

Applications of Polymers for Drug Delivery, Cancer Therapy and Antibacterial

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Abstract. The mortality rate of cancer is gradually increasing every year. The application of polymers in biomedicine is one of the key research directions today. A number of researchers have found that polymers have great potential in chemotherapy, yet there is a research gap regarding the toxicity of the drugs to patients. Therefore, this research will introduce the application of a diverse of different polymer materials in biomedicine. Specifically, this research will mainly demonstrate the application of functional polymer materials in the following aspects, including drug delivery, anti-cancer, and antibacterial. On this basis, this study will also look forward to some development trends of polymer materials in the future application of biomedicine. This research suggestion is to find a way to combine the good biodegradability of thermos responsive polymers with the manipulability of magneto responsive carriers to achieve more desirable polymer applications.

Keywords: Application, Polymer, Drug delivery, Anti-cancer, Antibacterial.

1. Introduction

Since 1830, when the first modern example of polymer science, derivatives of the natural polymer cellulose, was developed by Henri Braconid. After that, polymers have become an integral part of people's lives. Whether it's manufacturing, process engineering, new materials or biomedicine. They all have polymers involved. Therefore, as a relatively young field, polymers still have a lot of space to be explored and studied. That is why this research want to introduce this field, because polymer materials based on a diverse of polymers have great potential. Because ever since polymer applications have really served mankind, mankind has gained tremendous convenience from them whether in daily life, in various fields of professional research, or even in the military. And this situation is continuing to happen. After all of this being said, people may be wondering what exactly constitutes a polymer? A polymer is defined as a compound with a molecular structure in which a (usually large) number of similar polyatomic units are bonded together. Because of their chemical flexibility, polymers have unparalleled stability and excellent physical properties such as low moisture absorption, high temperature resistance, high corrosion resistance, and many other unique advantages. The first example of nylon (nylon 6,6) was produced using diamines in 1935, at DuPont's research facility. Three years later, IG Farben, which is a German chemical and pharmaceutical conglomerate formed in 1925, developed nylon 6. Farben, which is a German chemical and pharmaceutical conglomerate formed in 1925, developed nylon 6. As soon as nylon was commercially available, it quickly and dramatically increased the market for new materials. Because of its excellent impact resistance, high toughness, stiffness and hardness, and good electrical insulation properties, nylon was immediately used in a wide variety of applications and made into products such as seat belts, dental floss, and clothing. For this reason, polymers have been widely used in various fields, including environmental analysis, new material development, chemical industry and biomedicine [1].

Biomedicine, on the other hand, is dedicated to the application of biological and biochemical principles to medical research or practice. Based on the natural sciences, biomedicine has always intertwined with other fields of study to achieve its ultimate goal of promoting human health and healing. Although natural polymers have a long history of biomedical applications, the use of man-made polymers in this field is relatively new. The use of polymers in the field of biomedicine therefore implies endless possibilities and the great challenges that come with them. The main methods of

treating malignant tumors today are accompanied by great side effects. Surgical procedures to remove tumors or to remove as many tumors as possible may result in poor postoperative recovery resulting in decreased immunity. Chemotherapy uses drugs to kill cancer cells. However, the lack of targeting of the drug means that it can also kill normal cells. This side effect severely limits the dose of the drug and its effect on cancer cells. Radiation therapy uses beams of energy, such as X-rays, to kill cancer cells. This treatment faces the same problem as chemotherapy in that the high-energy rays can also kill normal cells. The degradability of polymers for drug loading and delivery can effectively improve the ability of chemical drugs to kill cancer cells with as little damage as possible to healthy cells.

To achieve this goal, the polymeric materials can be used for drug transport should have the following characteristics. 1) It can be able to degrade naturally in the human body or be absorbed. 2) It is not be toxic. 3) It can be able to contain the drug without leakage. 4) It can be able to release the drug accurately, neither early nor late. In order to make this treatment acceptable to the majority of people. The drug-carrying material should be relatively easy to synthesize or highly productive. As a result, this research will focus on analyzing the application of polymer functional materials in the field of biomedicine, including drug delivery, anti-cancer, and antibacterial.

2. Application of polymers for drug delivery

As many scholars know, polymer materials are used in a wide variety of ways, especially in biomedical applications. As well there are many successful applications being used for the treatment of disease and recovery. Targeted therapy, also known as molecularly targeted therapy, is a drug therapy that interferes with specific molecules needed for cancer or tumor proliferation to stop the growth of cancer cells [2]. To accomplish this, targeted drugs are often chosen as the means of targeted therapy. Targeted drugs are a class of drugs that act only on some specific tissues and cells. It is usually administered orally or intravenously into the body. In recent years, targeted therapies have gradually become more popular cancer treatments compared to surgery, chemotherapy and radiation therapy. Because targeted therapy can accurately find the malignant tumor before releasing the drug, thus not harming the surrounding healthy cells; the adverse effects of targeted drugs are milder; and targeted drugs often need to be used continuously, oral administration is undoubtedly the most convenient, and cancer patients' compliance is also better. Thus, the choice of vector for the targeted drug is extremely important. This is because it is related to the accuracy of drug release and the damage of drug toxicity to healthy cells. Different means of drug delivery can exhibit very diverse effects in humans. Soluble macromolecular carriers have some good characteristics that make them stand out from the crowd as a promising carrier. The use of soluble macromolecular carriers for drug delivery is achieved by introducing active targeting elements through focused heating of the tumor by a thermotherapy applicator [3]. Under the influence of local heating, the targeting of the drug is well navigated and released by means of intracorporeal injection. Therefore, the advantages of thermally targeted carriers are quite obvious. It does not require a concentration gradient to drive the accumulation of the thermos responsive polymer in the heated tumor and can finally reach high concentrations in the tumor when it is injected at low concentrations [4].

Figure 1 shows the representative heating turbidity curves for ELP and pNIPAAm vectors. The circles represent ELP, and the squares represent pNIPAAm. Also, the solid symbols are heat-responsive carriers, and the hollow symbols are non-heat-responsive carriers. A closer look at the graph shows that the solution turbidity of both thermal response carriers spikes when the temperature reaches 40 degrees Celsius. This is to increase the turbidity of the carriers [4]. This is because the LCST transition is designed to occur at 40 degrees Celsius. This ensures that the LCST transition is not mistakenly touched; at the same time, it needs to be kept at a lower temperature to ensure that the patient is not burned by the low temperature while receiving treatment.

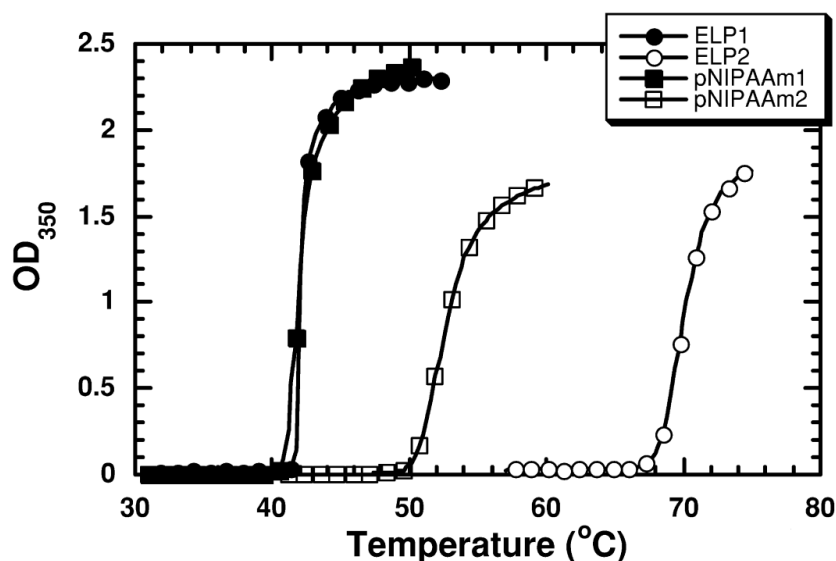


Figure 1. Variation trend of turbidity of ELP and polymer-based carrier with temperature [4]

This is precisely because the polymer carrier has undergone the LCST transition. LCST, also known as lower critical solution temperature, is a thermodynamically reversible transition in this case. This causes the water-soluble polymer to separate from the aqueous phase and complete the release of the drug [5]. An example of thermos responsive polymers that can be used as drug carriers is poly (NIPAAm). It has good and stable properties as a medical material and is used clinically. In addition to thermos responsive polymers. Nanomaterials also have good applications in biomedicine. In particular, magnetic nanoparticles combined with polymeric materials form magneto responsive targeted drugs. Magnetic nanoparticles can be functionalized because the surfactant molecules on their surface give them the ability to bind to some biomolecules due to their water-soluble nature [6]. Among the metallic materials that can be used as magneto responsive carriers, cobalt ferrite (CoFe_2O_4) and iron oxide (Fe_3O_4 NPs) are generally considered as suitable choices for biomedical applications. Drugs released by magneto responsive targeted delivery have a more precise guiding ability compared to common targeted therapies [7]. Because of this, magneto responsive carriers are characterized precisely by the ability to control the transfer of drugs to specific locations in the body by means of an applied external magnetic field.

Figure 2 illustrates two different routes of drug delivery: active targeting and passive targeting. In active targeting, nanocarriers and drugs identify tumors by recognizing markers of cancer cells. In passive targeting, magnetic nanoparticles are injected intravenously into the body and move through the blood vessels to other areas of the body. The target drug is then guided by an external magnetic field to bring the drug precisely to the tumor. At this point, the drug can penetrate smoothly into the tumor through the leaking cancerous vascular system [7].

However, the disadvantages of magneto responsive carriers are also obvious. As a metal it is more difficult to biodegrade in the human body, which can lead to instability in circulation and other problems [7]. However, if it is possible to combine the advantages of magneto responsive polymer carriers with thermos responsive polymer carriers. The composition of a carrier with both the high controllability of a magneto responsive carrier and the bio affinity of a thermos responsive carrier would allow this new carrier to be biodegradable while maintaining controllable performance.

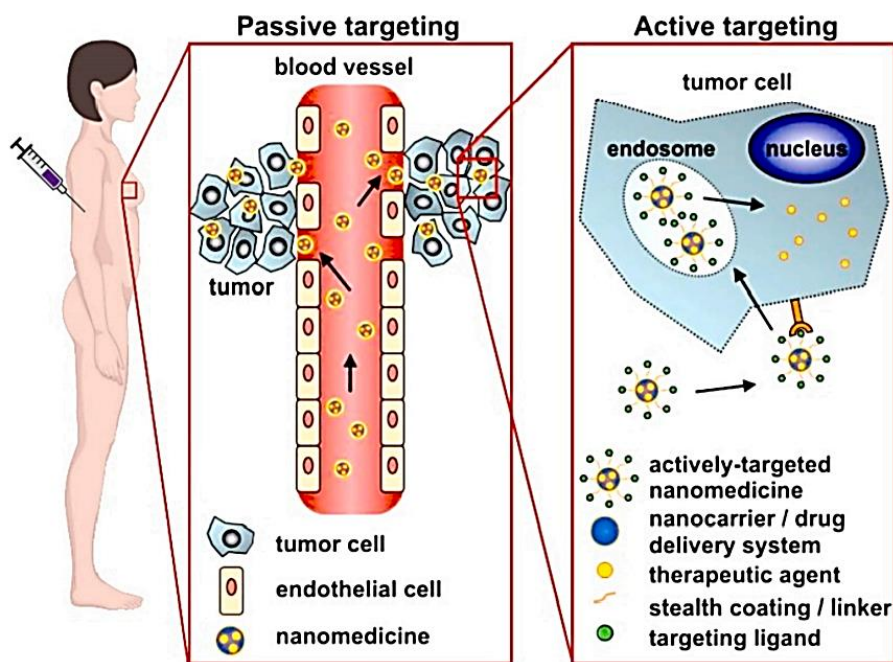


Figure 2. Two different routes of drug delivery [7]

3. Application of polymers for cancer therapy

Not only as a carrier for targeted drugs, polymers can have a wide range of applications and potential in antitumor therapy. In fact, polymers also have a very important role and a variety of uses in direct anti-cancer therapy. There are three main uses of polymeric drugs in anti-cancer therapy. One is to induce apoptosis of cancer cells and thus remove the tumor; the second is to inhibit continued tumor growth or even metastasis; and finally, to prevent tumor regrowth leading to cancer recurrence [8]. Regardless of the stage of the cancer or the type of treatment used. Polymers against cancer are almost always an important and integral part of cancer treatment. Since anti-cancer treatment is an ongoing process. During such a period it is necessary to constantly make sure that the tumor does not grow again. Therefore, an acceptable treatment option could be to keep the biodegradable polymer with the drug in the patient's body. The release of the drug and the inhibition of tumor growth continues for the next several months [8]. In this case, slow-release drugs are more effective in inhibiting tumor growth and preventing recurrence in the long term than a single injection. In addition, the polymer as an anti-cancer agent can be administered orally or intravenously into the patient's body. This effectively reduces the damage caused by the toxicity of the drug to the healthy cells in the cancer patient's body. Also, the oral route allows cancer patients to be less resistant to treatment.

Figure 3 illustrates the modern academic thinking on the mechanism of action of polymer-drug conjugates. Unlike ordinary chemotherapy, this drug, which is administered intravenously into the body, is retained in the circulatory system rather than being rapidly absorbed or eliminated. The flow of the targeted drug through the circulation in the renal system can be seen in Figure 2. The targeting of the tumor is driven by the flow in the blood vessels and the blood concentration [8]. Such chemotherapy can keep the patient's malignant tumor from continuing to grow rapidly for a longer period of time.

The compatibility between the polymer and the drug affects many key factors, including efficacy. Such as the accuracy of drug release, structural stability, and drug loading capacity [9]. Anti-cancer agents made by polymer-anticancer-drug conjugates can be used to hit different molecular targets. This undoubtedly allows the drug to be utilized with maximum efficiency. It will also improve the success rate of anti-cancer treatment. Although the process of chemotherapy is usually accompanied by more serious side effects due to the toxicity of the drug. Such as hair loss, vomiting, and insomnia

brought about by great mental stress [10]. However, polymer-anticancer-drug conjugates also bring better efficacy and less side effects compared to other anti-cancer treatments.

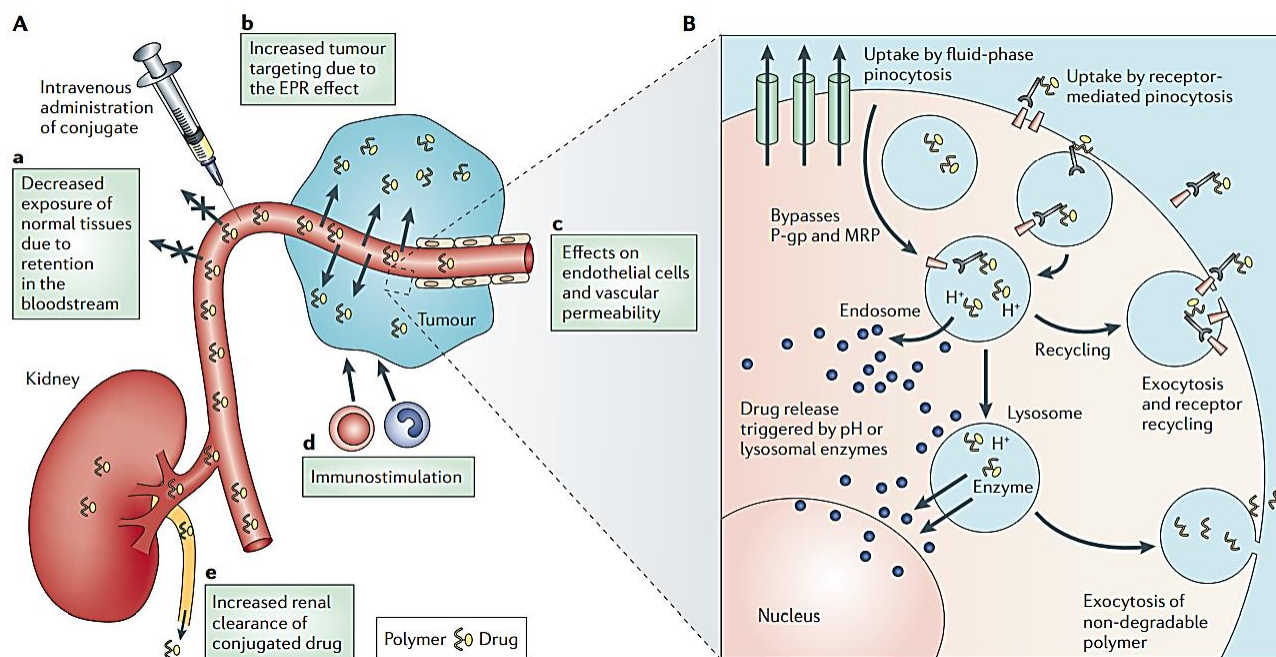


Figure 3. The mechanism of action of polymer-drug conjugates [8]

4. Application of polymers for anti-bacterial

The use of polymers in the biomedical field goes far beyond just cancer-related applications. Polymers also have many successful applications in a wide range of fields such as antibacterial. Bacterial problems are always an inevitable topic in the field of biomedicine. Whether it is in a sterile laboratory, in an operating room, or in some other scenario. Bacteria can cause infections in humans and animals, which can lead to further inflammation and other symptoms. These are undoubtedly no less troublesome and mentally stressful for both the researcher and the patient. Polymers can be used to inhibit bacteria because of the properties of the material. A typical example of application can be antimicrobial coatings that prevent the formation of bacterial biofilms. The antibacterial coating acts like a funnel with filter paper. viable bacteria can pass through normally without being affected. Damaged bacteria will adhere to the antimicrobial biofilm and thus achieve bacterial inhibition [11]. As with other applications containing polymers, polymers are always combined with other substances to achieve greater effectiveness. When it comes to bacterial inhibition, avoiding infection is the goal of this approach.

Bacteria inhibition in the biomedical field cannot simply end with the use of bactericidal additives because there is always the need to consider their environmental properties over environmental stability, the need to consider toxicity of release, and the volatile solubility of the bactericide. Therefore, simple bactericides are not always applicable in all cases. Eugenol is a natural bacteriostatic substance found in the plant clove. This substance has been shown to inhibit the growth of microorganisms. However, eugenol can cause inflammation on the oral mucosa at specific concentrations. This poses an additional risk when oral treatments like root canal therapy are performed with eugenol [11]. Therefore, an attempt to purify eugenol and then process it into polymeric material would be a good experiment to verify the inhibition of bacteria with the guarantee of less irritation to the oral cavity.

Figure 4 shows the adsorption pattern of proteins to polymer brushes in a bacteriostatic nanocoating. This is because small molecules are more likely to penetrate the brush than large molecules [11]. Another application of polymers in the field of antibacterial is the prevention of infections and rejection reactions caused by internal implants or after surgery [12] [13]. In general, whenever an environment is conducive to bacterial growth, bacterial colonies are produced and biofilms are formed. This is also

true for the surface of the implant in the body. When biofilm causes infection and inflammation, the implant has to be removed. Moreover, the effect of antibiotics is not significant for biofilms. Therefore, a good solution is to cover the implant with an antibacterial polymer coating. This way no biofilm is produced and no inflammation or infection is caused. It is also important to note that the antibacterial coating should not cause harm to the patient itself [14] [15].

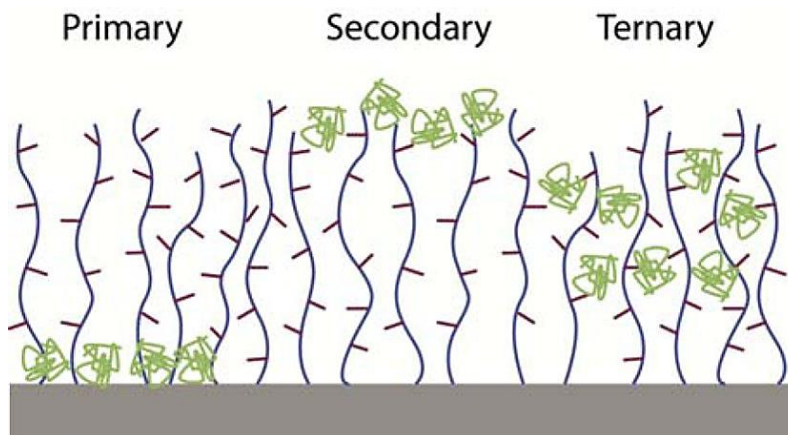


Figure 4. Adsorption pattern of proteins to polymer brushes in a bacteriostatic nanocoating [11]

5. Conclusions

After a series of studies and comparisons were conducted, and the application of polymers in biomedical field is very wide. However, this does not mean that it is perfect. Magneto responsive polymer carriers are manipulable to ensure that the drug is not released early or too late. Thermos responsive polymer carriers ensure that the patient's normal cells are not overly exposed to the toxicity of the drug. Thus, if the two are combined, the healthy cells of the patient's body can be protected without loss of control. Therefore, it is a reasonable hypothesis that the metal part of magneto responsive polymer such as cobalt ferrite (CoFe_2O_4) and iron oxide (Fe_3O_4 NPs) can be added to thermos responsive polymer carriers to achieve the drug release in this mode by both temperature and magnetic field. This mode of drug release is controlled by both temperature and magnetic field. With this double insurance, not only the toxicity of the drug to the patient's body is greatly reduced because of the very precise release, but also the accuracy of the targeted drug release is improved.

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