Editorial

Nanotechnology and its implication in medical science

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A revolution is occurring in science and technology in the form of a novel technology called Nanotechnology. Nanotechnology is considered to be an emerging technology due to the possibility of creating new innovative products with completely new characteristics and functions with enormous potential in a wide range of applications with significant positive impact on healthcare. In next few decades we will be coming across some novel innovations and this all will be possible by virtue of Nanotechnology also called 'nanotech' in short form. Many of the visions discussed in the literature of nanotechnology still seems to be part of science fiction, however, there have been some practical breakthroughs which cannot be ignored.

Although James Clerk Maxwell was the first person to give some concepts regarding nanotechnology in 1867, but it was Richard Feynman, a physicist, who presented the topic of nanotechnology in 1959 for the first time in his famous lecture entitled "There's Plenty of Room at the Bottom".[1] In 1974 Norio Taniguchi at Tokyo Science University coined the term 'nanotechnology'.[1]

Nanotechnology is a combination of atomic or molecular scale techniques that can establish devices or systems in the nanometer range. By definition, it is the manipulation of matter with at least one dimension having size from 1 to 100 nanometers. One nanometer represents one billionth of a meter. Nanotechnology is the ability to work at the molecular level, atom by atom, to create structures with fundamentally new molecular organization.[2] In this scale, and especially below 5 nm, the properties of matter differ significantly e.g. the effect of gravity will be almost negligible, surface tension and Van der Waals attraction would become more important, nanomaterials have a relatively greater surface area than do larger particles of the same mass of material etc.[1,3,4]

The nanotechnology dealing with healthcare is called nanomedicine. Nanomedicine is an offshoot of nanotechnology and is characterized by highly specific medical interventions at the molecular scale for development of medical therapeutics and diagnostics, monitoring diseases, cancer treatment via targeted drug delivery, improved cell material interactions, and gene delivery systems. It is foreseen that nanomedicine will have an enormous impact on human health.[3]

Almost all processes of living organisms occur at nanometer scale. Biological units like DNA, proteins and cell membranes are of this dimension. By nanotechnology, we can have better understanding of these biological units so that they can be specifically and precisely guided or directed. Nanoscale devices could be 100 to 10,000 times smaller than human cells but are similar in size to large biomolecules such as enzymes and receptors. Nanoscale devices smaller than 50 nm can easily enter living cells, and those smaller than 20 nm can move out of blood vessels as they circulate through the body. They can also pass through the blood-brain barrier.[3] By manipulating these nanoparticles at molecular level we can have surprising results.

In the coming decades nanomedicine will bring a paradigm shift in multiple areas of human healthcare. It will enable us to detect cancers in presymptomatic phase by highly sensitive imaging. It is about to bring revolutionary changes in the treatment of cancer by selectively killing tumour cells by transforming electro-magnetic energy into heat which will be lethal to cancer cells, or by targeted delivery of chemotherapeutic drugs to tumor cells (and sparing the normal cells) through nanovehicles.[5] It will also be used for the treatment of atherosclerotic diseases even before its development.[6] Healthcare providers could deliver specific amounts of drugs or use nanorobots to clean out arteries blocked by atherosclerosis. Artificial mechanical red blood cells will be expected to be able to deliver more oxygen to the tissues than natural red blood cells and artificial mechanical white blood cells will be able to destroy microbiologic pathogens.[3] Surgeons are always in search of minimally invasive techniques of surgery and this can be achieved successfully by nanotechnology. Application of nanotechnology in surgery is mostly at cellular level where a human hand cannot perform precisely. Femtosecond lasers (which emits ultrashort pulses with durations in the range of femtoseconds where 1 femtosecond=10-15 seconds), diamond scalpels (with a

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cutting edge of only a few nanometers), and nanoneedles are some of the great inventions of nanotechnology which are being used or will be used to manipulate intracellular molecules and organelles, and surgeries at nano level like corneal and brain surgeries.[7] Tissue engineering is the application of engineering and life sciences towards fundamental understanding of normal and pathological mammalian tissues and the development of biological substitutes to restore, maintain or improve tissue function.[7] Nanotechnology by virtue of producing tissue-engineered products, e.g. orthopaedic and dental implants, having characteristics matching the target tissue as closely as possible can lead to formation of successful functioning tissue with excellent lifetime and least possible rejection by immune system.[7]

Imaging techniques will also see a new era of using nanoparticles. For example, quantum dots (nanometer sized semiconductor nanocrystals with excellent fluorescent properties) possess remarkable optical and electronic properties that can be precisely controlled by changing their size and composition. Such products have already entered the market for imaging applications though at experimental level so far.[3] Quantum dots can be made to emit light at any wavelength in the visible and infrared ranges, and can be inserted almost anywhere, including liquid solution, dyes etc.[3]

Reducing the size of structures to nanolevel results in completely different properties. This is the reason that nanoparticles are more active both biochemically and biologically and thus potentially possess great benefits as well as great risks.[4] Since adverse effects of these nano-products are not explored yet to sufficient level, ethical and moral concerns also need to be addressed in parallel with the new developments in this area.[3,8] Despite insufficient knowledge about adverse effects of these products currently over 800 consumer products are estimated to incorporate nanoparticles.[9] Misuse of nanotechnology for warfare and terrorism cannot be ruled out. Moreover, very small surveillance devices such as nanosensors, nanocameras and nanomicrophones could enable illegal observation and control of subjects. Nanotechnology would enable total surveillance of entire civilian populations without them even noticing it.[10]

Although nanomedicine is in its infancy but it is the medicine of tomorrow. Developed countries are pouring their resources in the research and development of nanotechnology. The United States and Japan have started the largest national research programmes in nanotechnology.[11] There is a worldwide investment of more than $42 billion in the field of nanotechnology over the last few years.[12] India and China have already run a long way in this race.[13]

Out of 57 Islamic countries only six countries namely Turkey, Iran, Saudi Arabia, Egypt, Malaysia, and Pakistan seem to show promising trends in the development of nanotechnology.[14] Of these six countries Turkey, Pakistan and Egypt do not have any programme at the national level regarding nanotechnology. Pakistan and Egypt have a sound human resource but unfortunately there is no direction regarding the research and development activities in this newly emerging technology. Collaboration between the industry and academic institutes is almost nonexistent.[14]

If we consider the Braun's method of monitoring the trend of a new field of technology,[15] based on bibliometric quantification of that specific term in journals data base during a specific time period, research in nanotechnology is rapidly expanding in the universities of Pakistan.[16] However, these efforts remained somewhat hampered due to the lack of adequate equipment and facilities. On the other hand total number of publications on this important topic from medical institutions of our country is almost negligible.[16] Realizing the importance of the field, the Ministry of Science and Technology of Pakistan established the National Commission on Nanoscience and Technology (NCNST) in 2003. The NCNST was responsible for coordination of research and development activities, and manpower training in nanotechnology. Unfortunately NCNST ceased to exist after 2008. One of the recommendations of the National Commission was the setting up of a National Institute of Nanoscience and Technology-a dream which never came true.[16] Pakistan's first nanochemistry lab is being built at Karachi University.[17] Moreover, Higher Education Commission Pakistan has offered scholarship for overseas training in nanotechnology.[18] A private institute in Islamabad is offering a degree programme in nanotechnology with scholarships as well.[19]

Over the next few decades nanotechnology will bring revolutionary changes in medical science by offering an opportunity to enhance human health in novel ways by early disease detection and diagnosis, as well as precise and effective therapy tailored to the disease of an individual patient. In addition to various industrial and commercial uses great innovations are expected in healthcare. At the nanoscale, all scientific fields including physics, chemistry, biology, materials science and engineering converge toward the same principles. As a result, progress in nanoscience will have very far-reaching impact. Products based on nanotechnology in medicine

and medical technology are continuously emerging, with an anticipated tremendous positive impact on human health in the coming years. It is the time that we, the professionals belonging to healthcare sector, should focus on this important and emerging new technology as it has the potential to change healthcare dramatically in the coming years.

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