The Role of Gene Therapy in Cancer Treatment

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Abstract

Cancer is one of the major diseases in the world. This paper explores the biology of cancer cells and explains how they are originated. It also compares cancerous cells to normal cells in order to achieve a better understanding of the disease. The paper further investigates the problems associated with cancer treatment. It analyzes various treatments, such as chemotherapy and radiation, their procedures, and their secondary effects on patients. The in-depth analysis draws on the new findings regarding the techniques of gene therapy. The process of gene therapy is explained along with the various kinds of approaches scientists use to perform the therapy. The paper explains how gene therapy is used in recent research in order to kill the cancerous cells, replace them with correct cells, or fix their genetic material in order to cure them. Recent experiments on suicide genes and nanomagnetic technology are also discussed. The results from these experiments are used to support the claim that gene therapy is a very effective form of treatment compared to the other traditional treatment methods. Information contained in this paper is gathered from the most recent experiments and credible sources in order to ensure accuracy of the content.

Cancer is one of the fastest growing diseases in the world. Fayed (2006) explains that cancer is the leading cause of death in America for people under the age of 85. He further states that the number of people found to have cancer hit 1.4 million in the year 2005. The American Cancer Society states that there were a total of 10 million people dealing with cancer by the year 2006 (cited in Ascend Foundation, n.d.). The National Cancer Institute (2008) estimates that there will be 1,437,180 new cases and a total of 565,650 deaths resulting from cancer in the year 2008. These statistics clearly show that cancer is an enormous problem facing us today.

Cancer, one of the most common diseases, is also one of the diseases that does not have a cure. Even though scientists have progressed a lot in finding a cure for cancer, they have not been very successful in establishing an effective and reliable form of treatment. However, recent research has led to the development of a process known as gene therapy. This technique has provided hope to scientists and physicians when it comes to treating cancer. This paper will explore the role of gene therapy in cancer treatment. In doing so, the following issues will be addressed:

1. Why is treating cancer difficult?
2. What are the traditional ways of approaching cancer?
3. What is gene therapy, and how is it used to treat cancer?

Why is Treating Cancer Difficult?

Physicians have been attempting to treat cancer using different methods in order to establish an effective treatment, but they have not yet succeeded. Cancer treatment is a very difficult task because of the nature of cancerous cells. Before talking about how to prevent or treat this deadly disease, it is important to understand exactly what scientists are dealing with.

In order to understand why physicians have not been successful in treating this disease, it is important to consider the behavior of cancer cells and how they are originated. The word cancer refers to a group of cells that have lost the ability to control their reproduction or division cycles (National Cancer Institute, 2008). A cell is the functional unit of the body that is responsible for carrying out all of the biological mechanisms. It is commonly known that a cell's ability to maintain its proper function and regulation of its division is crucial for an individual's survival. The inability of cells to control their growth can be a result of various factors. An individual's diet and external environment can be considered minor factors, but one of the major factors is the genetic material that the cell possesses. According to "Gene Therapy" (2008), genes are responsible for making proteins that are used by the cells to carry out their various functions. A cancer develops when there is an overproduction of proteins that the cell uses in order to reproduce itself. Thus, due to an excess amount of reproducing proteins, these cells reproduce uncontrollably. From this information, it can be concluded that the malfunctioning of genes is the real cause of cancerous cells.

The initial step in the origin of cancer is the formation of a tumor. The word tumor refers to an overproduction of a specific type of cells in a specific part of the body (Fayed, 2006). The National Cancer Institute (2008) explains that there are two types of tumors. A benign tumor originates when the affected cells are localized in a particular region of the body. According to Fayed, this type of tumor can be easily treated. A surgical removal of the clump of cancerous cells would be sufficient to get rid of them. The second type of tumor, a malignant tumor, originates when the affected cells begin to affect the adjacent cells. These neighboring cells can either be altered from their proper functioning or destroyed completely due to the presence of cancerous cells. In some cases, a malignant tumor results in the spreading of cancerous cells throughout the body. It is this type of tumor, which is difficult to deal with, that is called a cancer (Fayed).

Due to the strange behavior of cancerous cells, there are many problems when it comes to treating cancer patients. The main problem is that the cells are spread throughout the body and are constantly replicating at a very high rate, preventing physicians from targeting all of them. According to Fayed (2006), when these growing cells enter the blood, they can circulate

throughout the body which allows them to reach out to virtually any organ. When physicians attempt to treat the affected part of the body, for the most part, they are successful. However, there are always some affected cells that are left over because they have traveled to other organs in the body. According to the American Academy of Family Physicians (2006), it is important to detect cancer's presence as early as possible. If a cancer is detected before it enters the blood stream, it can be easily removed. However, once cells begin to reach out to other organs, it becomes difficult to treat them.

What are the Traditional Ways of Approaching Cancer?

Cancer treatment has been a major issue in research laboratories. Scientists have been able to understand the origin and behavior of cancerous cells; however, they have not been very successful in establishing effective treatments for these cells. The current treatments are given to people at the expense of secondary effects. Cancer patients are still waiting for treatments that would be more effective in curing the disease and cause fewer side effects.

Physicians have attempted many ways to deal with cancer. The traditional way of treating cancer is the surgical removal of the affected cells (Mayo Clinic Staff, 2007). It is common knowledge that this is a very difficult technique because targeting each affected cell while preserving the unaffected ones seems like an unachievable task. There is always a high chance that some cells remain inside the body even after the surgery. These remaining cells can then re-grow and the cancer can initiate once again because those cells are constantly dividing (Women Republic, n.d.).

In order to prevent the return of cancer from leftover cells, physicians usually follow up the surgery with chemotherapy, radiation, or a combination of both. Applications of chemotherapy and radiation have been widely used to treat cancer patients. Chemotherapy refers to the oral intake of drugs or chemicals, in the form of tablets or liquid injections, which further eliminate the remaining cancerous cells (Women Republic, n.d.). Radiotherapy, on the other hand, uses radiation, especially x-rays, to kill any cells affected with cancer after the surgery has taken place (Cancernet- UK, n.d.). These therapies are sometimes used before the surgery for the purpose of reducing the tumor area and making the surgery easier. According to the American Academy of Family Physicians (2000), sometimes both forms of treatments are used in order to prevent the return of cancer.

Despite their frequent use, these treatments do not always work and often have dangerous side effects. According to American Academy of Family Physicians (2000), these therapies can result in different effects in different individuals. Some individuals can be cured using these therapies, while

others remain unaffected. In the most extreme cases, these treatments can cause serious secondary side effects which may be harmful to the patient. Side effects that the patient experiences usually depend on the area of the body that is affected and being treated. This is due to the effects of the drugs used in chemotherapy, which affect other healthy cells in the body as well as the cancerous cells. These side effects may lead to weakening of the immune response of the body (Women Republic, n.d.). According to Cross and Burmester (2006), chemotherapy may also cause a risk of bone fractures and development of other kinds of cancers.

Radiation has been proven to be a very effective treatment. However, there are various side effects associated with this technique as well. Women Republic (n.d.) explains that there are always side effects associated with any type of radiation. According to Cancernet – UK (n.d.), radiation can have acute or chronic effects on the patients. Acute effects refer to the short term side effects which may include sunburns, nausea and hair loss. These short term effects can be easily handled and do not last for long periods of time. On the other hand, chronic effects are long lasting. Though these chronic effects are less common, they can be very harmful and can cause damage to lungs, heart and nerves (Cancernet – UK).

Since the disease of cancer is rapidly growing and traditional ways of treatment have such risky side effects, scientists have been searching for alternative techniques to deal with the disease. One alternative technique is gene therapy. According to Cross and Burmester (2006), gene therapy is more promising than other types of treatments and has been very successful since it first began to be used about fifteen years ago. One of the reasons why gene therapy is a good approach to cancer is because it targets the genes, which are the origin of cancerous cells, unlike chemotherapy and radiation, which try to cure those cells ("Gene therapy," 2001).

What is Gene Therapy and How is it used to Treat Cancer?

The idea behind gene therapy is to target the genes of the cell, which are the origin of the defect. A gene is understood to be the building block of all living beings. As mentioned earlier, genes are responsible for making proteins that allow for the proper function of the cells. These proteins are also involved in cell division and are used heavily by cancerous cells. Gene therapy works on regulating the genes of the cells in order to enhance or suppress protein functions, hence controlling their division cycles. It alters the genetic material of the cells and causes the cells to either revert back to their original form or destroy themselves (Cross & Burmester, 2006). According to "Gene therapy" (2008), "Gene therapy is a technique for correcting defective genes responsible for disease development." Even though scientists are still struggling to make this method reliable for treatment, there is

evidence to show that it is more effective than other kinds of treatment.

There are various ways gene therapy can be done. The three most common types of gene therapy involve replacing the defective gene with a normal gene, altering the gene to revert it back to normal function, and controling the gene's regulation (Cross & Burmester, 2006). Gene regulation is understood as a natural process carried out by the body itself. It is responsible for maintaining the proper functions of the cell. It may enhance cell activity or suppress it depending on the body needs. This regulatory function is lost by cancerous cells and gene therapy may be used to regain it.

Recent research has come up with many other kinds of gene therapies which involve destruction of cancer cells. One such technique is called Oncolytic virotherapy. This technique involves the injection of a virus into the patient. The virus is genetically modified in such a way that its ability to harm the normal cells is decreased and its attraction to infect a cancerous cell is increased. Once injected, the virus approaches the cancerous cells, infects them, and causes them to die (Cross & Burmester, 2006). Another technique which causes the destruction of cancerous cells is a mechanism known as apoptosis. According to "Dual Gene Therapy Suppresses Lung Cancer in Reclinical Test" (2007), gene therapy can be used to initiate apoptosis in cancerous cells, which forces them to kill themselves. Various kinds of gene therapies such as "lipid-based nanoparticles" and "tumor-suppressing genes" are used in order to initiate apoptosis. Experiments show that the number of tumor cells reduced 70 to 80 percent within 48 hours after being treated with these therapies ("Dual Gene").

Another technique which involves the destruction of cancerous cells is the incorporation of suicide genes. According to "Breast Cancer Suicide Gene Hope" (2000), this technique involves the incorporation of an artificially altered gene into the patient. This gene is altered in a way that it finds the cancerous cells within the body. Once it encounters the cancerous cells, it injects itself into them. After it has been incorporated, it destroys itself, causing the death of the cancer cell as well. It is called a suicide gene because it kills itself in order to kill the cancer cells ("Breast Cancer").

Even though Oncolytic virotherapy and suicide genes are very efficient in getting rid of cancer cells compared to the traditional chemotherapy and radiation, scientists have recently developed an even better form of gene therapy. Rather than killing all of the cells, a process known as gene transfer enables the cancerous cells to revert back to their proper function (Cross & Burmester, 2006). In gene transfer, a gene is artificially introduced into the genome of the patient. These genes are modified to have specific properties which can help in cancer treatment. This method exchanges the genes responsible for rapid division with genes that have the ability to con-

trol their division (Hanna, 2006). However, the process of carrying out gene transfer is very complicated.

A series of steps need to be taken in order to perform gene transfer. First, a vector is injected into the patient. This vector is a tool to transport a gene from one cell to the other using some kind of virus. In this technique, the virus is genetically modified and its ability to cause disease to the patient is suppressed (Hanna, 2006). During the process of modification, the virus comes to carry the normal gene in it. Once the virus is injected into the patient, it approaches the cancerous cells and injects the normal human gene into those cells. This method is used in order to replace the defective gene on the cancerous cells and has shown much efficiency (Cross & Burmester, 2006).

Another aspect of gene therapy is the usage of nanomagnetic technology. Recent research on tumor cells indicates that gene therapy using this technology can play a major role in their treatment. According to "Breakthrough in Gene Therapy for Cancer Offered by Tiny Magnets" (2008), using human cells to transport drugs to the tumor is an insufficient method and does not provide the desired results. However, the "magnetic targeting method" is much more effective in accomplishing this task of transport. This method uses magnetic forces between tumor cells and monocytes (a class of cells involved in immune response). First, a nanomagnet is placed in a monocyte which carries the drug. Another nanomagnet is placed next to the tumor and the monocytes are injected into the blood stream. Due to the presence of magnets, which create a magnet field and an attractive force for other magnets, this technique has been very efficient in targeting only the cancerous cells while preventing the normal cells from being affected. The concept of magnetic targeting was around for many years, but was difficult to use; recent research has allowed scientists to overcome any problems involved in the procedure and has made this technique useful in clinics ("Breakthrough").

Another application of gene therapy has allowed the researchers to isolate tumor cells from the rest of the body's cells. According to "New Approach" (2008), a type of gene therapy has been developed which is able to create a "microenvironment" around the tumor that is able to prevent the cells from spreading. This process helps physicians deal with the tumor more easily because the affected cells can be distinguished from the normal cells. When this method was tried in laboratory mice, it showed significant results in treating brain tumors ("New Approach to Gene Therapy"). Another experiment done by the National Cancer Institute (2006) used 17 patients who were given therapy to create a type of microenvironment around the tumor in order to improve their natural immune response. The results from this experiment showed that 100 percent of the patients developed

their own natural ability to find and kill cancer cells.

Even though gene therapy is so far the best approach to cancer treatment, it still faces some challenges. One of the problems associated with gene therapy is the tendency of cancerous cells to divide rapidly. This makes it difficult for the modified cells to work over a long period of time. As "Gene Therapy" (2008) explains, the therapy has to be done multiple times in order to produce a desired effect. Furthermore, when a scientist injects a foreign substance (a vector) into the body, the substance becomes a target of the natural immune system of the body. This factor also weakens the strength and effectiveness of gene therapy. Another problem with injection of virus as a vector is that the virus may return to its original harmful form and may cause an infection.

One of the biggest challenges in gene therapies involving viruses is that the vector incorporation and regulation of target cells must be strictly monitored. It is very important to control the regulation of introduced genes ("New Approach to Gene Therapy," 2008). Otherwise, the overproduction of proteins from such genes can result in toxicity and undesirable results which may worsen the patient's condition. According to "Gene Therapy" (2001), the most efficient way of treating cancer is to directly inject the vector. The problem with this method is that each vector is only effective in the organ that it is injected into. If the cancer cells have spread throughout the body, the patient needs to be given many injections to reach each affected organ. These are some of the problems and issues related to gene therapy that scientists and physicians are still faced with.

Conclusion

There is no doubt that gene therapy has revolutionized the treatment process for cancer patients. Gene therapy has taken away many obstacles and side effects that were part of cancer treatment in older techniques such as chemotherapy and radiation. The information given in this paper clearly explains that gene therapy is a much more promising technique with which to approach this disease.

However, there are some aspects of this technique that still need to be worked on. Some kinds of therapies still need to pass pre-clinical trials and some of them are being limited to testing on laboratory animal models. However, scientists and physicians believe that soon these therapies will be allowed to be used in clinics as part of cancer treatment. They also believe that they are at the beginning of a new era and that gene therapy will lead them to a treatment that is effective and free of side effects.

This paper proposes that gene therapy is the future of cancer treatment and that humans are very close to the time when cancer can be cured

effectively. Cancer patients throughout the world are counting on gene therapy to give them a new life by curing their disease.

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