In-line phase-contrast stereoscopic X-ray imaging for radiological purposes: An initial experimental study

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ABSTRACT

We report results from a pilot study in which the in-line propagation-based phase-contrast imaging technique is combined with the stereoscopic method. Two phantoms were imaged at several sample-detector distances using monochromatic, 30 keV, X-rays. High contrast- and spatial-resolution phase-contrast stereoscopic pairs of X-ray images were constructed using the anaglyph approach and a vivid stereoscopic effect was demonstrated. On the other hand, images of the same phantoms obtained with a shorter sample-to-detector distance, but otherwise the same experimental conditions (i.e. the same X-ray energy and absorbed radiation dose), corresponding to the conventional attenuation-based imaging mode, hardly revealed stereoscopic effects because of the lower image contrast produced. These results have confirmed our hypothesis that stereoscopic X-ray images of samples with objects composed of low-atomic-number elements are considerably improved if phase-contrast imaging is used. It is our belief that the high-resolution phase-contrast stereoscopic method will be a valuable new medical imaging tool for radiologists and that it will be of help to enhance the diagnostic capability in the examination of patients in future clinical practice, even though further efforts will be needed to optimize the system performance.

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1. Introduction

X-ray attenuation has played an important role in medical imaging and diagnostics for over more than one hundred years. Despite of technological advances during the past century, we are still limited in our ability to detect tumors in their earliest stages, monitor tumor phenotype, quantify invasion or metastasis, and to visualize in real-time the effectiveness of cancer treatments. Tumors of sizes less than 1–2 mm are mostly localized in situ at an early stage when significant angiogenesis has not yet taken place [1]. Thus, the risk that patients develop metastatic disease can be minimized if we could discover and eliminate these early-stage tumors or residual tumors after initial treatments. However, at present, no clinical imaging modality is able to provide 3D medical images in humans with sufficiently high contrast and spatial resolution (<0.1 mm) of satisfactory diagnostic quality. The short-comings of conventional X-ray imaging systems are mainly due to the small contrast differences for different kinds of soft-tissue. This also led to the development of the multiple projection CT method by Cormack [2]. Due to motions and the fact that the minimum absorbed dose required for 3D X-ray imaging increases rapidly with increasing spatial resolution of the X-ray imaging modality used, today it is rarely clinically possible to have a spatial resolution higher than about 0.5 mm. A low dose is especially important in the case of imaging for screening purposes.

In recent years, phase-contrast X-ray imaging techniques have been explored in diagnostic research. Earlier studies demonstrated that the method allows for visualization of contrast in tissues in which conventional absorption-based contrast is weak or absent with a similar or even reduced tissue radiation dose [3]. Therefore, the spatial resolution of the images can be increased with acceptable clinical doses so that objects of sizes in the interval 10–30 μm can be recognized [3–8]. Furthermore, conventional stereoscopic mammography has recently been found to be much more effective with a 46% reduction of the false-positive cases compared with standard film mammography when detecting subtle lesions [9]. This finding suggests that 3D viewing techniques will allow clinicians to detect more true lesions and could significantly reduce the number of women who are recalled for additional tests or even biopsy following routine screening mammography. While this positive result has been reported for stereo mammography based on a conventional attenuation-contrast X-ray imaging system, we anticipate that by combining with the phase-contrast technique, the stereoscopic X-ray imaging techniques for medical purposes may be improved even further [5].