Nanotechnology and Drug Delivery

What is nanomedicine? How is nanotechnology expected to transform medicine and health care in the future?

Nanotechnology is a field of applied science and technology covering a broad range of topics. The basic concept is it deals with one nanometer (nm) is one billionth, or $10^{-9}$ of a meter. For comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 1.2–1.5 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular lifeforms, the bacteria of the genus Mycoplasma, are around 200 nm in length.

Nanotechnology and nanoscience got started in the early 1980s with two major developments; the birth of cluster science and the invention of the scanning tunneling microscope (STM). This development led to the discovery of fullerenes in 1986 and carbon nanotubes a few years later. In another development, the synthesis and properties of semiconductor nanocrystals was studied. This led to a fast increasing number of metal oxide nanoparticles of quantum dots.

Nanomedicine
Nanomedicine is the monitoring, repair, construction and control of human biological systems at the molecular level, using engineered nanodevices and nanostructures. Drugs with narrow therapeutic indexes create a major challenge for pharmaceutical scientists, during their developments. Application of nanotechnology for the delivery of such drugs can significantly overcome this problem. Six types of drug delivery systems in which nanotechnology is likely to have a significant impact. These six types of drug delivery systems is discussed below.

Injectable Drugs
Nanotechnology promises to create new dosage forms that are easier to administer, more pleasant for the patient, and more competitive in the marketplace. A new nanotechnology-based vaccine delivery method could allow the development of single-dose vaccines as well as new vaccines in some disease areas. Recently, researchers discovered a biodegradable polymer in a microsphere formulation that could be used to develop time-released vaccines, thus reducing the need for vaccine booster shots, as well as stimulate an immune response that traditional vaccines do not.
Implantable Delivery Systems

Nanotechnology is also opening up new opportunities in implantable delivery systems, which are often preferable to the use of injectable drugs, because the latter frequently display first-order kinetics (the blood concentration goes up rapidly, but drops exponentially over time). This rapid rise may cause difficulties with toxicity, and drug efficacy can diminish as the drug concentration falls below the targeted range.

Nano-implants will be used in the near future for treating cancer. Among the first nanoscale devices to show promise in anti-cancer therapeutics and drug delivery are structures called nanoshells, which may afford a degree of control never before seen in implantable drug delivery products. Nanoshells typically have a silicon core that is sealed in an outer metallic core. By manipulating the ratio of wall to core, the shells can be precisely tuned to scatter or absorb very specific wavelengths of light. For example, gold encased nanoshells have been used to convert light into heat, enabling the destruction of tumors by selective binding to malignant cells. A physician can use infrared rays to pass harmlessly through soft tissue, while initiating a lethal application of heat when the nanoshells are excited. Some researchers are also experimenting with temperature-sensitive drug delivery control methods, using nanoshells that release their payload only when illuminated with the proper infrared wavelength.

Oral Drug Delivery Systems

Drugs given orally remain preferable (to patients) to implantables or injectables. Thus, development continues with respect to traditional oral delivery systems with nanoengineered improvements. There are some areas where nano-enhanced drugs could make a big difference in increasing oral bioavailability and reducing undesirable side effects. By increasing bioavailability, nanoparticles can increase the yield in drug development and more importantly may help treat previously untreatable conditions. Because of the blood brain barrier (BBB), many new chemical entities aimed at treating brain disorders have proved not to be clinically useful. Some companies have came up with nanoparticles capable of reaching the brain for anesthesia (Dalargin; an analgesic), cancer drugs, and various other therapeutics.
Topical Delivery of Active Compounds
Nanomaterials provide a unique opportunity for rapid topical delivery of active compounds. Given their very small size, nanoparticles are able to enter human tissues and cells quickly, and companies such as Novavax have already developed regulated topical systems that take advantage of the unique properties of micellar nanoparticles.

Transdermal Systems
Microneedles are a combination of a needle and the transdermal patch. They are dime-sized pieces of polymer with hundreds of hollow microneedles between 100 and 1,000 micrometers long. These small needles penetrate the top layers of skin and allow the drug to pass through with ease. This size of needle does not penetrate deeply enough to stimulate the nerves and hence will cause no pain!

Toxin Removal
Nanotechnology is finding new applications in the area of toxin removal. Colloidal dispersions have been demonstrated to remove potentially lethal compounds from the bloodstream, including high concentrations of lipophilic therapeutics, illegal drugs, and chemical and biological agents.

A team of scientists at the University of Florida and Clarkson University in Potsdam, New York, has demonstrated favorable results to this end, using biocompatible microemulsions. These oil-in-water systems have a rapid and efficient absorption capacity for many target molecules that are frequently overdosed, whether this be intentional or accidental. The microemulsions use a polymeric surfactant, in combination with an ionic co-surfactant.

Injectable Drugs
Nanotechnology is already generating new dosage forms that are easier to administer and more pleasant for the patient.