CBCT metal artifact reduction based on source-detector trajectory optimization and PICCS reconstruction

S. Hatamikia*[a,b], A. Biguri[c], G. Kronreif[a]. J. Kettenbach[d]. T. Russ[e]. W. Birkfellner[f]

[a]Austrian Center for Medical Innovation and Technology, Wiener Neustadt, Austria
[b]Research center for Medical Image Analysis and Artificial Intelligence (MIAAI), Department of Medicine, Danube Private University, Krems, Austria
[c]Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, UK
[d]Institute of Diagnostic and Interventional Radiology and Nuclear Medicine, Landesklinikum Wiener Neustadt, Austria
[e]Medical Faculty Mannheim, Heidelberg University, Germany
[f]Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria

Introduction

Precise placement of interventional instruments plays a crucial role for all procedures particularly in percutaneous procedures such as needle biopsies in order to achieve higher diagnostic accuracy and accurate tumor targeting. C-arm cone beam computed tomography (CBCT) have the potential to precisely image the anatomy in direct vicinity of the needle to evaluate the adequacy of needle placement during the intervention, allowing for instantaneous adjustment in case of misplacement. However, even with the most recent C-arm CBCT devices capturing the exact needle position on intraoperative CBCT images is very difficult due to strong metal artifacts around the needle. Therefore, refining the intraoperative CBCT reconstructions quality for the task of needle placement has a great potential to improve target localization during the interventions.

Materials and Methods

In this study, we evaluated the performance of the prior image constrained compressed sensing (PICCS) CBCT reconstruction in presence of metal object inside an anthropomorphic thorax phantom. In order to investigate the performance of PICCS algorithm to mitigate metal artifacts, we proposed to acquire a case-specific digital model from a prior circular CBCT. The CBCT scan was acquired at the beginning of the intervention before the needle placement inside the thorax phantom including a 3D printed tumor model and was served as a template for the PICCS reconstruction. The PICCS reconstruction was then applied on the projection data from a sparse standard circular trajectory (including only 80 projections) which were taken after the needle insertion. The possible improvement of metal artifacts in the reconstructed image was then compared to the Feldkamp, Davis and Kress (FDK) reconstruction method as the widely commercially used reconstruction algorithm. We also used Structural Similarity index (SSIM) and Universal Image Quality index (UQI) as the image quality metrics.

Results

According to the results, for the reconstructed image related to FDK and optimized trajectory using PICCS the relative deviation of 53.31, 12.07 and 47.20, 7.89 was achieved for SSIM and UQI, respectively. Our results showed a significant improvement in metal artifact reduction based on PICCS reconstruction compared to the FDK algorithm when using a sparse-view circular trajectory.

Discussion

Our approach only uses 80 projections; this lower number of projections used in this study not only is efficient to reduce metal artifacts but also can introduce a dose reduction for needle-based CBCT interventions.