Review Article

IJCRR
Section: Healthcare
Sci. Journal Impact Factor 4.016

NANOTECHNOLOGY – A NEW ERA IN MEDICINE AND DIAGNOSTICS

Evarisalin Marbaniang[1], Donboklang[2]

[1]Department of Blood Bank and Transfusion medicine, NEIGRIHMS, Shillong, Meghalaya, India; [2]Ganesh Das Hospital, Shillong, Meghalaya, India.

ABSTRACT

An era of new and constantly advancing techniques is revolutionizing our world in the present times. We are in a phase where technology is evolving at its best. In the field of medicine and particularly, in the diagnostic realm ,we have seen the developing molecular diagnostics e.g polymerase chain reaction (PCR), hybridization techniques (flourescent in situ hybridization,etc), array based comparative genomic hybridization, so on and so forth. We are again fortunate to witness the evolution of another technology termed as NANOTECHNOLOGY. It has a wide variety of applications in diagnostics, cancer treatment, drug delivery, and tissue engineering. It is a vast field of modern science where it can be applied in organic chemistry, nuclear reactors, robotics, space applications, telecommunications, satellites, heavy industry and even cosmetics. The list goes on, but a word of caution as we humans are always crossing boundaries and may be using the technology for ignoble causes. So it is up to us to turn nanotechnology into a blessing or a curse.

Key Words: Nanoparticles, Nanosensors, Magnetic nanoparticles

INTRODUCTION

"Nanotechnology" was first defined by Tokyo Science University, Norio Taniguchi in 1974[1]. Although the application of nanotechnology to medicine appears to be a relatively recent trend, the basic nanotechnology approaches for medical application dates back to several decades[2]. Lipid vesicles which were named as liposomes, were described in 1965[3].

Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization, in at least one dimension, is on the nanometer scale or one billionth of a meter. At these scales, consideration of individual molecules and interacting groups of molecules in relation to the bulk macroscopic properties of the material or device becomes important, as it has a control over the fundamental molecular structure, which allows control over the macroscopic chemical and physical properties[4].

These technologies include nanoarrays, protein arrays, nanopore technology, nanoparticles (NPs) as a contrivance in immunoassays and nanosensors, among others. Gold NPs and quantum dots (semiconductors) are the most widely used, but new materials are becoming available as more molecular entities are discovered as amenable to nanoscale design and fabrication. Crystal materials like those of gallium, phosphate, quartz, and ceramic are chosen for their durability and piezoelectric properties of developing and retaining an electric potential (charge) when subjected to mechanical stress. Another area of development is nanobiosensors, in which antibody-based piezoelectric nanobiosensors are well developed[5-6].

Nanotechnology is rapidly evolving and is taking medicine forward in which cancer treatment, diagnostics and research has been reduced to a nanoscale. These applications include fluorescent biological labels, drug and gene delivery, bio-detection of pathogens, detection of protein, probing of DNA structure, tissue engineering, tumor detection, separation and purification of biological molecules and cells, MRI contrast enhancement and phagokinetic studies[7].

APPLICATIONS

1. Viral diagnostics - The use of nanoparticles as tags or labels allows for the detection of infectious agents in

Corresponding Author:
Evarisalin Marbaniang, Mawlai Kyntonmassar, Block B, Shillong 793022, East Khasi Hills, Meghalaya, India.
E-mail:evarisalinmarbaniang@yahoo.com

Received: 09.11.2014 **Revised:** 27.11.2014 **Accepted:** 14.12.2014

small sample volumes directly in a very sensitive, specific, and rapid format at lower costs than current in-use technologies[8].

A microfluidic platform-based detection system is now described. The term refers to precise control and manipulation of fluids contained typically in sub-millimetre scale volume. The assay can detect the avian influenza virus H5N1 in throat swab samples by using magnetic forces to manipulate a free droplet containing superparamagnetic particles (ferric oxide-labelled antibody) to concentrate the viruses[9]. A method for the respiratory syncytial virus (RSV) consisting of functionalized NPs conjugated to monoclonal antibodies can be used to rapidly and specifically detect RSV in clinical samples with a great degree of sensitivity[10].

A new nanoparticle-based biobarcode amplification (BCA) assay has been developed for early and sensitive detection of human immunodeficiency virus (HIV)-1 capsid (p24) antigen[11].

The hepatitis B virus (HBV), hepatitis C virus (HCV), and HBV/HCV gene chips with gold/silver NP staining amplification method were shown to be useful in detecting these viruses in patients' samples[12].

An array-based nano-amplification technique method for the detection of hepatitis E virus (HEV) has been developed by utilizing nano-gold-labelled oligonucleotide probes coupled with silver stain enhancement and the microarray technique. The microarray was shown to detect 100 fM of amplicon with the image development time as short as 2 minutes. A similar technique is also described for hepatitis A virus (HAV) [13-14].

Detection of herpes simplex virus (HSV)-1 virus particles is achieved by exposing the virus-containing sample to a sensor surface coated with a specific antibody against HSV-1. The Young interferometer sensor was shown to detect HSV-1 at very low concentrations (850 particles/mL) and even directly in serum samples[5].

A novel signal amplification technology for a human papillomavirus (HPV)-DNA hybridization assay based on fluorescein diacetate (FDA) nanocrystals has been developed. This approach resulted in high selectivity, short incubation times, and high sensitivity. This innovative method allows rapid detection of small amounts of target sequence in a fewer number of PCR cycles[15].

Diarrhoea-causing viruses today are a major public health concern, and newer agents with potential for large food-borne outbreaks have been described. Norovirus is a leading cause of gastroenteritis in many parts of the world. A matrix-assisted laser desorption ionization and nanospray mass spectrometry was developed and evaluated for norovirus detection using different approaches[16].

2. Molecular imaging has emerged as a powerful tool to visualize molecular events of an underlying disease, sometimes prior to its downstream manifestation. The merging of nanotechnology with molecular imaging provides a versatile platform for the novel design of nanoprobes that will have tremendous potential to enhance the sensitivity, specificity and signalling capabilities of various biomarkers in human diseases[17].

Nanoparticle probes can endow imaging techniques with enhanced signal sensitivity, better spatial resolution and the ability to relay information on biological systems at molecular and cellular levels. Simple magnetic nanoparticles can function as magnetic resonance imaging (MRI) contrast enhancement probes. These magnetic nanoparticles can then serve as a core platform for the addition of other functional moieties including fluorescence tags, radionuclides and other biomolecules, for multimodal imaging, gene delivery and cellular trafficking. An (MRI) with hybrid probes of magnetic nanoparticles and adenovirus can detect target cells and monitor gene delivery and expression of green fluorescent proteins optically[18]. Nuclear techniques such as positron-emission tomography (PET) potentially provide detection sensitivities of higher magnitude, enabling the use of nanoparticles at lower concentrations than permitted by routine MRI. Furthermore, a combination of the high sensitivity of PET with the anatomical detail provided by computed tomography (CT) in hybrid imaging, has the potential to map signals to atherosclerotic vascular territories[19].

3. Drug delivery-Nanotechnology plays an important role in advanced biology and medical research particularly in the development of potential site specific delivery systems with lower drug toxicities and greater efficiencies[20]. The era of nanotechnology has allowed novel research strategies to flourish in the field of drug delivery. Nanotechnology designed drug delivery systems have been seen to be suitable for treating chronic intracellular infections[21].

One of the major applications of nanotechnology in relation to medicine is drug delivery. The problems with the new chemical entities such as insolubility, degradation, bioavailability, toxicologic effects, targeted drug delivery, and controlled drug release are solved by nanotechnology. For example, encapsulated drugs can be protected from degradation. Specific nanosized receptors present on the surface of the cell can recognize the drug and elicit appropriate response by delivering and releasing the therapy exactly wherever needed. Because of their small size and large surface area relative to their volume, nanoscale devices can readily interact with biomolecules. Nanoscale devices include: nanoparticles, nanotubes, cantilevers, semiconductor nanocrystals, and liposomes[22].

APPROVED PRODUCTS OF NANOTECHNOLOGY:

Due to the stringent food and drug act (FDA) regulations, only a few products based on nanotechnology are available for clinical use. Doxil® (Centocor Ortho Biotech Products L.P, New Jersey, USA.) and Abraxane® (Abraxis Bioscience, Los Angeles, USA.) are among the two available for clinical use[23].

CANCER DETECTION AND TARGETING :

Detection and targeting of the cancerous tissues or cells have always been a challenge to the formulator. Cancerous tissues or cells being self becomes very difficult to target the specific cells or organs; as a result, many normal cells are being killed in the process. Many devices based on nanotechnology have come to the rescue of the formulators, wherein, using biomarkers, the anticancer agents can be targeted only to specific cells or organs[24-25]. One such method to detect cancer is use of Photodynamic Therapy (PDT) using 5-aminolaevulinic acid which is metabolized in body to protoporphyrin IX which is a photosensitizer[26]. Quantum dots (QD) are very useful in lymph node mapping which is an important technique for cancer mapping during surgery and in vivo cancer imaging using semiconductor QD is also well documented in the literature[27-28].

DISCUSSION

Nanotechnology is a part of science where the engineer and the scientist functions together as a unit. The potential of its applications are so diversified that it is not possible to address all of them here. In this review, we are dealing more with the nanomedicine aspects i.e the medical applications of nanotechnology.

Due to nanoscale effects and increased surface area, nano-materials have been investigated as promising tools for the advancement of diagnostic biosensors, drug and gene delivery, and biomedical imaging[29].

The use of nanoparticles as tags or labels allows for the detection of infectious agents in small sample volumes directly in a very sensitive, specific, and rapid format at lower costs than current in-use technologies. This advance in early detection enables accurate and prompt treatment. The quantum dot technology is currently the most widely employed nanotechnology. The technology strengthens and expands the DNA and protein microarray methods and has applications in genomic analysis, proteomics, and molecular diagnostics. Nanosensors are the new contrivance for detection of bioterrorism agents[8].

Imaging modalities like MRI etc with low sensitivity, nanoparticles bearing multiple contrast groups provide signal amplification. The same nanoparticles can, in principle, deliver both the contrast medium and the drug, allowing monitoring of the bio-distribution and therapeutic activity simultaneously (referred to as theranostics)[30].

Such nanofiber-based scaffolds are available in a wide range of pore size distribution, high porosity and high surface area-to-volume ratio. Such a wide range of parameters are favourable for cell attachment, growth and proliferation, and also provide a basis for the future optimization of an electrospun nanofibrous scaffold in a tissue-engineering application.

The genesis of nanotechnology can be traced to the promise of revolutionary advances across medicine, communications, genomics and robotics[31].

Target specific nature of the delivery systems developed applying nanotechnology principles have been able to reduce the amount of drug that needs to be loaded and hence prevent many dose-related adverse reactions. Currently, not many products are available for clinical use, but looking at the amount of research activity happening in this field, the next few years will witness the outburst of nano-medical devices, therapeutic aids, and many products being launched in the market for clinical use[22].

Nanotechnology is a multifaceted weapon as its applications is evolving and developing in many fields of medicine, both diagnostic and therapeutic especially targeted therapy for the treatment of cancer. In view of its varied uses, the need arises for more research and trials along with regulations so the suffering of mankind may be alleviated in this already disease filled universe.

CONCLUSION

The future of medicine is bright and hopeful with the latest technologies particularly nanotechnology emerging to give us an optimistic view of solutions relating to diseases and their dilemmas. Its utility in organic chemistry, nuclear reactors, robotics, space applications, telecommunications, satellites, heavy industry and even cosmetics has been documented. Nanotechnology is here to stay and its uses and applications are unlimited provided we use it wisely and ethically to benefit mankind.

ACKNOWLEDGEMENT

Authors acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript. The authors are also grateful to authors / editors / publishers of all those articles, jour-

nals and books from where the literature for this article has been reviewed and discussed.

Author(s) contributions: Evarisalin Marbaniang conceived and wrote the review, Donboklang Lynser gathered materials and together contributed equally in writing the paper.

Source of funding: nil

Conflict of Interest: None

REFERENCES

1. Taniguchi N. On the basic concept of 'nano-technology Proc. Intl. Conf. Prod. Eng. Tokyo, Part II, Japan Society of Precision Engineering 1974;10:5 -10.
2. Farokhzad OC, Langer R. Nanomedicine: Developing smarter therapeutic and diagnostic modalities. Adv Drug Deliv Rev 2006;58:1456 -9.
3. Bangham AD, Standish MM, Watkins JC. Diffusion of univalent ions across the lamellae of swollen phospholipids. J Mol Biol 1965;13:238-52.
4. Silva GA. Introduction to nanotechnology and its applications to medicine. Surg Neurol 2004;61:216-20.
5. Jain KK. Nanotechnology in clinical laboratory diagnostics. Clin Chim Acta 2005;358:37-54 .
6. Demidov VV. Nanobiosensors and molecular diagnostics: A promising partnership. Exp Rev Mol Diagn 2004;4:267-8.
7. OV Salta. Applications of nanoparticles in biology and medicine. J Nanobiotech 2004;2:3.
8. Abraham A M, Kannangai R, Sridharan G. Nanotechnology: A new frontier in virus detection in clinical practice. Indian J Med Microbiol 2008;26:297-301
9. Neuzil P, Zhang C, Pipper J, Oh S, Zhuo L. Ultra fast miniaturized real-time PCR: 40 cycles in less than six minutes. Nucl Acids Res 2006;34:e77.
10. Tripp RA, Alvarez R, Anderson B, Jones L, Weeks C, Chen W. Bioconjugated nanoparticle detection of respiratory syncytial virus infection. Int J Nanomed 2007;2:117-24.
11. Tang S, Zhao J, Storhoff JJ, Norris PJ, Little RF, Yarchoan R, et al . Nanoparticle-Based biobarcode amplification assay (BCA) for sensitive and early detection of human immunodeficiency type 1 capsid (p24) antigen. J Acquir Immune Defic Syndr 2007;46:231-7.
12. Wang YF, Pang DW, Zhang ZL, Zheng HZ, Cao JP, Shen JT. Visual gene diagnosis of HBV and HCV based on nanoparticle probe amplification and silver staining enhancement. J Med Virol 2003;70:205-11.
13. Wan Z, Wang Y, Li SS, Duan L, Zhai J. Development of array-based technology for detection of HAV using Gold-DNA probes. J Biochem Mole Biol 2005;38:399-406.
14. Liu HH, Cao X, Yang Y, Liu MG, Wang YF. Array-based nanoamplification technique was applied in detection of hepatitis E virus. J Biochem Mol Biol 2006;39:247-52.
15. Chan CP, Tzang LC, Sin K, Ji S, Cheung K, Tam T, et al . Biofunctional organic nanocrystals for quantitative detection of pathogen deoxyribonucleic acid. Anal Chim Acta 2007;584:7-11.
16. Colquhoun DR, Schwab KJ, Cole RN, Halden RU. Detection of norovirus capsid protein in authentic standards and in stool extracts by matrix-assisted laser desorption ionization and nanospray mass spectrometry. Appl Environ Microbiol 2006;72:2749-55.
17. Jones. Nanoprobes for medical diagnosis: Current status of nanotechnology in molecular imaging. Curr Nanosci 2008;4:17-29.
18. Cheon J, Lee JH. Synergistically integrated nanoparticles as multimodal probes for nanobiotechnology. Acc Chem Res 2008;41:1630-40.
19. Nahrendorf M, Zhang H, Hembrador S, Panizzi P, Sosnovik DE, Aikawa E, et al. Nanoparticle PET-CT imaging of macrophages in inflammatory atherosclerosis. Circulation 2008;117:379-87.
20. Ramachandran R, Shanmughavel P. Preparation and characterization of biopolymeric nanoparticles used in drug delivery. Indian J Biochem Biophys 2010;47:56-9.
21. Putheti RR, Okigbo RN, Sai advanapu M, Chavanpatil S. Nanotechnology importance in the pharmaceutical industry. Afr J Pure Applied Chem 2008;2:27-31.
22. Martis EA, Badve RR, Degwekar MD. Nanotechnology based devices and applications in medicine: An overview. Chron Young Sci 2012;3:68-73.
23. Patel S, Bhirde AA, Rusling JF, Chem X, Gutkind SJ, Patel V. Nano delivers big: Designing molecular missiles for cancer therapeutics. Pharmaceutics 2011;3:34-52.
24. Ferrari M. Cancer Nanotechnology: Opportunities and Challenges. Nature Reviews. Cancer 2005;5:161-171.
25. Retel VP, Hummelb MJ, van Hartena WH. Review on early technology assessments of nanotechnologies in oncology. Mol Oncol 2009;3:394-01.
26. Yang TH, Chen CT, Wang CP, Lou PJ. Photodynamic therapy suppresses the migration and invasion of head and neck cancer cells in vitro. Oral Oncol 2007;43:358-65.
27. Kim S, Lim YT, Soltesz EG, De Grand AM, Lee J, Nakayama A, et al. Near-infrared fluorescent type II quantum dots for sentinel lymph node mapping. Nat Biotechnol 2004;22:93-7.
28. Bertolini G, Paleari L, Catassi A, Roz L , Cesario A, Sozzi G, et al. In vivo Cancer Imaging with Semiconductor Quantum Dots. Curr Pharm Anal 2008;4:197-05.
29. Lifeng Dong, Michael M. Craig, Dongwoo Khang, and Chunying Chen, "Applications of Nanomaterials in Biology and Medicine," Journal of Nanotechnology, vol. 2012, Article ID 816184, 2 pages, 2012. doi:10.1155/2012/816184.
30. Debbage P, Jaschke W. Molecular imaging with nanoparticles: Giant roles for dwarf actors. Histochem Cell Biol 2008;130:845-75.
31. Saini R, Saini S, Sharma S. Nanotechnology: The future medicine. J Cutan Aesthet Surg 2010;3:32-3.