Molecular Imaging through Magnetic Resonance for Clinical Oncology

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CISP

CAMBRIDGE INTERNATIONAL SCIENCE PUBLISHING

THE BOOK

Molecular imaging is impacting dramatically upon virtually all areas of clinical medicine. This is particularly true for oncology, where there is a growing appreciation of the possibilities offered for early detection, by identifying key changes for the emergence and progression of cancer on the molecular and/or cellular level. Among the potentially most promising of these functional imaging modalities are Magnetic Resonance Spectroscopy (MRS) and Spectroscopic Imaging (MRSI) that involve the in vivo application of traditional laboratory-based Nuclear Magnetic Resonance (NMR) techniques, and provide, in addition to the anatomic picture, complementary biochemical and physiologic information in the form of spectra. MRS and MRSI should be able to identify key biochemical changes, much before the tumor becomes detectable by other functional imaging methods that mainly rely upon single markers that are not entirely sensitive or specific for malignant activity. Molecular imaging through magnetic resonance could be potentially suited for screening and repeated monitoring since it entails no exposure to ionizing radiation. Modern systems now often have localization capabilities that can connect imaging to spectroscopy. MRS and MRSI have been shown to enhance diagnostics as well as assessment of response to therapy for a number of cancers, most notably brain, prostate and lymphoma, with some encouraging results for breast cancer, hepatic and head and neck tumors, inter alia. Most striking is that adding spectroscopic information from MRS substantially improves the specificity of MRI in oncology. The combination of anatomic localization and quantification by metabolite spectra is often decisive in accurate and timely identification of malignancy. This has proven invaluable, especially in the most difficult cases, e.g. differentiating recurrent tumor from radiation necrosis or post-operative changes.

In the first part of this book we review the basic principles of magnetic resonance (MR), and then MRS and MRSI. Some computational aspects are included. Signal processing is initially presented intuitively, using a conceptual approach to conjugate variables, with familiar clinical examples. This is followed by a succinct mathematical exposition aimed at a broad audience. The reader will thereby gain an appreciation of the strategies that allow MR signals to be transformed into clinically meaningful information. A brief overview of key technological aspects of MR and the nomenclature is also given.

Next, the current state of the art of in vivo MR imaging and spectroscopy for cancer diagnostics is presented, beginning with brain tumors, for which molecular imaging through MRS and MRSI have now become key modalities. In fact, in no other area of oncology have MRS and MRSI been so widely incorporated into clinical practice, with a literal “explosion” of information in neuro-oncology in the last 2-3 years. We have performed a systematic review of this very recent body of knowledge, which, indeed, represents an important advance for the detection and characterisation of tumors of the brain. This is followed by systematic reviews of the achievements to date using MRS and MRSI in prostate cancer, gynecological tumors, head-and-neck, lymphomas, musculoskeletal and renal tumors. Functional anatomic imaging, advanced MRI and initial results with MRS are presented for hepatic, gastrointestinal and other tumors. This second part of the book concludes with a chapter on the current approach to screening and early diagnosis of breast cancer, and what MRI and MRS have offered to date.

The chapters in this second part of the book include a brief background of epidemiological and clinical aspects of the tumor types examined with MRS and MRSI. Within this background, emphasis is placed upon etiology and risk factors, in order to suggest when the clinical index of suspicion should be raised, and when, therefore, the information provided by MRS and MRSI might be of particular benefit. Other diagnostic modalities and typical findings using MRI are presented, as well, so that the reader will have a comprehensive view of how these tumors are currently identified. The differential diagnosis is thoroughly discussed, which helps the reader to learn about other indications for MRS and MRSI. Available in vitro MRS data are also presented for each of the malignancies reviewed. Such data consistently yield deeper insights into the metabolite features of specific cancers, and help motivate the quest, presented in the next, and final, part of the book, to extract further information in the clinical setting from molecular imaging via MRS.

In this final part of the book, we discuss the current limitations of in vivo MRS and MRSI and their relationship to reliance upon the conventional Fourier-based framework for data analysis. It is then demonstrated how recent advances in signal processing via the Fast Padé transform, can circumvent many of these problems. Salient illustrations are provided. We examine how these advances could impact upon cancer diagnostics, with a view to early detection and screening, including surveillance of high-risk groups. In the concluding chapter, we explore the role of molecular imaging through MR within a broader context, in which working and general quality of life, treatment, clinical monitoring and surveillance are part of an integrated whole.

This book is written for clinicians and clinical researchers – at various levels of training and experience. It is a self-contained text with ample references on a chapter-by-chapter basis to facilitate in-depth study of a given topic. The style is pedagogical, and will be amenable for use in courses on MR, as well as in oncology. The chief aim of this book is "translational": to help clinicians and clinical researchers more actively and confidently engage in more basic areas such as molecular imaging through magnetic resonance, as part of the battle against the scourge of cancer.

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The Author

Dr. Karen (Edinger) Belkic was born in Los Angeles, California. She is an Adjunct Associate Professor of Preventive Medicine at the University of Southern California School of Medicine—Institute for Health Promotion and Disease Prevention Research, and currently is a visiting Clinical Researcher and Pedagogue at the Department of Oncology-Pathology, Karolinska Institute, Stockholm, Sweden. She received her B.A. in biology from the University of California, Santa Barbara and her M.D. degree from the University of Southern California School of Medicine. She holds a PhD in the neurosciences and is a physician specialist in internal medicine. Dr. Belkic has served as a physician within the fields of occupational medicine as well as internal medicine and cardiology.

She has authored over 60, widely cited peer-reviewed articles and book chapters, one book and four monographs in multi-disciplinary areas related to preventive and internal medicine. She is a member of the Editorial Board (Responsible for Computational Medicine) for the *Journal of Computational Methods in Sciences & Engineering* (*JCMSE*), formerly published by Cambridge International Science Publishing, and currently by IOS Press, Amsterdam, the Netherlands. She has twice been an invited guest co-editor of special issues in international journals, most recently on "How Mathematical Advances can Optimize Magnetic Resonance Spectroscopy in Oncology" for the *JCMSE*.

A major thread tying together the clinical research activity of Dr. Belkic has been the search for non-invasive, sensitive and specific tools for early detection and prevention of disease. Her current scientific activity is focused upon incorporating advances in signal processing for biomedical imaging to take fuller advantage of the possibilities offered by MRSI for surveillance imaging in oncology, to optimize diagnostics and fine-tune therapy within a multi-level patient-centered strategy in which quality of life, treatment and clinical monitoring are part of an integrated whole. She is exploring how these advances might be implemented as part of screening surveillance for early cancer detection, particularly for malignancies that afflict women.

Dr. Belkic has taken a broad view, looking not just at the immediate (i.e. proximal) markers of risk, but taking into account the more distal, and potentially key, determinants of disease. Thus, she has been very interested in how the environment impacts upon target organs, often mediated by the central nervous system. Within this functional-diagnostic framework, she has developed multi-level models, which incorporate non-linear, parametric methods in relation to multiple physiological time signals.

Dr. Belkic has a special interest in pedagogy. She has focused much of her current activity on how to incorporate a multi-disciplinary approach into the medical school curriculum, whereby a firm grounding in clinical medicine is integrated with an appreciation of biology, physics and mathematics, and how this can be placed within the larger framework of comprehensive care and prevention.

Bibliographic data

ISBN 1-904602-29-0, 240×160 mm, hardback, 320 pages, October 2004, £50 ($85, Euro 80)