The Use of Nanorobotics in Cancer Treatment

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Until recently, the idea of tiny robots travelling through the human body, repairing organs and curing diseases, was something out of a science fiction film. However, the idea of applying nanorobotics in the field of medicine has been around for years, evolving and progressing to a point where there is evidence and hope of these miniature robots becoming a feasible solution to medical problems. It is important to note that a nanometer is on billionth (1x10⁻⁹) of a meter. To put this into perspective, one red blood cell is approximately 2500 nanometers (nm). The body is an intricate system, made up of miniature blood vessels and arteries; therefore, the use of a nano-sized robot to manoeuvre around and potentially make changes to the body is entirely appropriate. With this being said, there are also impending side effects. Scientists and engineers are now faced with the daunting task of using existing knowledge and resources to develop a nanorobot that can navigate through the body with an efficient power source, possibly carrying a payload of medication (Strickland, 2007). With the hope of using these robots to address a myriad of health problems, there is also talk of the machines carrying tools that they can use once inside the body (Strickland, 2007). This article will talk about the challenges, goals, advantages and the future of nanorobotics in the treatment of cancer.

Traditional methods of treating cancer, besides surgery, include chemotherapy and radiotherapy. Depending on the type of cancer and what stage the patient is in; the use of either method varies. The main idea behind both methods is to stop rapidly dividing cells and to prevent the cancer from spreading to other parts of the body. Chemotherapy involves the patient taking medication that targets quickly dividing cells. It interrupts the chemical process during cell division in a part of the cell’s control center, killing dividing cells. Cells that are at rest are less likely to be affected by the drug, thus not harming the majority of the healthy cells. There are parts of our body, however, that have quickly dividing cells: hair is always growing, bone marrow is constantly producing blood cells, and the cells of the skin and the lining of the digestive system are constantly renewing themselves (Cancer Research UK, 2013). Therefore, chemotherapy destroys many healthy cells and causes side effects such as hair loss, fatigue, bone marrow suppression, sore mouth, inflamed veins, pain, skin changes, organ damage and may sometimes even cause a second cancer (Canadian Cancer Society). Radiotherapy involves high-energy radiation and can be either
internal or external. The radiation destroys the DNA inside the cancer cell, causing it to perish. This method is used to cure certain types of cancer or is combined with other methods to make the process more effective. It is also successful in shrinking tumors in order to make them more operable and can be used to remove small amounts of residual tumors after an operation. In some cases of incurable tumors, radiotherapy is used to control the symptoms the patient might be having due to the cancer. However, the side effects from this method do not go unnoticed. The radiation can damage nearby cells either temporarily or permanently and it takes some time for the results to be evident (National Health Service UK, 2013).

As has been noticed by doctors, scientists, and the patients themselves, chemotherapy and radiotherapy are rather invasive methods that cause trauma to the body (Cancer Research UK, 2013). As the drugs go through the body, they harm healthy cells in the body and can cause organ damage. The solution to these side effects needs to be non-invasive and involve direct drug delivery. Even though nanorobots are rather invasive, they are targeted and controlled, making them a possible solution to this problem. The use of nano-sized biomachinery to deliver drugs is an idea that has been in the works since the early 1960’s, originating from physicist Richard Feynman (National Nanotechnology Initiative). Dr. Feynman’s talk, “There’s Plenty of Room at the Bottom”, focused on manipulating and controlling individual atoms and molecules. His talk was veered towards scientists as it took place at an American Physical Society meeting at the California Institute of Technology (National Nanotechnology Initiative). Since then, research has come a long way as scientists and engineers try to design nano-scaled robots with a sufficient enough power source to successfully navigate and move throughout the body (Strickland, 2007).

With regards to cancer treatment, the main goals are: the ability to carry a load (drug), to migrate to specific sites in the body, to latch on to cancerous cells, and to be able to recognize the binding site and to release the payload (Strickland, 2007).

A common strategy in designing these robots is to use already existing biological resources and biokleptic methods. Scientists in South Korea are now using the salmonella bacteria as a means of delivering chemicals to the cancerous cells (Reuters, 2014). The germs are engineered to identify the harmful DNA within a cell and release the cancer-treating drug that upon detection of the cancer cells. Studies have shown that the tumorous cells secrete a specific biochemical that the healthy cells do not (Reuters, 2014). Subjecting this into further investigation, scientists have designed these bacteria with the appropriate receptors to target and bind to these chemicals. The reasons for using the salmonella bacteria were mainly because it is easily grown in a lab and it has its own propulsion system, the flagella. This appendage allows for the cell to move through the body in search of the tumor (Reuters, 2014). Similarly, viral capsids with a nano-particle based core have also been used as a means of drug delivery (Scott, 2013).
Once a core has been established for the robots, it is then a question of how the cancer will be eradicated. Just like chemotherapy treatment, the goal is to stop the rapid cell growth and kill the cells. Researchers at the California Institute of Technology have been working on doing so using messenger RNA (mRNA) interference (Sprouse, 2010). The idea originated from Fire and Mello’s discovery from ten years ago that won them a Noble Prize (Sprouse, 2010). Fire and Craig, originally using worms for their research, and discovered that by using small interfering RNAs (siRNA) they could cut out pieces of the genetic code in the mRNA that they did not want to replicate in future cells (Hill, 2010). This proved to be more useful than interfering with the DNA or RNA. Today, a research team at Caltech lead by Mark Davis is working on incorporating these siRNAs into nanorobots in hopes of targeting and killing the cancerous cells in patients (Noyes, 2010).

In the Ovarian Cancer Institute, at the Georgia Institute of Technology, researchers have found a way to get the siRNAs into the cancer cells without harming the healthy cells (Noyes, 2010). The technique involves ligand coated hydrogels, less than 100nm in size, that will trick the cancer cell into picking up the particle. Once inside, the siRNA will be leaked out over a period of a few days (Noyes, 2010). Traditional chemotherapy induces apoptosis, natural/programmed cell death, but does not always account for epidermal growth factor receptors: EGFR. These receptors, once bound to the epidermal growth factors, simulate cell growth. siRNAs can be targeted against EGFR, reducing and shutting down its production (Noyes, 2010).

The field of nanorobotics is vast and highly applicable in the field of medicine. From diagnosis to curing diseases to enhancing cells in our body, there is a lot of potential. When it comes to cancer treatment, the fundamental ideas have been established for quite some time now. Today, the challenge for scientists and engineers is to find a way to shrink it to the nano-scale. As traditional methods of treating cancer such as chemotherapy and radiotherapy have shown to be much too invasive, researchers have been adamant to design an efficient nanorobot that will aid in killing the cancerous cells without causing distress to the rest of the body. Much research has been conducted and some results have been positive. Researchers have found that using biological material (such as bacteria) as the core of the robot will solve the question of propulsion. Furthermore, past and present research is being combined to use mRNA interference in the eradication of the cancerous cells. The siRNA particles target the section of the RNA that codes for the production of the EGFR and is responsible for apoptosis. Disguised inside a hydrogel that the cancer cell will take up, the siRNAs are hoped to shrink the tumor and, at the very least, aid traditional chemotherapy by making it more susceptible to the chemotherapeutic drugs.

Though innovative studies with viable results have been conducted, there are still many unanswered questions. There is still no common method for engineering and programming these nanorobots. The ways in
which the robots will be controlled, powered, navigated and designed is still unclear. Also, many have concerns regarding the immune response to these foreign bodies and whether or not we will reject them (Sprouse, 2010). Much research is still being conducted and will hopefully answer these questions in the near future.

References


Strickland, J. How Nanorobots Will Work.  