DEVELOPMENT OF HIGH-RESOLUTION MOLECULAR PHASE-CONTRAST STEREOSCOPIC X-RAY IMAGING FOR ACCURATE CANCER DIAGNOSTICS

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A new high-resolution molecular phase-contrast stereoscopic X-ray imaging (PSXI) modality is under development. It is aimed at offering oncologists and radiologists a system solution to discover and locate early-stage cancers and to assess tumour characteristics and therapeutic responses. The method is primarily developed for clinical implementation of biologically optimised target-specific cancer therapy to maximise cure and improve quality of life of cancer patients. The investigations here indicate theoretically that it is possible to achieve high-resolution and high-contrast 3D medical imaging with the PSXI technique at relatively low dose, almost an order of magnitude lower than those used in conventional computed tomography (CT) imaging, depending on image resolution and contrast of interest. Unique features of this new molecular imaging modality will be discussed in comparison with currently available molecular imaging modalities, such as positron emission tomography-computed tomography and magnetic resonance spectroscopic imaging. Some challenging issues with respect to the possible use of nanotechnology with the new molecular imaging modality will also be discussed.

INTRODUCTION

X-ray imaging has played an important role in medical imaging and diagnostics over more than 100 years. Despite the technology progresses during the past century, radiologists are still limited in their ability to detect tumours in their earliest stages, monitor tumour phenotype, quantify invasion or metastasis and to visualise in vivo in real time the effectiveness of anticancer treatments. Tumours of sizes \( \leq \frac{1}{2} \) mm are mostly localised at its early stage when significant angiogenesis has not been initiated\(^{(1)}\). Thus, the risk of patients to get metastatic diseases can be minimised if these early-stage tumours or residual tumours after initial treatments could be discovered and eliminated. However, at present, no clinical imaging modalities are available to provide 3D medical images of these tumours with high resolution \( (\leq 0.1 \) mm) and diagnostic accuracy in humans.

Limitations of conventional X-ray imaging systems are mainly due to their intrinsic low soft-tissue contrast and clinical dose limitations set for human examination. Since the X-ray dose required for 3D imaging increases rapidly with increasing spatial resolution\(^{(2)}\), it is hardly possible for conventional X-ray or computed tomography (CT) techniques to achieve 3D medical imaging at a spatial resolution of \( \leq 0.1 \) mm for human examinations at a clinically acceptable dose level, not only because of its low soft-tissue contrast especially for small objects. In contrast, the phase-contrast X-ray imaging techniques have been investigated and demonstrated recently with extraordinary image quality, showing enhanced soft-tissue contrast, revealing soft-tissue discrimination with spatial resolutions down to the micrometer scale\(^{(3)}\). Human examinations with phase-contrast X-ray mammography have also been conducted recently, showing improved diagnostic accuracy with synchrotron radiation at Elettra, Italy\(^{(4)}\).

MOLECULAR PHASE-CONTRAST STEREOSCOPIC X-RAY IMAGING

Anatomic image information obtained from a CT scan may help in cancer diagnostics and treatment planning in the definition of the extent of tumour spread and to localise important normal-tissue structures. However, targets delineated based on anatomic structures alone have limitations, sometimes, leading to over treatment of healthy tissues or under treatment of sites of disease by using, for instance, radiation therapy. In fact, the radio-sensitivity of malignant tumours depends on many factors, which include cell cycle phase, cancer metabolism, apoptotic potential, proliferation, radiation damage and repair capacity as well as the presence and severity of hypoxia. Some of these features can now be studied by molecular imaging and may be utilised for designing a biologic target volume, determining the radiation dose schedule and the need for adjuvant chemotherapy or treatment with specific radiation sensitisers, etc. Besides, by molecular imaging, specific molecular probes may be exploited as sources of image contrast. Thus, molecular imaging has the potential to be used much earlier than conventional anatomic imaging techniques in...