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Why Targeted Alpha Particle Therapy is the key to cancer remission?

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Abstract: Since 1882, attempts have been made to develop a remedy for cancer. Even today, we still seek out more modern, safe, and effective remedies to potentially find a way to do away with cancer permanently. However, thus far we have only discovered methods to temporarily remove cancer. Although there is a chance you would be cured for good, most people only experience remission, a time when they are free of symptoms. New discoveries have changed cancer treatment for the better. A recently discovered cancer treatment method called targeted alpha particle therapy could potentially become a safe and effective form of cancer treatment. Although it is still in development, its potential is huge. Targeted alpha particle therapy could be a breakthrough that could save many lives.

Keywords: Cancer treatment, Targeted alpha particle therapy, Nuclear medicine

1. Introduction

A revolutionary method has appeared recently in cancer research, a method called Targeted Alpha particle Therapy (TAT). First, I will explain the relatively old methods of cancer treatment, evaluate their advantages and disadvantages, and lastly explain why TAT is the most effective and revolutionary and compare TAT to the previously mentioned treatment methods.

2. What is cancer?

Cancer is a "disease in which some of the body's cells grow uncontrollably and spread to other parts of the body" (National Cancer Institute, May 2021). Cancer can be very dangerous if left unnoticed or untreated. There are many types of cancer, all originating from different body parts. Cancer can spread to separate areas than it was started, making it even harder to treat. An area of these mutated cells is called a tumor. Some tumors are nonmalignant and do not cause cancer. However, some tumors become a threat when they become too big, spread, or negatively affect the body. These tumors are malignant, and they are cancerous. In 2021 (the latest year for which there is global data), more than 10 million people died of cancer worldwide. That is 1 out of every 6 deaths (Kendall K Morgan, 2022).

3. Treatment methods for cancer

3.1 Surgery

Surgery is likely the most direct and straightforward option for cancer treatment. A surgeon cuts the tumor off the patient, hopefully removing the complete tumor. This is called curative surgery because it removes tumors directly. However, there is also a chance that tumor cells could be missed, or that cancer has spread to another body part that was not removed by the surgery.

Some advantages of this treatment method include the relative simplicity of the process, that it is available in more places, is the most direct, as well as having a higher success rate compared to some other options.

Disadvantages include the limited reach of surgery. Some places are hard to reach, increasing the risk of an accident. Also, if the tumor has spread too much, it is impossible to remove the necessary crucial organs. Surgery also has trouble dealing with tumors that have already spread. Accidents or mishaps could result in damaged or unusable body parts.

3.2 Chemotherapy

Chemotherapy (Chemo) is a drug that kills off cells in a particular state of cell life or prevents them from reproducing by damaging their DNA. Chemo can damage normal cells as well, so doses are often limited to prevent large amounts of healthy cell loss.

Some advantages of chemo are that it affects the whole body, meaning it could support the reduction of multiple tumors across the body. Chemo is compatible with surgery, as chemo can reduce and weaken tumors while surgery can take the weakened and smaller tumor out.

Chemo has many drawbacks that make it not as effective as other methods. Chemo affects the whole body’s cells, which also damages normal cells. Chemo can also cause hair loss. The main issue with chemo is that it is almost impossible to remove tumors by itself. Even if that were the case, there would be serious damage to normal cells.

4.What is targeted alpha particle therapy

TAT (targeted alpha particle therapy) is a novel treatment that attempts to use alpha particles to kill cancer cells (if the cell DNA is damaged severely) or delay their spread (Figure 1). An alpha particle is composed of two neutrons and two protons released from radioactive isotopes, such as Actinium-225, during spontaneous disintegration. The alpha particle has the advantage of a relatively low stop range, which is the distance that the alpha particle requires to travel in order to reduce its initial high speed and eventually stop. The relative low stop range, typically a few centimeters in tissues, limits the damage to normal cells while pinpointing cancer cells. The short range of alpha particles is compared to beta particles, which have a much longer range that could penetrate the whole body and cause further damage to normal cells. (Narges K. Tafreshi, Et. al, 2019)

Targeted Alpha Therapy is based on the coupling of alpha particle emitting radioisotopes to tumor selective carrier molecules, such as monoclonal antibodies or peptides. These molecules have the ability to selectively target tumor cells even if they are spread throughout the body. They recognize the targeted cancer cells through antigens that are expressed on the cell surface and can bind selectively to these cells, similar to a key fitting into a lock. In targeted alpha therapy, these carrier molecules serve as vehicles to transport the radioisotopes to the cancer cells. This is called the "magic bullet" approach. Radioisotopes that emit alpha particles seem particularly promising. (European union, medical applications of radionuclides and targeted alpha therapy, n.d.)

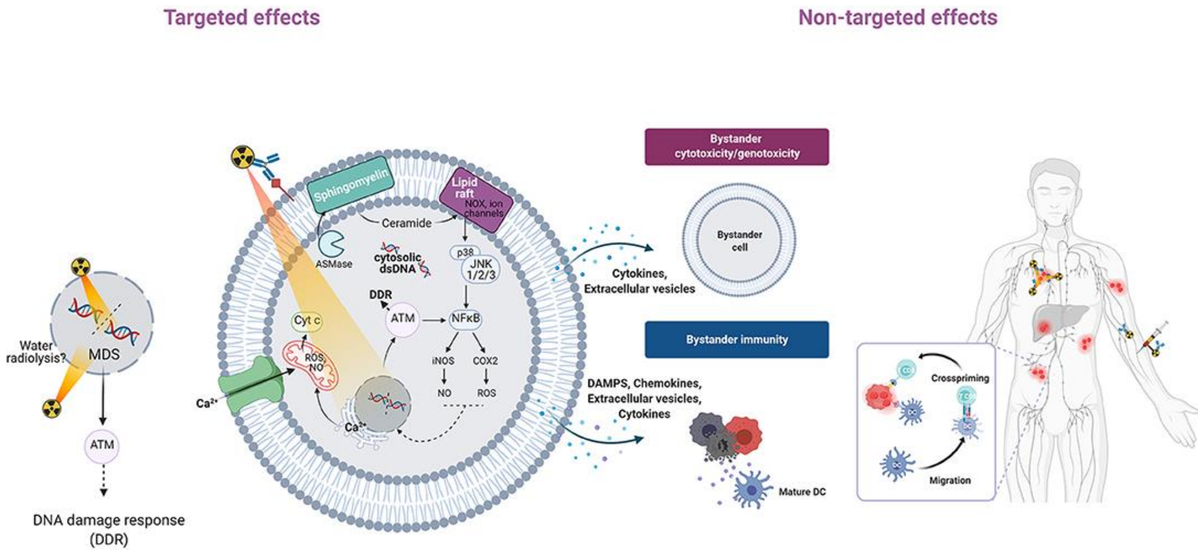

Figure 1. How TAT damages Cancer cell DNA

4.1 Advantages of Targeted alpha particle therapy as a cancer treatment

TAT is very specific and targeted, meaning it can minimize damage to normal cells while maximizing DNA damaging effects on cancer cells. This allows it to be safe for normal cells and better for the body. Extensive damage to healthy cells, which is inevitable in many forms of cancer treatment, can cause a depreciation in organ function, and in turn, may cause many other health issues. TAT minimizes or almost completely removes these effects making it safer for the body.

TAT can induce remission of tumors refractory to beta radiation with favorable acute and mid-term toxicity at effective therapeutic doses (Kratochwil C, et al, 2014). The treatment is also stronger than other options such as gamma or X-rays and damages cancer cells more significantly (Pouget, Constanzo, 2021). These statements prove that the use of TAT is effective at minimizing or even removing tumors from the body, and its efficiency compared to other common methods used to treat cancer. These statements also show alpha particles can also prove to be effective against patients that have tumors that ignore or have minimal damage from beta particles.

TAT will also avoid pain or organ function loss experienced in surgery, and the risk of mistakes in which the body can be damaged is severely minimized compared to the highly precise and potentially risky procedure of surgery.

There is little restriction on where you can administer TAT. For example, you cannot altogether remove a large portion of organs crucial to life. In this case, TAT does not have restrictions on application location. Because of the previously mentioned reduced healthy cell damage, it is safe to use on crucial organs as it does not destroy the organ, only the cancer tumor.

In combination, these 3 advantages make TAT one of the most effective cancer treatments, with its high effectiveness, low risk, and good reach on the body. However, TAT does have some problems with cost and maturity.

4.2 Disadvantages of Using targeted alpha particle therapy

Despite the little impact on healthy cells, it could potentially modify the DNA in normal cells, because breaking then repairing DNA may cause a mutation or for a healthy cell to die. However, these chances are slim and do not have a large or significant impact on your body.

Although TAT is highly effective in terms of damaging cancer cells, the technology and effects have not been completely and thoroughly researched, and the technology is not completely mature yet, resulting in high costs. However, when complete research has been done, it would be a common form of treatment. A major issue that may hamper wide implementation in the clinic and that needs to be simultaneously addressed is the availability of suitable α-particle emitters at a reasonable cost (Elgqvist J, et. al, 2014).

The cost of TAT can be very high due to the relative immaturity of TAT technology. Ideally, with research in the future, costs can be reduced. However, in the current situation, there is low supply resulting in high costs. Research should begin to focus on how to more easily obtain these alpha particles and lower the cost. Below, I will identify what makes TAT so expensive and solutions to high costs.

4.3 Why TAT is revolutionary

TAT is revolutionary because of its ability to be administered almost anywhere, its significantly reduced damage to healthy cells, and its ability to rapidly kill cancer cells. This gives TAT an advantage in targeting and removing cancer no matter where in the body cancer cells are. However, TAT is still in development, with the main drawback being cost. Hopefully, the research could lower prices, making it an advanced and effective treatment option. Below is a table of the attributes of each treatment type.

Treatment type	Effectiveness	Reach of treatment on body	Range	Cost	Risks
Surgery	High	Limited on organs	Highly specialized	Relatively cheap	Relatively high risk
Chemotherapy	Medium	Limited due normal cell damage	Whole body	Expensive	Low risk
TAT	High	Low limitations	Highly specialized	Expensive	Low risk

Table 1. Comparison of cancer treatment types

Despite how promising TAT is, it is important that we acknowledge that TAT still requires research and development, so it is not going to become a popular treatment method within a short time period. However, because of its ability to effectively diagnose cancer, it is key that we continue research on TAT, as it is still a promising remedy that could change cancer treatment for the better.

4.4 Analysis: How to overcome TAT's cost barrier

4.4.1 Cost of alpha particles

The reason alpha particle emitters are expensive to obtain is because of the high cost of radioactive materials that produce alpha decay. These materials then must be modified to stay with the carriers, which further increases the cost of TAT. Then, they have to be made into an injection. Specialists are required to inject these radioactive materials. Because alpha emitters are already expensive, adding them to carriers and modifying them is very expensive. Therefore, it is crucial that studies focus on alpha emitters and how to make them cheaper than their current price. These studies opens and opportunity to make TAT and common treatment type.

The major bottleneck for alpha emitters is their limited availability. High Z of TAT radionuclides resulting in complex production and lengthy irradiations using powerful reactors or cyclotrons creates this problem. Alternatively, irradiations of highly radioactive targets at specialized facilities or generation from uncommon isotopes may be required. Therefore, the demand for alpha emitters often significantly exceeds availability and supply (Valery Radchenko, et al., 2021).

Potential research could be directed at alpha emitters such as Actinium 225, and how to effectively obtain them in mass quantities. It should then be analyzed how to get emitters to decay into alpha particles faster. These two discoveries could make alpha particles more common and therefore less costly.

4.4.2 Training and equipment

Funds for research and education for new specialists would mainly come from government funding and nonprofit organizations, like most research. Donations would assist how much money can be raised. It is probable that the government would provide most of the money for the research to make TAT available at viable cost.

Training programs would be required to introduce specialists to the treatment because there are currently few specialists. That process requires teachers and learning supplies, both requiring payments and costs.

Hospitals also will have to buy new equipment for TAT. The equipment could be expensive and hard to operate, so hospitals will have to increase costs to make sure they are earning money. For example, areas would be required to store these radioactive materials in a safe manner. In addition, precautions have to be made in order to prevent ingestion or inhalation of these particles, because it could damage the normal cells of the patient, specialist, or any exposed person (because the carrier molecules are not attached).

These three factors combined result in expensive treatment costs. Research in the future could reduce costs by improving on these three issues. The focus should be directed on the lowering of costs of radioactive materials, as there is already some focus on this topic due to growing interest in nuclear energy in an effort to protect from climate change.

Specialists require salaries often, and those would have to be covered in hospitals, as specialists often take home a hefty salary, it is quite expensive for hospitals to maintain specialists.

Tuition would cover some or all of education costs, as colleges and training organizations charge tuition enough to cover the costs and mak;,e money. Hospitals charge for their treatments, which covers staffing and equipment fees. Hospitals might start research projects of their own, as an investment.

There are solutions to the v,;arious issues raised by cost, but the most important takeaway is that we must invest in research towards effectively obtaining alpha particles and their carriers at and effective cost.

4.5 Applications of modern TAT technology

After the application of the above suggestions, it is probable that TAT will become a common form of cancer treatment. The most straightforward of the many applications of advanced TAT technology is that it can be used to treat cancer patients and save many lives. Since if TAT is cheap, it is likely to be used in many areas because of its favorable characteristics. Because cancer is a common yet dangerous disease, so implementing and effective remedy will positively benefit society greatly.

Another possible benefit of studying and improving of TAT is that it is possible new breakthroughs in discovery of new cancer remedies or improve old treatments. It is also possible we could gain additional knowledge about cancer, nuclear medicine, nuclear energy, or the human body. Many of today's discoveries are made unintentionally.

The research on nuclear medicine could potentially fuel new findings in nuclear energy, a growing form of energy, and a promising energy form to use in space travel.

5. Conclusions

TAT is a recent discovery that could revolutionize cancer treatment due to its low restriction on application area, and its minimal damage to normal cells while being deadly to cancer cells. Not only is TAT effective by itself, but /it is also compatible with other methods, such as surgery. TAT could greatly reduce tumor size, if not wipe out cancer cells. The remaining radiation would wipe out cancer cells that come back or survive initially. With its high efficiency and minimal side effects, TAT is a key discovery in causing cancer remission, if research is continued.

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