Fighting Brain Cancer with Electricity: Exploring Tumor Treating Field

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1 Overview

This outreach activity was designed to introduce school students to the concept of Tumor Treating Fields (TTFs) in brain cancer therapy, using engaging analogies, interactive demonstrations, and links to their science curriculum. The session aimed to demystify cancer treatment research, spark curiosity about biomedical science, and demonstrate how physics, biology, and technology intersect in real-world healthcare solutions.

2 Objectives

- Explain the basics of cancer and its treatment in accessible terms.
- Demonstrate how electric fields can disrupt cancer cell division using relatable analogies.
- Connect the science to IGCSE/A-level curriculum topics (cell division, electric fields, experimental design).
- Inspire students to consider careers in STEM and biomedical research.

3 Presentation Structure

Introduction The outreach session began with an introduction designed to spark curiosity, where I asked students about their experiences with static electricity and balloons. This familiar phenomenon served as a bridge to the main topic—how electricity can be used in medicine, specifically for treating brain cancer. I then provided a brief, accessible explanation of what cancer is, using the analogy of a city with both well-behaved and rogue construction crews to illustrate the difference between healthy and cancerous cell growth.

Explaining Cancer and Treatment Next, I described the three main traditional treatments for cancer—surgery, chemotherapy, and radiation therapy—explaining both the medical terms and their real-world side effects. I emphasized the challenge that these treatments often harm healthy cells as well as cancer cells, which can lead to unpleasant or serious side effects for patients.

Introducing Tumor Treating Fields (TTFs) After discussing the limitations of traditional treatments, I introduced Tumor Treating Fields (TTFs) as an innovative and gentler approach to fighting cancer. I explained that TTFs use gentle electric fields, applied at just the right frequency and strength, to interfere with the cancer cell's ability to divide. Here's the brilliant part: when a cancer cell is about to split, it uses tiny structures called microtubules—like ropes—to pull itself apart. The electric fields from TTFs act like invisible hands that tangle up these ropes right at the crucial moment. As a result, the cell gets confused, can't divide properly, and eventually dies.

I also shared that these electric fields have another effect called dielectrophoresis. While it sounds complicated, it simply means the electric field can push and pull small parts inside the cell, such as chromosomes, in specific directions. I compared this to using a magnet to move metal filings on a table—except in this case, the electric field is moving important cell parts during division, causing even more trouble for the cancer cell.

Finally, I pointed out that when these fields disrupt the division process, sometimes the cell ends up with the wrong number of chromosomes—a condition known as aneuploidy. Chromosomes are like instruction books for the cell, and having too many or too few can make the cell sick or unable to function. In cancer cells, this usually means the cell can't survive or grow properly, which helps stop the tumor from spreading. This explanation helped students understand not just what TTFs do, but how they work at the microscopic level to target cancer cells more precisely than traditional treatments.

Demonstration with Van De Graaff generator During the demonstration, I used a Van de Graaff generator —a device that builds up static electricity on its shiny metal sphere. I attached paper strips to the side of the sphere, and when the generator was switched on, the students could see the strips stand out and move, visually showing how the electric field pushes on them (Figure 1). I then asked the students to imagine what would happen if I slowly moved a needle or my hand around the sphere, changing the direction of the electric field. The paper strips would move in different directions, not just one way.

Figure 1: Demonstration with the Van de Graaff generator

I explained that this is similar to my research project: in Tumor Treating Fields therapy, electric fields are used to disrupt cancer cells as they try to divide. Traditional

TTFs use a static field—like holding the needle in one place—so only the strips (or, in real life, cancer cells) lined up in that direction are most affected. However, in my project, we rotate the direction of the electric field, just like moving the needle around the sphere. This allows us to affect more strips, or more cancer cells, no matter which way they're pointing. Since tumor cells in the brain are arranged in all directions, rotating the field means we can target and disrupt more of them, making the treatment more effective.

Results and Discussion The session concluded with a discussion of real research results, including microscope images of cancer cells exposed to different TTF conditions. I explained in simple terms how rotating fields killed more cancer cells than static fields or no treatment. I also highlighted how modern TTF devices are personalized for each patient using MRI scans and computer modeling. To wrap up, I discussed the many career paths in science and engineering that contribute to medical advances, encouraged questions, and left students with the message that curiosity and creativity are at the heart of scientific discovery.

Discussion During the session, the students were very engaged and asked a range of insightful questions that reflected both their curiosity and understanding of the topic. For example, one student asked, "Can Tumor Treating Fields be combined with other cancer treatments, like chemotherapy or radiation?" I explained that this is a very promising area of research. In fact, in the next stage, we will be combining TTF with drug deliver to investigate whether the treatment will be more effective.

Another student wondered, "Why do you focus on glioblastoma—are there other cancers that could be treated with TTFs?" I shared that glioblastoma is one of the most aggressive and difficult-to-treat brain cancers, which is why it is a priority for new therapies. However, researchers are also testing TTFs on other types of cancer, such as lung and pancreatic cancers, and early results are encouraging.

A particularly thoughtful question was, "What would happen if TTFs were used on children, since their brain cells are still dividing?" I explained that this is an important consideration. Because TTFs mostly affect cells that are actively dividing, using them in children—whose brains are still developing—would require extra caution and research to make sure healthy growth is not disrupted.

Students also asked about the technical aspects of my research, such as, "Does your current setup only create electric fields in two directions? What improvements could be made in the future?" I responded that my current experiments use a two-dimensional setup, but in real life, tumors are three-dimensional. A future goal is to develop systems that can rotate the electric field in all three dimensions, to target even more cancer cells no matter how they are arranged in the brain.

These excellent questions not only showed the students' engagement but also highlighted important future directions for this research, including combining treatments, expanding to other cancers, ensuring safety for young patients, and advancing the technology to work in three dimensions. Their curiosity and critical thinking made for a lively and inspiring discussion.