8

Magnetic Nanoparticles for MR Imaging

Lee Josephson
Center for Molecular Imaging Research, Massachusetts General Hospital/Harvard Medical School, Building 149, 13th Street, Charlestown, MA 02129

8.1. INTRODUCTION

The combination of a nonmaterial, magnetic nanoparticles, with magnetic resonance imaging, is yielding major advances in diverse areas of biology and medicine. This review will present a short history of iron oxide based nanoparticles, and review important new developments in the fields of magnetic nanoparticles and MRI. Magnetic nanoparticles are currently used in approved MRI contrast agents for imaging hepatic metastases and show considerable potential in clinical testing for imaging nodal metastases. New applications of magnetic nanoparticles include (i) ex-vivo labeling of cells with nanoparticles, followed by MR imaging in vivo, (ii) magnetic nanoparticles as biosensors termed magnetic relaxation switches, to measure a wide range of analytes in vitro, (iii) magneto/optical nanoparticles providing a fluorescent signal in addition to their magnetic character and (iv) biomolecule targeted magnetic nanoparticles for the imaging of specific molecular targets by MRI. This review will cover each of these diverse developments.

8.2. A BRIEF HISTORY OF POLYMER COATED IRON OXIDE NANOPARTICLES AS PHARMACEUTICALS

Unlike many of the probes and chemistries spawned by the field now termed molecular imaging, magnetic nanoparticles are chemically similar to a large number of materials with a long history of clinical use. Magnetic nanoparticles consist of a core of superparamagnetic (highly magnetic) iron oxide and polymer coating, and to this basic design biomolecules
are attached. Polymer-coated iron oxides have been used in the treatment of iron anemias since the 1960’s [1, 2]. Dextran has often been used as polymeric coating of the core iron oxide because of its prior use as a plasma expander and because of its affinity for iron oxides. The iron oxides used for anemia treatment are paramagnetic (weakly magnetic) and are injected in widely varying amounts depending on the severity of the anemia. The affinity between dextran and iron oxide was then used to develop a nanoparticle termed “dextran magnetite,” which exhibited a far stronger form of magnetism than the paramagnetic iron used in the treatment of anemia, that is superparamagnetism. Since it was first recognized that superparamagnetic iron oxide nanoparticles could shorten water relaxation times, a large literature on the use of magnetic nanoparticles with MRI has developed. This recognition was far from obvious, since image distortions and spectral degradation were known to occur when many different types of magnetic materials occurred accidentally in the applied fields of MR imagers or MR spectrometers. One of the first to demonstrate the ability of magnetic nanoparticles to shorten the T2 relaxation times in a controlled and useful fashion was Oghushi, who in 1978 demonstrated this effect with a dextran-magnetite [3]. The field has advanced slowly but continuously, with magnetic nanoparticles forming the active ingredient of several approved drugs and others in clinical trials. Table 8.1 provides examples of polymer-coated iron oxides used clinically, both paramagnetic and superparamagnetic.