Rationale and Background on Tumor-Treating Fields for Glioblastoma

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Background: More than 150 years after the first description of glioma cells, patients with glioblastoma (GBM) continue to have a poor prognosis despite standard-of-care therapy. With the introduction of tumor-treating fields (TTFields) therapy for the treatment of recurrent GBM in 2011 and for newly diagnosed GBM in 2015, the opportunity to increase progression-free survival and overall survival while improving quality of life provides a welcome option.

Objectives: This article describes how TTFields therapy may be used in the treatment of patients with recurrent GBM.

Methods: This article provides oncology nurses with two case studies that examine how TTFields therapy can be integrated into the overall treatment paradigm.

Findings: These two patient case studies demonstrate the autonomy and lack of adverse effects that TTFields therapy offers to patients with GBM.

Key words: tumor-treating fields; Optune; glioblastoma; alternating electric fields; TTFields

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Glioblastoma (GBM) is a malignancy of the central nervous system. In the 1860s, Rudolf Virchow was the first to provide a pathologic description of glioma cells (DeAngelis & Mellinghoff, 2011). Johnson (1885) published the first attempted resection by A. Hughes Bennett. Bailey and Cushing (1926) provided the first modern pathologic classification of GBM. Modern medicine has evolved to the current standard of care of maximal safe resection followed by concurrent radiochemotherapy and then adjuvant chemotherapy. However, there remains no cure. Following U.S. Food and Drug Administration (FDA), 2011 approval, tumor-treating fields (TTFields) entered the oncologist's arsenal. TTFields use the device Optune® as an innovative therapeutic option approach for treating patients with GBM.

GBM is the most common malignant primary brain tumor. From 12,500–18,000 new cases of GBM are diagnosed annually in the United States (Ostrom et al., 2016; Schwartzbaum, Fisher, Aldape, & Wrensch, 2006). Prognosis remains poor, with about 15-month median survival from diagnosis with the current standard-of-care treatment (Stupp et al., 2005). Prior to 2011, treatments were limited to surgery, radiation, and chemotherapy. Effective chemotherapeutic options are limited, often leaving patients and providers with a sense of desperation in the face of this malignancy. At progression of disease, providers may offer additional chemotherapy from the limited armamentarium of FDA-approved therapies or may suggest clinical trials. At specialized treatment centers, re-resection or re-radiation may be considered.

Case Study: Recurrent Glioblastoma

Jason was a left-handed 28-year-old man approaching his wedding day when he experienced his first seizure while at work. Jason was taken from his office to the hospital by ambulance. Upon arrival to the emergency department, he experienced a second seizure. Jason was slow to recover full consciousness after the second seizure, prompting the
healing and too high to stimulate nerve or muscle tissue. TTFields treatment generates an intermediate-frequency electrical field within tissues and does not affect quiescent (non-dividing) cells. TTFields therapy exerts its effects on dividing cells by moving intracellular macromolecules and organelles toward the neck of the dividing parent cell. As the intracellular contents move toward the neck of the cell, they are trapped and the cell divides into abnormal daughter cells. Application of TTFields also inhibits proper formation of spindles during spindle tubulin polymerization. These effects on dividing cells ultimately result in apoptosis (programmed cell death) (Gera, Yang, Holtzman, Lee, & Swanson, 2015).

Systemic adverse effects are minimized with TTFields because the local administration of therapy is delivered via four transducer arrays placed directly on the scalp. The ceramic, disposable arrays are connected to the delivery device, Optune. When turned on, Optune delivers TTFields at a frequency of 200 kHz for treatment of GBM (Stupp et al., 2005). This frequency is too low to generate local tissue heating and too high to stimulate nerve or muscle tissue.

Benefits of Tumor-Treating Fields Therapy

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GBM include TMZ, bevacizumab (Avastin®), lomustine (Gleostin®), and carmustine (BiCNU® for IV use, Gliadel® wafers for intraoperative implantation). Each of these chemotherapies has an established adverse effect profile (see Table 1). Patients may experience hematologic toxicities, particularly with TMZ, an alkylating agent. In longer-surviving patients, there is a risk of developing a secondary malignancy, such as leukemia or myelodysplastic syndrome.

The localized, focal therapy delivered by TTFields provides for a lack of systemic adverse effects. Safety data from the EF-14 trial demonstrated notably lacking systemic adverse effects in TTFields therapy compared to chemotherapeutic agents (Stupp et al., 2015). The reasons for this are varied. The delivery of TTFields ceases when the device is turned off. This is in stark contrast to alkylating chemotherapies or anti–vascular endothelial growth factor therapies. The half-life of bevacizumab is 21 days; TMZ, lomustine, and carmustine all have prolonged expected nadirs for hematologic toxicities (Merck, 2008). In addition, TTFields therapy is anatomically limited to the brain tissue.

When TTFields therapy was approved by the FDA in 2011, the approval was limited to patients with recurrent GBM. The studies leading to FDA approval were the EF-07 and EF-11 trials (DeAngelis & Posner, 2009). The EF-07 trial was a pilot trial designed to evaluate safety and feasibility in 10 patients with newly diagnosed GBM after resection and chemoradiotherapy. The EF-11 trial was a phase III randomized trial in which 237 patients with recurrent GBM were treated with either chemotherapy alone or with TTFields therapy alone (FDA, 2011). In this trial, patients receiving TTFields experienced about the same six-month progression-free survival (PFS-6) and overall survival (OS) as the cohort receiving chemotherapy. However, evaluation of toxicities and quality of life clearly favored TTFields. In the follow-up study to EF-11, 695 patients with newly diagnosed GBM were enrolled in the EF-14 clinical trial. After completing maximal safe surgical resection and chemoradiotherapy, patients were randomized (2:1) to treatment with either maintenance TMZ plus TTFields or to maintenance TMZ alone. Patients in the TMZ plus TTFields arm had a statistically significant survival benefit in PFS-6 and OS in the interim analysis (Stupp et al., 2015). Data evaluated at this interim point demonstrated a 3.2-month increase in PFS-6 and OS. These data led to FDA approval for crossover of patients in the control arm to the TMZ plus TTFields arm (Stupp et al., 2015).

## Case Study: Newly Diagnosed Glioblastoma

Lisa was 63 years old when she traveled to her hometown to care for her dying sister. She found herself dragging her left foot and bumping into the wall during the few weeks that she was home. After Lisa’s sister passed away, she finally agreed to see her physician. The physician ordered an MRI

### TABLE 1. Common Chemotherapeutic Agents Used for the Treatment of Glioblastoma

<table>
<thead>
<tr>
<th>Chemotherapeutic Agent</th>
<th>Bone Marrow Nadir</th>
<th>Common Short-Term AEs</th>
<th>Long-Term AEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temozolomide (Temodar®)</td>
<td>Platelets: day 26 Neutrophils: day 28</td>
<td>Myelosuppression (including prolonged pancytopenia and aplastic anemia), opportunistic infections, constipation or diarrhea, nausea and vomiting, headache, allergic reaction or rash</td>
<td>Myelodysplastic syndrome, myeloid leukemia</td>
</tr>
<tr>
<td>Lomustine (Gleostin®) or CCNU (CeeNU®)</td>
<td>Platelets: day 28 Leukocytes: day 28</td>
<td>Myelosuppression (including fatal cytopenias), nausea and vomiting, pulmonary toxicity, renal toxicity (including renal failure), secondary malignancy</td>
<td>Secondary hematologic malignancies, pulmonary toxicity</td>
</tr>
<tr>
<td>Carmustine for IV use (BiCNU®)</td>
<td>Platelets: days 28–36 Leukocytes: days 28–35</td>
<td>Myelosuppression (including fatal cytopenias), nausea and vomiting, pulmonary toxicity (including renal failure), secondary malignancy</td>
<td>Secondary hematologic malignancies, pulmonary toxicity</td>
</tr>
<tr>
<td>Carmustine wafer (Gliadel®)</td>
<td>–</td>
<td>Myelosuppression, nausea and vomiting, meningitis, intracranial edema, seizures, impaired cranial wound healing, wafer migration with the potential to cause obstructive hydrocephalus</td>
<td>–</td>
</tr>
<tr>
<td>Bevacizumab (Avastin®)</td>
<td>–</td>
<td>Headache, severe or fatal hemorrhage, impaired wound healing or wound dehiscence, GI perforation, hypertension, proteinuria, VTE, arterial thrombosis, fatigue, ovarian failure, nausea and vomiting, leukopenia, hypertensive encephalopathy</td>
<td>Renal failure/ nephrotic syndrome, heart failure</td>
</tr>
</tbody>
</table>

AE—adverse event; GI—gastrointestinal; VTE—venous thromboembolism

brain scan, which demonstrated a large ring-enhancing right parieto-occipital lesion with central necrosis and associated vasogenic edema (see Figure 2). Lisa went to surgery the same day for a decompressive craniotomy. Pathologic analysis confirmed the surgeon's suspicion of GBM. After a near-total resection, she consented to standard-of-care treatment with chemoradiotherapy for her diagnosis of GBM. At her appointment after completing radiation, Lisa reported recurrence of left-leg weakness. Neuroimaging demonstrated a large cyst within Lisa's tumor cavity with mass effect in the left precentral gyrus, consistent with her neurologic symptoms. She underwent a repeat craniotomy for cyst decompression. The neuro-oncology tumor board reviewed Lisa's imaging and pathology specimens. The consensus of the tumor board was that Lisa's tumor had not recurred. Lisa was advised to proceed with standard-of-care treatment; therefore, the oncology nurse must be prepared with appropriate knowledge. As the case studies in this article illustrate, TTFields therapy can be an empowering experience for patients with GBM.

**Conclusion**

After years without advances in treatment for GBM, TTFields therapy offers a welcome treatment option for patients with a dire diagnosis. The lack of side effects makes TTFields an appealing choice for many patients. The self-administered nature of treatment with TTFields translates to a high level of educational needs for the patient and family at initiation of treatment; therefore, the oncology nurse must be prepared with appropriate knowledge. As the case studies in this article illustrate, TTFields therapy can be an empowering experience for patients with GBM.

**References**


