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# Sequentially Programmed Magnetic Field Therapy in the Management of Recurrent Anaplastic Astrocytoma: A Case Report and Literature Review

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## Key Words

Sequentially Programmed Magnetic Field Therapy · Anaplastic astrocytoma · Grade III astrocytoma · Recurrent astrocytoma · Pulsed Electromagnetic Field Therapy

## Abstract

**Background:** Anaplastic astrocytomas are progressive brain tumors with a tendency to infiltrate the surrounding tissue. Recurrence is very common, with recurrent tumors being extremely refractory to existing therapies.

**Case Presentation:** A 33-year-old woman presented with a history of an unprovoked fall, followed by seizures. An MRI scan revealed a mass in the fronto-temporo-parietal region of the brain, suggesting a primary tumor. She underwent craniotomy and surgical debulking of the tumor. The histology of the tumor tissue revealed an anaplastic astrocytoma. Follow-up MRI scans indicated the presence of a residual, rapidly progressing tumor. A 6-week course of fractionated radiation and concurrent chemotherapy with Temodar® (temozolomide capsules) did not stop tumor progression.

**Intervention:** Due to the failure of conventional therapies in preventing rapid disease progression, the patient volunteered to undergo a 28-day course of Sequentially Programmed Magnetic Field (SPMF) therapy.

**Results:** Immediate post-therapy MRI scan showed a cessation of tumor growth, and follow-up imaging at 6, 12, 24 and 36 months revealed a gradual but steady decrease in the size of the tumor. The patient reported an alleviation of clinical symptoms and a subjective improvement in the quality of life at 6, 12, 24 and 36 months following SPMF therapy.

**Conclusion:** The remarkable improvement of this patient suggests that SPMF therapy may be a valuable option for anaplastic astrocytoma, especially in recurrent and rapidly progressing tumors.

## Introduction

Anaplastic astrocytomas are pathologically classified by WHO as grade III tumors that demonstrate pleomorphism, increased mitosis and vascular proliferation, with a characteristic absence of necrosis seen in glioblastomas [1]. The currently accepted treatment modality for such tumors is surgical debulking, followed by external beam radiation and adjuvant chemotherapy [2]. However, due to the nature of the tumor, a complete surgical resection is almost impossible [3]. The prognosis is highly variable and dependent on the age of the patient, symptom duration, Karnofsky performance status, extent of resection, dose of radiation and several other factors [4]. Also, recurrence is extremely common, with subsequent tumors being highly refractory to further therapy [2]. The median survival period for patients with anaplastic astrocytomas is less than 2 years [5]. Anaplastic astrocytomas, in particular recurrent tumors, clearly have an unfavorable prognosis, affirming the need to explore new therapeutic modalities.

Sequentially Programmed Magnetic Field (SPMF) therapy is based on the principle that exposure to sequentially programmed electromagnetic fields can suppress tumor growth. The magnetic fields are delivered by a SPMF machine that consists of multiple magnetic field generators arranged in a circular fashion around the gantry. The fields from these generators are focused on the centre of the affected tissue with the aid of laser guides. The SPMF machine generates sequential pulsed magnetic fields of <30 milli-tesla in the range of 10–1,000 Hz. The field strength that the machine delivers is within the International Commission for Non-Ionizing Radiation Protection's safety norms [6].

A study assessing the SPMF therapy for terminally ill cancer patients showed appreciable pain relief and improvement in Karnofsky performance scores in 80% of the cases [7]. The failure of conventional modalities of treatment in preventing rapid tumor progression substantiated the use of SPMF therapy in the current study subject.

## Case Presentation

A 33-year-old woman presented at the Emory Adventist Hospital, Atlanta, Ga., USA, in October 2005 with a history of an unprovoked fall, followed by seizures a few hours later. A CT scan of the brain revealed a large mass in the right fronto-temporo-parietal region involving the basal ganglia, with features suggestive of a primary tumor. The patient underwent a right craniotomy with debulking of the tumor at the WellStar Cobb Hospital, Atlanta, Ga., USA. An aggressive parieto-frontal resection was done, and tumor tissue, roughly measuring 4 × 5 × 5 cm, was removed. Histopathological examination of the specimen revealed an astrocytoma with increased cellularity and the presence of mitotic figures, but without any evidence of necrosis or endothelial hyperplasia. The histological features were consistent with the diagnosis of an anaplastic astrocytoma (WHO grade III).

A post-surgical MRI scan revealed a persistent nodular enhancement within the right temporal lobe posterior to the resection cavity, suggesting residual disease in this location. The patient was started on fractionated radiation and concurrent chemotherapy. She was administered 34 fractions of 180 centigray (cGy) over a 7-week period, and prescribed 105 mg Temodar® (temozolomide capsules) daily for 45 days. This was followed by a 5-day course of high-dose Temodar (300 mg) one month after the completion of the initial cycle. Monthly follow-up investigations indicated the presence of a progressive tumor with increasing enhancement and edema. PET scan showed a hypometabolic lesion but Magnetic Resonance Spectroscopy showed that the lesion was progressing and the patient was advised to undergo a second surgery for decompression. The patient refused surgery and opted for SPMF therapy at the Institute of Aerospace Medicine (IAM), Indian Air Force, Bangalore, India.

At the time of admission in June 2006, the patient complained of tingling in the lower half of the left side of the face and left extremities, with some loss of recent memory. An MRI taken before starting the SPMF therapy showed a mass in the right fronto-temporo-parietal region measuring 3.82 × 2.3 × 2.32 cm (antero-posterior x transverse x supero-inferior). Based on the MRI findings, the fields from the

magnetic field generators were adjusted to focus on the centre of the tumor. The therapy was given for 1 hour, daily, usually at a fixed time, for 28 consecutive days.

An MRI scan taken on completion of the therapy showed a marginal reduction in mass ( $3.42 \times 2.19 \times 2.19$  cm), along with some reduction in the thickness of the peripherally enhancing component. The patient had subjective signs of recovery, with an improvement in memory and a complete alleviation of the tingling sensation in the lower half of the left side of the face and left extremities. The MRI scans performed 6 months after SPMF therapy showed a reduction in the size of the lesion ( $2 \times 2 \times 1.3$  cm), as well as a corresponding decrease in the thickness of the peripherally enhancing component and perilesional edema. Follow-up MRI scans at 12, 24 and 36 months after the SPMF therapy demonstrated a progressive decrease in the lesion size ([fig. 1](#)). PET scans at 12, 24 and 36 months confirmed that the tumor had become metabolically inactive.

The radiological responses were mirrored by similar improvements in subjective assessment. The Functional Assessment for Cancer Therapy – General (FACT-G) scores improved dramatically at 6 months post-therapy and were maintained at 12 and 24 months ([table 1](#)). Corresponding changes were also seen with the Karnofsky performance status, with scores of 70, 80 and 100 during pre-SPMF, immediate post-SPMF and 6 months post-SPMF therapy periods, respectively. A score of 100 was maintained at 12, 24 and 36 months post-therapy.

## Discussion

Several studies have demonstrated the efficacy of magnetic fields in preventing neoplastic progression in cancer cell lines and animal models. Prostate cancer cell lines exposed to 60 Hz sinusoidal magnetic field have demonstrated increased apoptosis and cell cycle arrest; the effect being mediated by the generation of reactive oxygen species [8]. Gastric adenocarcinoma cell lines treated with magnetic fields have shown a significantly higher incidence of apoptosis in comparison to untreated cells [9].

Exposure of mice mammary adenocarcinoma cells to pulsating magnetic fields was reported to cause a reduction in vascularization and an increase in tumor necrosis [10]. Similarly, mice with breast cancer xenografts exposed to pulsed magnetic fields were observed to have less lung metastasis and slower growth of tumors compared to sister controls [11].

Static magnetic fields, produced by nuclear magnetic resonance spectroscopy, induced apoptosis in tumor cells of hematopoietic origin due to an increase in cytosolic calcium. Such a response was not seen in normal mononuclear white blood cells exposed to the same magnetic fields [12].

Studies have also demonstrated that electromagnetic fields cause anti-tumor activity and a significant increase in apoptosis in tumors of treated animals, together with reduction in immunoreactive p53 expression [13]. SPMF therapy induces apoptosis of tumor cells through the same mechanism.

Centrioles control cell division, differentiation, morphogenetic status and the process of aging. The cells can divide only a defined number of times and then perish (Hayflick Limit). With each mitotic cycle, they lose one molecule in the cytoplasm, such that the daughter cell contains one molecule less than the mother cell. Microtubules and centrioles have their endogenous electromagnetic fields and can condense this energy required for transport of ions and organelles and duplication of centrioles during mitosis [14, 15]. In cancer, these electromagnetic fields are aberrant, which can be normalized by exposure of these cancer cells to SPMF therapy.

It is a well-known fact that the cell membrane potential of cancer cells is about  $-15$  mV to  $-30$  mV. Exposure of cancer cells to SPMF will normalize this potential, thereby halting

the process of cell proliferation. A cascade of effects follows normalization of cell membrane potential, such as an increased influx of calcium, potassium and magnesium ions and efflux of sodium and water out of cells, and reduction in intracellular acidity [16, 17].

The frequencies and field strength used in SPMF therapy are well within the specified norms of the International Commission for Non-Ionizing Radiation Protection. The magnetic fields do not have any harmful effect on the normal surrounding tissue. The previous studies conducted at the IAM have shown that SPMF therapy is a safe treatment modality [6, 7].

### Conclusion

The efficacy of SPMF therapy in this patient with a rapidly progressing anaplastic astrocytoma demonstrates the enormous potential of this new treatment modality. Considering the poor prognosis of anaplastic astrocytoma grade III with standard modalities of treatment, SPMF holds promise to improve overall survival and quality of life non-invasively.

### Acknowledgements

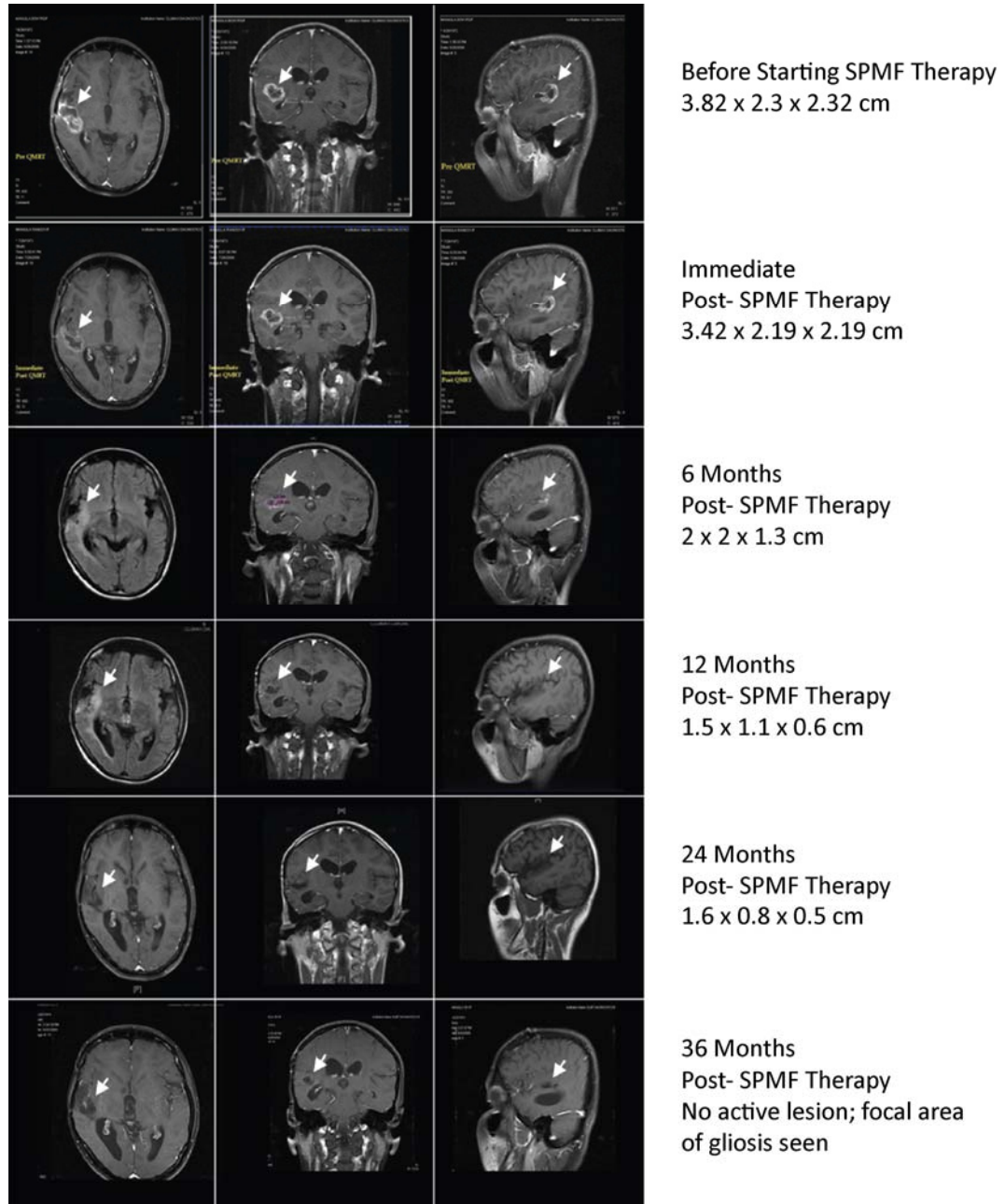
The author wishes to thank Dr. Kulkarni J.S., Dr. Subramanya H., Dr. Pankaj Tyagi and Dr. Garg R.K., all from the IAM, Indian Air Force, Bangalore; late Dr. Gopalkrishna A., Professor Emeritus, former Director of the Institute of Science, Nagpur; Dr. Khati C., Command Hospital Air Force, Bangalore; Dr. Iqbal Kaur, Bangalore; and Sgt. Ravi Shankar and Staff of the Department of Radiodiagnosis, IAM, Indian Air Force, Bangalore; for providing assistance in various ways during the management of this particular patient.

**Table 1.** FACT-G scores at various time points pre- and post-SPMF therapy

	Pre-SPMF therapy	Immediately post-SPMF therapy	6 months post-SPMF therapy	12 months post-SPMF therapy	24 months post-SPMF therapy
Physical well-being	4	4	0	0	0
Social/family well-being	5	4	15	15	15
Emotional well-being	5	3	0	1	0
Functional well-being	11	11	23	24	24

Physical well-being scores varied from 0 to 24 with higher scores indicating unfavorable subjective estimation. Social/family well-being scores varied from 0 to 16 with higher scores indicating favorable subjective estimation. Emotional well-being scores varied from 0 to 16 with higher scores indicating unfavorable subjective estimation. Functional well-being scores varied from 0 to 24 with higher scores indicating favorable subjective estimation.

**Fig. 1.** Serial MRI scans before starting SPMF therapy and at various time points following completion of therapy. The serial images at different time points show a gradual decrease in the size of the tumor after SPMF therapy. The tumor measurements are in antero-posterior × transverse × supero-inferior dimensions, respectively.



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