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Nanorobots the Future of Neurology: A Perspective on Alzheimer's Disease

Nanorobots are complex machines measured in nanometers that operate at the molecular level inside patients. In the future these small nanoscale machines could potentially be used as biosensors to screen for disease, to combat pathological cellular or molecular processes or to deliver medication to precise locations. Nanorobots are akin to manipulatable electronic white blood cells that patrol the body. A nanorobot in the form of a micro-rocket has already been shown to bind and transport cancer cells in physiological fluids *in vitro* (1) and micromotors have been developed to deliver cargo via self-propulsion to the stomach in mice (2). Moreover, in 2016 Fraser Stoddart, Bernard Feringa and Jean-Pierre Sauvage won the Nobel Prize in chemistry for their work in the development of nanomachines in which they utilised chemical energy to create motion (3). Collectively, these breakthroughs are paving the way for the design of more complex nanorobots for medicinal use. The aim of this editorial is to inspire further research in the new field of nanorobotics for the prevention of Alzheimer's disease (AD) and other neurological disorders.

Nanorobots in Alzheimer's disease

Nanorobots could be used in older adults to screen the blood for β-amyloid (Aβ) and tau, biomarkers of AD, thereby monitoring disease onset and progression. Nanorobots could also be programmed to remove blood-borne Aβ, which if the peripheral sink hypothesis of AD (4) holds true might serve to reduce central pathology and hence improve cognition or delay cognitive decline. Moreover, if extravasation out of the blood across the blood brain barrier (BBB) is one day technologically possible, nanorobots could enter the central nervous system (CNS) to directly combat pathology. Hypothetically directed motion of nanorobots could be achieved through the detection of chemotactic molecules in an analogous manner to microglial migration. What is more microglia themselves could be targeted and 'programmed' serving as endogenous nanorobots. For instance, microglia could be manipulated to enhance their phagocytic capacity to reduce Aβ accumulation (5). Nanorobots could also be programmed to deliver therapeutic agents such as anti-amyloid or anti-tau therapy and anti-inflammatory drugs directly to the CNS.

In addition to monitoring Aβ and tau in peripheral blood, nanorobots could be used to sense nutritional elements in the blood such as fats, vitamins and glucose all of which have been linked to Aβ deposition (6–9) and cognitive decline (10–14). Such bio-sensing would prove particularly useful for diabetic patients for the prevention of hyperglycaemia. Furthermore, nutritional deficiencies could be rectified by nanorobots in a patient specific tailor-made manner, which would represent the first 'smart vitamin pill' for medicinal use.

Design considerations

Nanorobots must be biologically inert, like medical implants, to avoid provoking an immune response and controlled elimination from the body must be attainable. Nanorobots must also be able to travel through the smallest blood vessels without posing a risk of occlusion. How the transmission of data from a nanorobot and the delivery of instructions to a nanorobot will be achieved is another major hurdle, amongst others, that requires overcoming.

Conclusion

The development of nanorobots for use in AD and other neurological disorders remains one of the 'grand challenges' of the 21st century requiring the development of new multi-disciplinary collaborative networks between research scientists, medical practitioners and engineers. It is apparent that in the foreseeable future nanorobots could be implemented in medicine to fulfil a multitude of uses for both the maintenance of health and also for the combat of neurological diseases such as AD.

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