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Medicinal Uses of Nanoparticles

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ABSTRACT: The use of nanotechnology in medicine offers some exciting possibilities. Some techniques are only imagined, while others are at various stages of testing, or actually being used today.

The use of nanoparticles in medicine involves applications of nanoparticles currently under development, as well as longer range research that involves the use of manufactured nano-robots to make repairs at the cellular level (sometimes referred to as nanomedicine).

Whatever you call it, the use of nanotechnology in the field of medicine could revolutionize the way we detect and treat damage to the human body and disease in the future, and many techniques only imagined a few years ago are making remarkable progress towards becoming realities.

KEYWORDS-nanoparticles, medicinal, nanomedicine, research, repairs

I. INTRODUCTION

Applications of Nanotechnology in Medicine:

Drug Delivery

One application of nanoparticles in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Particles are engineered so that they are attracted to diseased cells, which allows direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease.

For example researchers at North Carolina State University are developing a method to deliver cardiac stem cells to damaged heart tissue. They attach nanovesicles that are attracted to an injury to the stem cells to increase the amount of stem cells delivered to an injured tissue.[1,2,3]

Diagnostic Techniques

Researchers John Hopkins University are using nanoimprint lithography to manufacture a sensor that can detect covid-19 and other viruses that can be used with hand held testing device for quick reults.

Researchers at Worcester Polytechnic Institute are using antibodies attached to carbon nanotubes in chips to detect cancer cells in the blood stream. The researchers believe this method could be used in simple lab tests that could provide early detection of cancer cells in the bloodstream.[4,5,6]

A test for early detection of kidney damage is being developed. The method uses gold nanorods functionalized to attach to the type of protein generated by damaged kidneys. When protein accumulates on the nanorod the color of the nanorod shifts. The test is designed to be done quickly and inexpensively for early detection of a problem.

Antibacterial Treatments

Researchers at the University of Houston are developing a technique to kill bacteria using gold nanoparticles and infrared light. This method may lead to improved cleaning of instruments in hospital settings.

Researchers at the University of Colorado Boulder are investigating the use of quantum dots to treat antibiotic resistant infections..

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Wound Treatment

Researchers at the University of Wisconsin have demonstrated a bandage that applies electrical pulses to a wound using electricity produced by nanogenerators worn by the patient.

For trauma patients with internal bleeding another way to reduce the blood loss is needed. Researchers at Chase Western Reserve University are developing polymer nanoparticles that act as synthetic platelets. Lab tests have shown that injection of these synthetic platelets significantly reduces blood loss.

Treatment of Diseases

Nanotechnology is being used to treat various diseases:

Cancer

Heart Disease

Diabetes

Kidney Disease

Applying Nanorobots in Medicine[7,8,9]

Nanorobots could actually be programmed to repair specific diseased cells, functioning in a similar way to antibodies in our natural healing processes. Read about design analysis for one such cell repair nanorobot in this article: The Ideal Gene Delivery Vector: Chromallocytes, Cell Repair Nanorobots for Chromosome Repair Therapy

II. DISCUSSION

Nanorobots in Medicine

Future applications of nanomedicine will be based on the ability to build nanorobots. In the future these nanorobots could actually be programmed to repair specific diseased cells, functioning in a similar way to antibodies in our natural healing processes.

Developing Nanorobots for Medicine

Design analysis for a cell repair nanorobot: The Ideal Gene Delivery Vector: Chromallocytes, Cell Repair Nanorobots for Chromosome Repair Therapy

Design analysis for an antimicrobial nanorobot: Microbivores: Artifical Mechanical Phagocytes using Digest and Discharge Protocol

A Mechanical Artificial Red Cell: Exploratory Design in Medical Nanotechnology

Nanorobots in Medicine: Future Applications

The elimination of bacterial infections in a patient within minutes, instead of using treatment with antibiotics over a period of weeks.

The ability to perform surgery at the cellular level, removing individual diseased cells and even repairing defective portions of individual cells.

Significant lengthening of the human lifespan by repairing cellular level conditions that cause the body to age.[10,11,12]

When you hear the word "nanomedicine," it might call to mind scenarios like those in the 1966 movie "Fantastic Voyage." The film portrays a medical team shrunken down to ride a microscopic robotic ship through a man's body to clear a blood clot in his brain.

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Nanomedicine has not reached that level of sophistication yet. Although scientists can generate nanomaterials smaller then several nanometers – the "nano" indicating one-billionth of a meter – today's nanotechnology has not been able to generate functional electronic robotics tiny enough to inject safely into the bloodstream. But since the concept of nanotechnology was first introduced in the 1970s, it has made its mark in many everyday products, including electronics, fabrics, food, water and air treatment processes, cosmetics and drugs. Given these successes across different fields, many medical researchers were eager to use nanotechnology to diagnose and treat disease.

III. RESULTS

Nanomedicine refers to the use of materials at the nanoscale to diagnose and treat disease. Some researchers define nanomedicine as encompassing any medical products using nanomaterials smaller than 1,000 nanometers. Others more narrowly use the term to refer to injectable drugs using nanoparticles smaller than 200 nanometers. Anything larger may not be safe to inject into the bloodstream.

Several nanomaterials have been successfully used in vaccines. The most well-known examples today are the Pfizer-BioNTech and Moderna COVID-19 mRNA vaccines. These vaccines used a nanoparticle made of of lipids, or fatty acids, that helps carry the mRNA to where it needs to go in the body to trigger an immune response.

Researchers have also successfully used nanomaterials in diagnostics and medical imaging. Rapid COVID-19 tests and pregnancy tests use gold nanoparticles to form the colored band that designates a positive result. Magnetic resonance imaging, or MRI, often uses nanoparticles as contrast agents that help make an image more visible.[13,14,15]

Several nanoparticle-based drugs have been approved for cancer treatment. Doxil (doxorubicin) and Abraxane (paclitaxel) are chemotherapy drugs that use nanomaterials as a delivery mechanism to improve treatment efficacy and reduce side effects.

Cancer and nanomedicine

The potential of nanomedicine to improve a drug's effectiveness and reduce its toxicity is attractive for cancer researchers working with anti-cancer drugs that often have strong side effects. Indeed, 65% of clinical trials using nanoparticles are focused on cancer.

The idea is that nanoparticle cancer drugs could act like biological missiles that destroy tumors while minimizing damage to healthy organs. Because tumors have leaky blood vessels, researchers believe this would allow nanoparticles to accumulate in tumors. Conversely, because nanoparticles can circulate in the bloodstream longer than traditional cancer treatments, they could accumulate less in healthy organs and reduce toxicity.

Although these design strategies have been successful in mouse models, most nanoparticle cancer drugs have not been shown to be more effective than other cancer drugs. Furthermore, while some nanoparticle-based drugs can reduce toxicity to certain organs, they may increase toxicity in others. For example, while the nanoparticle-based Doxil decreases damage to the heart compared with other chemotherapy options, it can increase the risk of developing hand-foot syndrome.

Improving nanoparticle-based cancer drugs

To investigate ways to improve how nanoparticle-based cancer drugs are designed, my research team and I examined how well five approved nanoparticle-based cancer drugs accumulate in tumors and avoid healthy cells compared with the same cancer drugs without nanoparticles. Based on the findings of our lab study, we proposed that designing nanoparticles to be more specific to their intended target could improve their translation from animal models to people. This includes creating nanoparticles that address the shortcomings of a particular drug – such as common side effects – and home in on the types of cells they should be targeting in each particular cancer type.

Using these criteria, we designed a nanoparticle-based immunotherapy for metastatic breast cancer. We first identified that breast cancer has a type of immune cell that suppresses immune response, helping the cancer become resistant to treatments that stimulate the immune system to attack tumors. We hypothesized that while drugs could overcome this

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resistance, they are unable to sufficiently accumulate in these cells to succeed. So we designed nanoparticles made of a common protein called albumin that could deliver cancer drugs directly to where these immune-suppressing cells are located.[16,17,18]

When we tested our nanoparticle-based treatment on mice genetically modified to have breast cancer, we were able to eliminate the tumor and achieve complete remission. All of the mice were still alive 200 days after birth. We're hopeful it will eventually translate from animal models to cancer patients.

IV. CONCLUSION

Nanomedicine's bright but realistic future

The success of some drugs that use nanoparticles, such as the COVID-19 mRNA vaccines, has prompted excitement among researchers and the public about their potential use in treating various other diseases, including talks about a future cancer vaccine. However, a vaccine for an infectious disease is not the same as a vaccine for cancer. Cancer vaccines may require different strategies to overcome treatment resistance. Injecting a nanoparticle-based vaccine into the bloodstream also has different design challenges than injecting into muscle.

While the field of nanomedicine has made good progress in getting drugs or diagnostics out of the lab and into the clinic, it still has a long road ahead. Learning from past successes and failures can help researchers develop breakthroughs that allow nanomedicine to live up to its promise.[19,20]

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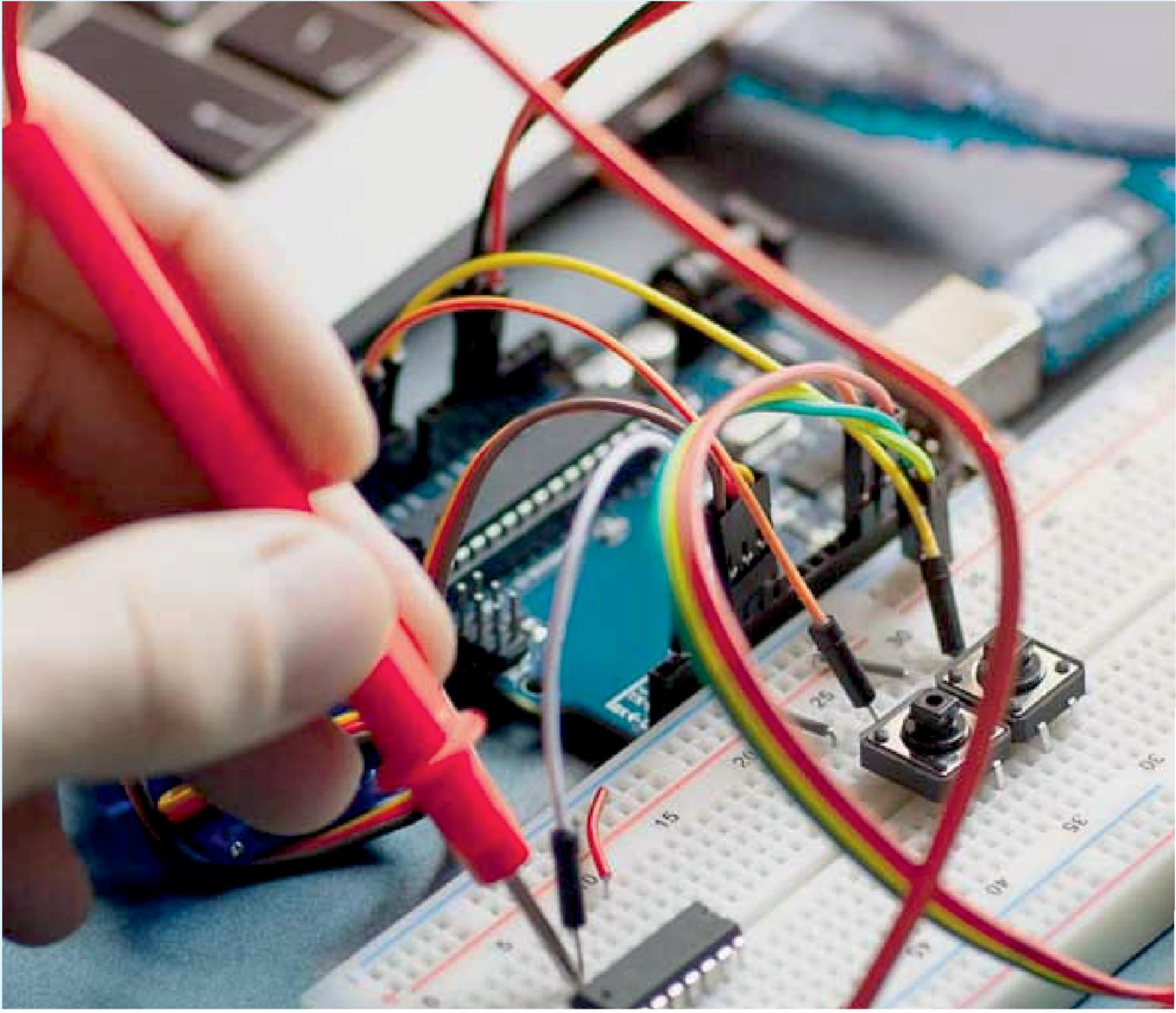

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