Editorial

Will Magnetic Nanomedicine Realise the Future of Therapy and Diagnosis?

Silvia Marchesan

Medicine has long been looking at nanotechnology to continue its development in new directions, especially towards personalized therapy and early diagnosis of some fatal diseases. Amongst the many facets of the so-called "nanomedicine", those related to the application of magnetic forces are particularly appealing to detect, or even to guide, nanodevices in a minimally-invasive manner. This special issue covers only the most recent advances in "magnetic nanomedicine". The aim is to provide the medicinal chemist with a concise guide of both 1) the most innovative tools that offer new paradigms for clinical intervention, and 2) the more conventional approaches that made significant progress to realise the ambitious goal of reaching the patient.

Tay and Di Carlo open this hot topic discussing the innovative use of magnetic nanoparticles to generate mechanical forces and allow remote control of brain circuits. This new paradigm is discussed in the wider context of promising techniques for the minimally-invasive manipulation of cell behavior with high spatiotemporal resolution. Comparison with more conventional (electrical stimulation and drugs) and second generation (ultrasound and light) techniques is made, to highlight requisites, strengths and weaknesses of each approach. The authors conclude with a view of the challenges and progress in related fields to translate the use of such novel nanoparticle-based platforms, both in research and clinical settings.

Magnetic drug targeting using nanocarriers based on superparamagnetic iron oxide nanocrystals (SPIONs) is another interesting approach in magnetic nanomedicine that is discussed by Kralj and co-authors, including myself. Magnetic nanocarriers based on SPIONs have emerged amongst other nanostructured materials in medicine, thanks to their excellent biocompatibility. In fact, research in this area reached a level of maturity to the point that several products are already in the market both for research and clinical use. A snapshot of the current situation is presented, as well as a discussion on current and future strategies for the design and fabrication of magnetically responsive nanocarriers based on SPIONs, including the underlying physical requirements, the possibility of drug loading, and the control of drug release at the targeted site.

Iron-based nanostructured components find application in the well-established field of Magnetic Resonance Imaging (MRI). In particular, bimetallic particles that also contain gold have been attracting increasing interest for biomedical use because of the synergy with the plasmonic features and biocompatibility of the inert gold component. These hybrid nanomaterials are suitable not only for imaging, but also for therapeutic and analytical applications. They are described in the minireview by Sanavio and Stellacci. Another approach to advance the current status of MRI agents is the use of innovative nanostructured carriers for improved relaxivity and resolution, increased circulation time, stability and better targeting. An interesting option in this sense is provided by cubosomes, which are described by Alcaraz and Boyd. These self-assembled nanostructures are analogous to liposomes. However, they contain a complex internal structure of high-surface area that is responsible for attractive properties. The minireview included in this hot topic provides a brief overview of what cubosomes are, how they are prepared and characterised, their use in MRI, and it also includes a discussion on future developments in the field.

Besides MRI, there are also other diagnostic applications for magnetically-responsive materials, where magnetic forces can be used for purification and enrichment purposes. In modern society, where the fight against cancer still presents a number of challenges, there is an active quest towards the identification and detection of useful biomarkers. The manuscript by Piovesana and Capriotti ilustrates the use of novel magnetic nanostructured materials for

the diagnosis of peptide and protein biomarkers. Their concise review deals with the key aspects, such as performance comparison over conventional techniques, ease of use, derivatization versatility and automation, together with quantification through coupling with powerful characterization techniques, such as mass spectrometry.

One of the current limitations to exploit magnetic nanomedicine to its full potential is given by the need to extend current knowledge about the physical challenges in the translation of magnetic forces in a biological context in vivo. A useful view of the existing models available to medicinal chemists, their prospects and limitations, is provided by Prof. Winkler. Good computational models could accelerate the design of magnetic nanoparticles for medical applications, including: hyperthermia induction in aberrant cells for cancer therapy, medical imaging, targeted drug delivery, or gene therapy.

Key technological advancements require not only better models, but also innovative components, and the contribution by Prof. Prato et al. discusses how 2D-graphene and its related materials allow for a qualitative leap in the performance of magnetic nanodevices used in medicine, spanning from MRI and controlled drug delivery, to magnetic photothermal therapy and cellular separation and isolation. The authors include a concise view on the chemical approaches used in the preparation of magnetic hybrids that contain graphene-based materials and conclude their interesting contribution by highlighting on the use of these magnetic hybrids towards the next generation of theranostics. This work is followed by Dr. Parry's mini-review on the use of another innovative nanostructured component for novel medical devices, i.e., nanocellulose. Nanocellulose is an attractive material for wound dressings, medical implants, drug delivery, tissue engineering, and diagnostics. Key advantages include low-cost, biocompatibility, and biodegradability. Importantly, nanocellulose displays functional groups, which can act as chemical handles to introduce further properties. In addition, composites can be envisaged also for innovative biomedical use such as magnetically-responsive nanomaterials and 3D printing. In conclusion, this hot topic issue of Current Medicinal Chemistry aims at introducing key areas of magnetic nanomedicine to assist the medicinal chemists who wish to embrace novel research directions and who seek to understand the key relevant principles and current challenges with up-to-date information and forward-looking perspectives. The applications in medicine illustrated here take advantage from the high potential of emerging nanotechnologies and nanostructured materials. In particular, concepts of medicine innovation are described, which draw strength from the combination of nanotechnologies and nanomaterials with convenient magnetic forces, to realise futuristic smart devices for better therapy and diagnosis.