Applications of Nanotechnology in Veterinary Medicine

Vikrama Chakravarthi. P and Sri N. Balaji*

1. Assistant Product Manager, 2. Product Manager,
Natural Remedies Pvt. Ltd, Bangalore-100.
* Corresponding author email : nbalaji@naturalremedy.com, Mobile No.+91-9341263967.

Abstract

In the recent years the application of nanotechnology in human and veterinary medicine has shown a great progress. Scientists foresee that this progress in the field of nanotechnology could represent a major breakthrough in addressing some of the technical challenges faced by human and veterinary profession. While the great hopes of nanomedicine are disease detection and new pharmaceuticals for humans, veterinary applications of nanotechnology may become the proving ground for untried and more controversial techniques from nanocapsule vaccines to sex selection in breeding. Nanotechnology has the potential to impact not only the way we live, but also the way we practice veterinary medicine. Examples of potential applications in animal agriculture and veterinary medicine include disease diagnosis and treatment delivery systems, new tools for molecular and cellular breeding, the security of animal food products, modification of animal waste, pathogen detection, and many more. Existing research has demonstrated the feasibility of introducing nanoshells and nanotubes into animals to seek and destroy targeted cells. These building blocks of nanotechnology are expected to be integrated into systems over the next couple of decades on a commercial basis. This article describes some of the principal areas of nanotechnology currently being undertaken in the world of medicine. The main purposes of this article are to trigger the interest of discoveries of veterinary profession in the field of nanotechnology and to provide a glimpse at potential important targets for nanotechnology in the field of veterinary medicine. Also it is important to mention that because nanotechnology is at a very early stage of development, it may take several years to perform the necessary research and conduct clinical trials for obtaining meaningful results. This tool as it develops over the next several decades will have major implications in veterinary and animal science.

Keywords: Nanotechnology, Nanopharmaceuticals, Diagnostic tools

Introduction

In the era of new health related technologies, veterinary profession will enter a phase of new and incredible transformations. The major contributor to those changes is our recent ability to measure, manipulate and organize things at the nanoscale level. Our understanding of the principles that rule the nanoscale world will be of great impact on veterinary research leading to new discoveries never before imagined.

Nanotechnology, shortened to "nanotech", is the study of the controlling of matter on an atomic and molecular scale. Generally nanotechnology deals with structures of the size 100 nanometers or smaller in at least one dimension, and involves developing materials or devices within that size.

A simple definition of nanotechnology is the art of manipulating matter, atom by atom. This new area of science can provide us with the ability to assemble things from atomic and molecular blocks.The term nano is derived from the Greek word dwarf and is usually combined with a noun to form words such as nanometer, nanobot and nanotechnology.

Nanotechnology, as a new enabling technology, has the potential to revolutionize our agriculture and food systems. Food systems security, disease treatment delivery systems, new tools for molecular and cellular biology, new materials for pathogen detection and protection of the environment are examples of the important links of nanotechnology to the science and engineering of agriculture and food systems.

Nanotechnology can be viewed as a series of technologies that are used individually or in combination to make products and applications and to better understand science (Gordon and Sagman, 2003).Nanotechnology materials can be grouped into three main areas: raw materials, nanostructured materials and the group composed by nanotubes and fullerenes. The raw material includes nanoparticles and nanocrystalline materials that are readily manufactured and substitute for less performing bulk materials. Nanostructured materials are typically processed forms of raw material that provide special

shapes and functionality. Examples of nanostructured materials include the quantum dots and the dendrimers. Nanotubes and fullerenes can produce materials that are 100 times stronger than steel, more conductive than copper, and can be safely used in some medical applications.

Nanomedicine

The term nanomedicine refers to the use of molecular machine systems (i.e. nanobots) to address medical problems, and to the use of molecular knowledge to maintain and improve health at a molecular scale. As a specialized field within nanotechnology, nanomedicine would work towards bodily repair through the use of engineered, in vivo probes and sensors that would operate, in a semi-permanent fashion, within the body. The development of nanomedicine will have extraordinary implications for the veterinary profession, because it will change the definition of disease and the way we do diagnosis and treatment of medical conditions.

Nanopharmaceuticals

One of the areas of veterinary medicine that would benefit most from the nanotechnology research is the field of pharmacology (Feneque, 2000). The creation and manipulation of new synthetic molecules can provide us with new therapeutical compounds to treat diseases in our pet population. These new compounds for example would protect animals from viral or bacterial infections and accelerate wound healing. Also these new compounds could carry drugs and genes into cells, making treatment of diseases more efficacious.

One of the most promising and productive areas of nanotechnology are the nanopharmaceuticals. Most of pet diseases one day will be addressed by the use of nanopharmaceuticals (Feneque,2003). Research in the area of nanopharmaceuticals would provide new advances in the area of drug delivery systems. These systems have an impact on the rate of absorption, distribution, metabolism, and excretion of drugs or other substances in the body. They must allow the drug to bind to its target receptor and influence the receptor's action. Drug delivery systems have severe restrictions on the materials and production process that can be used. The drug delivery material must be compatible and bind easy with the drug, and be bioresorbable. The production process must respect stringent conditions on processing and chemistry that won't degrade the drug, and still provide a cost effective product.

One of the major classes of drug delivery systems are materials that encapsulate drugs to protect them during transit through the body. When encapsulation materials are produced from nanoparticles in the 1 to 100 nanometer size range instead of bigger micro particles (existing molecules), they have a larger surface area for the same volume, smaller pore size, improved solubility, and different structural properties. This can improve both the diffusion and degradation characteristics of the encapsulation material.

Another class of drug delivery system is nanomaterials that can carry drugs to their destination sites and also have functional properties. Certain nanostructures can be controlled to link with a drug, a molecule or an imaging agent, then attract specific cells and release their sustances when required. Because of their size, nanostructures have the ability to enter cells, as cells will typically internalize materials below 100 nanometers.

Nanoemulsion

Soybean oil in its standard form has very few medical applications. But once it is emulsified with detergents to form nanodrops with measurements less than 600 nanometers, it can act as a very potent destroyer of pathogens. Its mode of action is not chemical, but a physical one. When the oil nanodrops contact the membranes of bacteria or envelope viruses, the drops surface tension forces a merger with the membrane, blowing it apart and killing the pathogen. One very important characteristic of the nanoemulsion is that they don't affect cell structures of higher organisms, which make it ideal to use in animals and humans. While the nanoemulsion is entirely safe when applied externally, unfortunately scientists had discovered that the oil droplets can also destroy erythrocytes and sperm cells. The reason seems to be that both types of cells lack the support structures that make other cells invulnerable to the effects of the nanodrops. This means that the nanoemulsion can't be use intravenously. If nanoemulsion research continues showing promising results, in the near future we may see bactericidal and viricidal products that can be use topically in animals and humans.

Dendrimeters

One of the most important and promising areas of medical research of today is the study of nanomaterials known as dendrimers. They are synthetic polymers, a thousand times smaller than cells. Dendrimers can be synthesized in various predetermined sizes and can interact with biological agents by modifying their surfaces properties. Three very important properties of dendrimers make them an excellent candidate as pharmacological agents. First, they can hold a drug's molecules in their structure and serve as a delivery vehicle. Second, they can enter cells very easily and release drugs right on target. Third and most important, dendrimers don't trigger immune

system responses.

Dendrimers have a lot to offer to the field of Veterinary Medicine. In the future one of the major contributions of these synthetic nanomaterials will be the diagnoses, treatment and eradication of malignant tumors that commonly affect the small animal geriatric population. They can serve as a drug delivery vehicle for drugs or radioactive isotopes directly into a tumor microvasculature, which may be considered as an alternative to direct irradiation of tumors with fewer side effects.

Besides targeting tumor cells and drug delivery systems, dendrimers have demonstrated promising results as tools for MRI imaging (Margerum, et al., 1997 and Kim and Zimmerman, 1998) and gene transfer techniques. Also dendrimer-based nanocomposites are been studied as possible antimicrobial agents against Staphylococcus aureus, Pseudomonas aeruginosa and Escherichia coli.

Vaccines:

Another area that probably would benefit from nanotechnology research is the production of vaccines. The most recent studies indicate that synthetic oligodeoxynucleotides and antigens in biodegradable nanospheres can be use as an alternative approach for immunization (Diwan, et al., 2002). A better immune response seems to be obtained with biodegradable nanospheres then with vaccines produced by conventional methods.

Diagnostic Tools

Commonly available diagnostic tests that are usually sent to outside laboratories and can take from hours to days to provide the results may be considered obsolete sooner than expected. Nanotechnology can bring to our veterinary hospitals cheaper, faster and more precise diagnostic tools.

A. Quantum dot particles:

Quantum dot particles are tiny crystals which are a ten-millionth of an inch in size. These particles enable powerful new approaches to genetic analysis, drug discovery and disease diagnostics. Today quantum dots are considered an important advancement in our understanding of how genes work. Scientists believe that in a couple of years these particles will be instrumental in allowing researchers to monitor reactions of cells to certain drugs or viruses. Some scientists envision the possibility of injecting quantum dots into animal bodies. Once injected into the body they may detect cells that are not working normally. Because they respond to light, it may be possible to affect the behavior of the dot once it is inside the cell. For example, they may be able to respond to a flash and heat up enough to destroy cancerous cells.

Quantum dots offer many technical advantages over traditional fluorescent dyes, which are commonly used to detect and track biological molecules. They not only can stay for a prolonged period of time, they are also brighter and easier to visualize than organic dyes. They can be very helpful in visualizing cell pathways, which is essential for our understanding of how certain drugs are going to behave in an animal's body. In addition to their usefulness in identifying and tracking molecules, they promise faster, more flexible and less costly tests for clinical analysis.

B. Immunoassay:

Immunoassay technology capitalizes on the characteristic way that antibodies attach themselves to invading pathogens in the body. Antibodies recognize and bind to antigens with great specificity. One of the diagnostic applications of this behavior is the conventional immunoassay. In a routine immunoassay test we expose a solution, such as blood plasma for example, to a tray containing antibodies that bind with a specific antigen under investigation. When the antibodies bind to the antigen, the test changes color. This system is used to identify and diagnose various conditions that afflict the animal population.

Unfortunately, we haven't produced a fast and reliable whole blood immunoassay yet, in part because blood is so viscous and murky that it interferes with the chemical reactions in the test solution and make it difficult to get accurate readings. Instead, clinicians must purify the blood to remove these contaminants before proceeding with the immunoassay, a time consuming step that typically takes an hour or more. Nanotechnology research may have found a way to overcome the problems with whole blood immuno-assays. Nanotechnology researchers have developed a new method of testing whole blood using optically active gold-coated glass particles commonly known as gold nanoshells (Hirsch, et al., 2003). Nanoshells are also being tested as a noninvasive way to detect tumors. Since they are gold coated, nanoshells would not trigger an immunity response. Scientists have found that they can attach to the shells antibodies that would lock onto specific tumor cells. The nanoshells are then injected into the body of a laboratory animal, a light source is turned on (a laser or infrared light for example) and they observe if and where the nanoshells accumulate. But nanoshells are more than a marker, it turns out. It has been found that they could be used to destroy tumors as well. Like a magnifying glass, nanoshells concentrate light beamed at them and heat up. Their studies showed the shells killed tumor cells without harming skin or nearby healthy tissue. While more studies with this novel optical material need to be done, we can say today that nanoshells will play an important role in the future of veterinary care.

Human R&D support

When it comes to technologies like gene therapy,

tissue engineering or nanotechnology, there is no doubt their use on veterinary medicine will yield immediate insights for human medical research. One of the newest fields of research that could have a positive influence on the diagnosis and treatment of cancer is nanotechnology. Thanks to nanotechnology, a complete new set of tools for the diagnosis and treatment of cancer in the pet population will be available. For example, with the use of magnetic resonance imaging (MRI) along with fluorescents nanoparticles researchers are able to visualize the lymphatic drainage of mice affected with breast cancer. This technique may have a very important application in the diagnosis and treatment of human breast cancer.

Conclusions

Clearly, the profession of Veterinary Medicine will be substantially different in 25 years from that of today. It can be hoped that nanotechnology, in addition to contributing to the creation of changes in veterinary profession, will also be one of the technologies that help practitioners stay abreast of and manage these developments. In order to appreciate the advantages of this technology, the veterinary profession needs to understand its basic concepts and contributions. Veterinary profession needs to be more vocal about issues arising from new technologies such as cloning and stem cell research. Despite initial success, the veterinary applications of nanotechnology are in its infancy, and a number of hurdles remain prior to bringing these therapies into the clinical arena. Encouraging commercial organizations to make good and useful products based on these technologies can be crucial for the ultimate benefit of veterinary profession. The real challenge to veterinary medicine is to understand and apply these technologies in a way that will provide maximum benefits to animal's health. Nanotechnology will raise our technological capabilities to a new level, improving pet health care and quality of life. It will also increase our standard of living and it will drive further economic expansion into the veterinary profession.

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