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EDITORIAL

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Molecular imaging in radiology: the latest fad or the new frontier?

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Molecular imaging is "hot". The past 5 years have seen a gradual increase in the number of publications on this topic in concert with the release of a number of specialized journals and the foundation of several "Molecular Imaging Institutes". More papers utilizing (repeatedly) the term "Molecular Imaging" have been published in the last month than in the entire year 2000. What is all this commotion about? At a first glance it may seem to be a hype, with a lot of effort being put into formulating the right definition of what "Molecular Imaging" entails. Several renowned researchers have launched a definition that encompasses the visualization/characterization of biological processes in living organisms [1, 2]. However, at the April 2005 summit on molecular imaging organized by the Radiological Society of North America (RSNA) and the Society of Nuclear Medicine (SNM), a large panel of physicians and scientists, representing societies of biomedical imaging professionals and nuclear medicine specialists from around the world, agreed that the existing definitions do not fully cover the existing variety of imaging tools available in humans and in animals. In order to correct this deficit the group developed the following definition: "MI techniques directly or indirectly monitor and record the spatiotemporal distribution of molecular or cellular processes for biochemical, biologic, diagnostic, or therapeutic applications" [3, 4].

Next to this linguistic exercise, molecular imaging seems to be characterized by abstract images consisting of (colorful) dots in space, sometimes superimposed on the anatomical shadow of a laboratory animal and rarely of a human. These images can be quite impressive and pretty, but of what interest are they to radiologists? Are these not the products of the toys of molecular or cell biologists? From a traditional point of view, in which radiologists examine gross anatomical or functional consequences of disease, molecular imaging may seem to be of little concern to radiologists. However, when looking beyond the pretty pictures and sometimes complex vocabulary, it becomes clear that molecular imaging is a serious matter in modern medicine and that radiologists need to get involved in this emerging field if they want to maintain their central role in health care. After all, molecular imaging is expected to be pivotal to early diagnoses, patient stratification, and early response assessment.

Aberrant anatomy and organ dysfunction are late manifestations of disease resulting from pathological cellular and molecular processes. Similarly, normalized morphology and organ function are late indicators

of response to treatment, preceded by restorative cellular and molecular responses. These latter aspects are what molecular imaging in modern medicine is all about. Molecular imaging is aimed at the characterization, visualization, and quantification of the specific cellular and molecular processes underlying disease. Central to this is the use of injectable probes that specifically target the disease of interest and through which the complex cellular and molecular behavior of disease in space and time can be non-invasively monitored and recorded.

The concept of molecular imaging is not new. Molecules and molecular processes have been made visible by nuclear medicine for decades. Initially, this was limited to the use of radiolabeled, native antibodies for the detection of residual or relapsing tumor. More recently, specific peptides binding to specific tumor markers (i.e. somatostatin-2 receptor) and markers of increased metabolic (^{18}F-FDG) activity are being employed. While molecular imaging used to be primarily linked to imaging modalities not commonly associated with radiology departments – i.e., optical imaging (mostly preclinical research), positron emission tomography (PET) and single photon emission computed tomography (SPECT) – modalities such as computerized tomography (CT), magnetic resonance imaging (MRI), and ultrasound are becoming essential tools in the field, either as a single modality or in hybrid imaging approaches, such as in PET-CT, SPECT-CT, or PET-MR scanners. These modalities offer advantages in terms of increased anatomical resolution and an integrated assessment of anatomy and physiology with molecular processes.

The convergence of technological revolutions of recent years within different fields of research has broadened the horizon for molecular imaging applications both in basic research and in clinical settings. These revolutions involve: the mapping of the entire human genome; tools to genetically manipulate cells or organisms; new treatment strategies, including molecular and cell-based therapies, nanotechnology, and state-of-the-art imaging modalities with increased spatial and temporal resolutions. Through this convergence, the potential for "personalized medicine" is increasing. In the setting of personalized medicine, the exact molecular background of disease in a single patient could be assessed, upon which an individualized treatment regimen could be designed with maximized therapeutic effect and minimized adverse effects.

While many issues still need to be resolved before "personalized medicine" becomes a fact, molecular imaging has already entered the clinical arena and will only gain in importance in the coming years [5]. Currently, the most prominent or pressing clinical applications of molecular imaging are in the fields of oncology and cardiovascular disease [6–8]. In oncology, molecular imaging has already resulted in some breakthroughs in cancer staging [9, 10] and treatment response assessment [11, 12], and it is anticipated to facilitate early disease detection. In cardiovascular disease, molecular imaging is expected to serve a central role in addressing basic questions regarding cell therapy for cardiac repair and vulnerable plaque detection [13, 14]. In these fields, tremendous effort is being put into the development of new probes for clinical use [5].

Further evidence of molecular imaging being serious business in healthcare is provided by the endeavors of the large medical technology companies. Companies such as GE Healthcare, Hitachi Medical Corporation, Philips Medical Systems, Siemens Medical Solutions, and Toshiba Medical Systems have all created separate business lines and/or cooperative agreements with academic or research institutes to develop and implement molecular imaging probes, equipment, and concepts. Moreover, the recent mergers of General Electric with Amersham Biosciences (now GE Healthcare) and of Siemens with Bayer Diagnostics are clear signs that these big companies are preparing for the revolution in diagnostic imaging.

Clearly, molecular imaging is the new frontier in diagnostic imaging and, therefore, European radiologists have to be part in this development. It is the role of academic and research institutions to gather knowledge and dedicate resources in this field. The radiological community needs to invest in this future by education and participation in the molecular sciences and by creating relevant research facilities. But it is not only research – clinical radiologists have to be aware of the ongoing innovations in our profession and support training and education of the next generation.

The European Congress of Radiology (ECR) and European Society for Magnetic Resonance in Medicine and Biology (ESMRMB) are increasingly trying to bring molecular imaging and its anticipated importance in future diagnostic imaging to radiologists' attention by offering introductory courses and focused sessions on molecular imaging in their yearly meetings. This trend must be continued and expanded. In Europe, two platforms have recently been created that allow or facilitate radiologists to join forces amongst themselves and with other disciplines. In January 2006, the European Institute for Biomedical Imaging Research (EIBIR) was officially instated. The EIBIR (http://www.eibir.org) is an initiative of the European Society of Radiology (ESR) having the purpose to promote and facilitate interaction among researchers involved in the field of biomedical imaging in Europe, including molecular imaging. In May 2006 the kick-off meeting of the European Society for Molecular Imaging was held in Paris. The ESMI (http://www.e-smi.eu) is dedicated to the development and practical application of molecular imaging within Europe by fostering co-operation between researchers/specialists from European countries in the various disciplines in its field. The broad participation of radiologists in both these efforts of the scientific community in Europe should be encouraged.

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