared with 3 patients in the placebo group. Surviving patients in the chloroquine group had survived 59, 45, 30, 27, 27, and 20 months after surgery compared with 32, 25, and 22 months for the surviving patients who received placebo. Median survival time was 24 months for patients in the chloroquine group and 11 months for patients in the placebo group. The median is the middle of the distribution, which means that half of the patients survived longer and half died sooner than the reported median survival time.

What were the limitations of the study?

Despite the promising findings, the study was too small to provide a definite answer about whether chloroquine improved survival in patients with glioblastoma multiforme. It was also too small to determine whether chloroquine leads to unwanted side effects.

What are the implications of the study?

This preliminary study suggests that larger, more definitive studies should be done to evaluate whether the addition of chloroquine to conventional treatment improves outcomes for patients with glioblastoma multiforme.