Ultrahigh Resolution Whole-Body Photon-Counting CT

A Novel Versatile Tool for Translational Research from Mouse to Man

S. Sawall[1], J. Kuntz[1], C. Amato[1], L. Klein[1], E. Wehrse[1], L. T. Rotkopf[1], D. Franke[2], N. Gehrke[2], A. Briel[2], H.-P. Schlemmer[1], C. H. Ziener[1], S. Heinze[3], and M. Kachelrieß[1]

[1] German Cancer Research Center (DKFZ), Heidelberg Germany
[2] nanoPET Pharma (Berlin, Germany)
[3] University Hospital Heidelberg, heidelberg, Germany

dkfz.
GERMAN CANCER RESEARCH CENTER
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Introduction

Computed tomography is a valuable tool in clinical practice since it provides cross-sectional images of the specimen under investigation within seconds and a resolution of up to 0.4 mm. Preclinical CT requires dedicated micro-CT systems providing higher spatial resolutions compared to clinical scanners. The need for multiple imaging systems hinders the rapid translation of preclinical findings to clinical practice. This drawback might be overcome by the future introduction of clinical ultrahigh resolution (UHR) photon-counting (PC) CT systems combining preclinical and clinical capabilities.

Methods

The prototype of a clinical UHR PCCT (SOMATOM CounT, Siemens, Germany) was used for all experiments. The system comprises a conventional energy-integrating (EI) detector and a novel PC detector. While the EI detector provides a pixel size of 0.6 mm in the center of rotation, the PC detector provides a pixel size of 0.25 mm, with future adaptations potentially allowing for 0.125 mm pixel size (fig. 1), and it allows for a quantification of photon energies in up to four distinct energy bins. This acquisition of multi-energy data allows for a multitude of applications, e.g. pseudo-monochromatic imaging. We illustrate the capabilities of UHR PCCT by presenting pilot studies conducted in mice and human cadavers after the system has been thoroughly characterized using appropriate phantoms measuring spatial resolution and spectral properties.

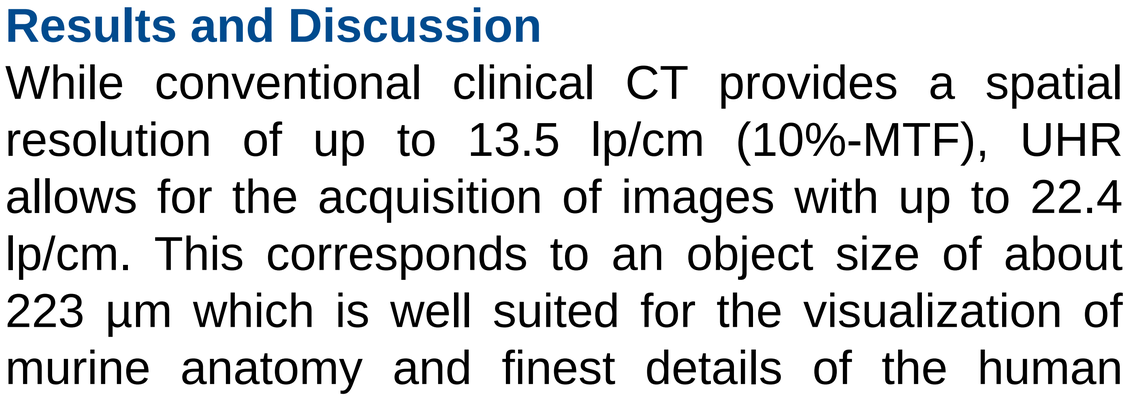

Fig 1: Left: Photograph of the prototype system. Right: Conventional CT detectors exhibit pixel sizes of about 0.6 mm (left). The novel photon-counting detector provides a pixel size of 0.25 mm (middle). These UHR pixels are actually binned from even smaller pixels with a size of 0.125 mm. Currently, only the 0.25 mm pixels are available due to data transfer rate limitations. However, future updates might allow measurements with a pixel size of down to 0.125 mm.

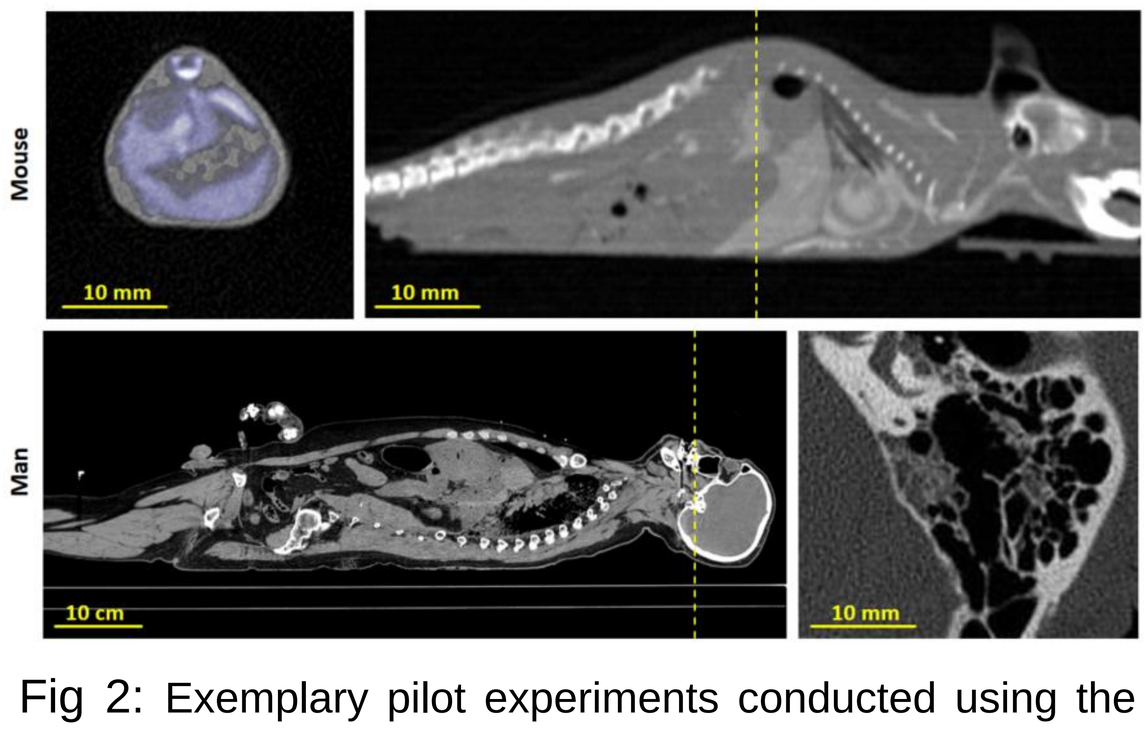

Fig 2: Exemplary pilot experiments conducted using the UHR PCCT system to highlight its versatile capabilities. Top: Acquisition of a mouse (C=200 HU, W=2500 HU) after administration of an experimental Bismuth-based blood pool agent with a Bismuth-overlay (blue, left). Bottom: Whole-body UHR image of a human cadaver acquired in scope of a forensic study. Sagittal overview (left, C=40 HU, W=300 HU) and the inner ear (right, C=1000 HU, W=3500 HU). Yellow lines in the sagittal reformats indicate the z-position of transversal sections.

Results and Discussion

While conventional clinical CT provides a spatial resolution of up to 13.5 lp/cm (10%-MTF), UHR allows for the acquisition of images with up to 22.4 lp/cm. This corresponds to an object size of about 223 µm which is well suited for the visualization of murine anatomy and finest details of the human body. I.e., all major anatomical structures in mice could be identified (fig. 2) after the administration of a prototype Bismuth-based blood pool agent (nanoPET Pharma, Berlin). Similarly, studies in large animals, human cadavers and patients show a level of detail superior to conventional clinical CT. The capability of performing preclinical and clinical experiments in a single system while achieving a sufficient spatial resolution might significantly improve the translation from preclinical research to clinical practice. The intrinsic acquisition of multi-energy data allows for various applications. Among others, the data allow for the computation of contrast media overlays, e.g. Bismuth as shown in fig. 2, and the computation of pseudo-monochromatic images. Clinical CT typically offers tube voltages from 70 kV to 150 kV. While preclinical scans could be performed with 70 kV, the computation of pseudo-monochromatic images shows energy levels more appropriate for preclinical settings at lower energies.

Conclusion

Clinical UHR PCCT will boost translational research as it allows for the versatile imaging of specimens from mice to man within a single system while providing clinically well-established applications, e.g. contrast media quantification.