An overview of Nanomedicine

What is Nanomedicine research all about?

Nanomedicine is defined as the application of nanotechnology to achieve innovation in healthcare areas. The use of nanotechnology in the development of new medicines offers an enabling tool for providing new and innovative medical solutions to meet unmet medical needs. Nanomedicine provides better imaging and diagnostic tools to enable early detection and rapid diagnosis, allow scientists to recognise, measure and interact with single biological events. The application of nanotechnology in pharmacology is promising to overcome the drawbacks associated with traditional therapies, such as low bioavailability, poor stability, non-specific drug delivery, and systemic toxicity. Nanomedicine approaches can diagnose, prevent, and treat complex health conditions such as cancer, diabetes, cardiovascular and neurodegenerative diseases.

Research focus areas

- Synthesis and manufacturing of nano-enabled products (chemical and biological synthesis, lab-on-a-chip microfluidic system and nanoscale 3D printing technique)
- Fabrication of sensitive biomedical sensor (diagnostics and detection of diseases)
- Design air cleaning technology (for prevention of airborne transmission of pathogens)

A summary of the four ongoing projects

The pre-clinical development of nanomedicine-based products using chemical and biological synthesis, lab-on-a-chip microfluidic system and nanoscale 3D printing.

1. **Pharmaceutical Nanotechnology Project**
   Diabetic Foot Ulcers

A diabetic foot ulcer (DFU) is one of the major complications of patients with diabetes mellitus. DFU is characterised by complications such as leg ulcers, infections, neuropathy and ischemia. Current treatments for DFU and diabetic foot infection (DFI) include debridement, wound dressings, and antibiotics to combat gram-positive bacteria (such as Staphylococcus aureus) and gram-negative bacteria (such as Pseudomonas aeruginosa and aerobic bacteria). The emergence of multidrug resistance (MDR) micro-organisms delays wound healing, leading to hospitalisation, lower limb amputation, and/or death of DFU patients.

The purpose of this study is to design a nanocomposite hydrogel system for antibacterial and wound healing applications in patients with diabetic foot ulcer (DFU). The nanocomposite hydrogel system will consist of polymer hydrogel materials impregnated with green nanoparticles and/or drug-loaded nanoparticles. Effective nanocomposite hydrogel will be incorporated or coated on a biodegradable bandage, socks and insole.

2. Breast Cancer

Breast cancer is the most frequent cause of cancer death in South Africa. According to the 2014 National Cancer Registry (NCR), 1 in 27 women in South Africa are at a risk of developing breast cancer. Triple negative breast cancer (TNBC) is the most aggressive form of breast cancer. TNBC represents a group of different tumours that usually lack the expression of estrogen receptor (ER) and progesterone receptor (PR), as well as human epidermal growth factor receptor (HER2). There is a high prevalence of TNBC in African women when compared to women of other ethnicities. Poor prognosis increases the aggressiveness and high mortality of TNBC in young African women, which is caused by a mutant copy of breast cancer type 1 (BRCA 1). The high expression of Kaiso and BRCA1 in TNBC tissues/cells is associated with higher treatment failure and survival rates in breast cancer patients. The focus of this research is twofold.

Drug delivery system: The purpose of this study is to use nanoliposomes, lipid nanoparticles containing chemotherapy and/or green nanoparticles to develop a personalised nanomedicine for TNBC patients.

Disease detection and diagnosis: The purpose of this study is to develop a nano-biosensor for fast and accurate diagnosis of TNBC.

3. Blood Transfusion Project

Blood transfusion is very important to save the lives of patients who have lost blood during surgery, trauma, accidents and wars. Although there are several national blood banks, there is a severe shortage of blood and blood donors today. Blood donation in South Africa, where we have the highest number of people living with HIV is the biggest challenge. Screening blood donors for HIV, hepatitis virus and syphilis are time-consuming and expensive, and blood donations can only be done based on blood type. Another challenge is the storage time. Donated red blood cells (RBC) can be stored for about 42 days at 4^{o}C and 1 day at room temperature. RBC can only be stored in the refrigerator which makes it more difficult to transport injured or bleeding patients that need immediate blood transfusions, by ambulance to the hospital and/or to store the RBC in remote areas without electricity. Therefore, there is a need to look for a blood substitute that does not contain HIV, that is, a universal blood substitute without blood type, which can be stored at room temperature and has a long life of more than one year. Attempts to develop HBOC can be traced back to the 1970s and early 1980s, using different haemoglobin carriers. Today, many artificial red blood cells in clinical trials or clinical approvals, such as the polyhemoglobin (PolyHb). Despite safety concerns, South Africa has approved the use of PolyHb for the routine treatment of anaemia during surgery.

The purpose of this study is to develop a blood substitute composed of haemoglobin or perfluorocarbon and/or O_2 encapsulated in self-assembled nanomaterials (e.g., natural polymers and lipid materials). The manufacturing process will be based on the use of microfluidics, lab-on-a-chip technology and/or 3D printers

4. **Environmental Health Project**
   Air Purifier (Robotic)

Tuberculosis (TB) is the leading cause of death in South Africa. According to a report released by the World Health Organisation (WHO) there were an estimated 360,000 cases of active TB in South Africa in 2019. Mycobacterium tuberculosis is the bacterium that causes tuberculosis. It is spread by tiny droplets released into the air when an infected person coughs, sneezes and talks. To win the fight against tuberculosis, many strategies and interventions are needed, this may include preventing the spread of tuberculosis. In recent years, air purification technologies have been developed to inactivate microorganisms and/or airborne pathogens, such as bacteria, viruses, fungal spores, allergens, and pollen. Nanoparticles can inactivate attached microorganisms and/or inhibit their growth in the air or surface environment.

The purpose of this study is to develop a nanotechnology-based air purifier (robotic) that can capture, deactivate, neutralise and inhibit the growth of M. tuberculosis (and other infectious pathogens such as the influenza virus and coronavirus) in the air and on the surface environment.

Pharmaceutical nanotechnology enables

- Improved drug encapsulation and delivery of water-insoluble drugs
- Extended bioactivity by providing protection of the "payload" against a potentially destructive biological environment
- Enabled to control and/or prolong drug release (extended release) to reduce dosing frequency – once in every three months (in future - once a year)
- Allow the combination of more than two drugs in one unit (single nanoparticle)
- Allow the combination of therapeutic and diagnostic activities in one unit (known as theragnostic) and real time
- Enhanced transport across biological barriers e.g., Blood Brain Barrier (BBB), epithelial and endothelial barriers,
- Targeted drug delivery at the site of disease / specific site to improve the uptake of poorly soluble drugs and for good bioavailability
- Enabling individualised medicine, less toxic and improve patient compliance

What impact it has on our society

- Nanomedicine provides better treatment that has fewer side effects and with a less toxic and cost-effective therapeutic and diagnostic device
- Provides personalised treatment options and improve quality of life for survivors
- Design a better imaging and diagnostic tools that is capable to detect disease before physical symptoms appear in the patient
- A point-of-care device that can see how the patient is doing after treatment and capable to test a wide range of diseases and viruses with just one drop of blood.

What the future holds for nanomedicine

Post covid-19 pandemic, we are more likely to see novel nanotechnologies being used in the reformulation of old vaccines and drugs that are no longer in clinics, with the advantage that nanocarrier-based delivery systems can deliver vaccines and drugs in the areas traditional vaccine cannot reach.

The advent of nanorobots may revolutionize medicine. Doctors will be able to use tiny robots with the size of a bacteria to quickly cure diseases from heart to cancer diseases.