Optimization of 4DCBCT image reconstruction at proton gantry systems

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INTRODUCTION

Recently, Cone Beam Computed Tomography (CBCT) imaging became available for proton facilities as a tool for daily patient positioning verification. Furthermore, CBCT provides internal anatomy information. When reconstructed into 4D images, tumor motion amplitudes can be measured which will help to evaluate the motion on even a daily basis. In this study we compared two projection binning approaches for the 4DCBCT reconstruction. Overall image quality and presence of diaphragm artefacts were evaluated for the resulting images. The aim was to determine the best method for projection binning which will lead to good quality images and a fully automatic 4DCBCT reconstruction workflow for clinical use.

MATERIALS & METHODS

Two sets of CBCT-projections and accompanying Anzai signals were acquired at our proton facility. For this, a porcine lung phantom was provided by the department of radiation oncology at the Ludwig-Maximilian University hospital in Munich. Porcine lungs were inflated in a dedicated chest phantom and set at a regular breathing pattern of 12-13 respirations per minute.

Using the two sets of CBCT projections, three 4DCBCT images were reconstructed per set using the MA-ROOSTER* reconstruction method. The projections were additionally reconstructed in 3DCBCT images for image quality comparison. Projection binning during 4D-reconstruction was performed using the Anzai signal (method A) and the Amsterdam Shroud method. The Amsterdam Shroud method could be used automatically (method B) as well as with manual correction (method C).

The diaphragm region in the images was inspected visually for artefacts. Furthermore, the structural similarity index measures (SSIM) were calculated comparing the 4DCBCT images to the reconstructed 3DCBCT images. The SSIM indicated the amount of image quality when reconstructing in ten different breathing phases instead of statically in 3D.

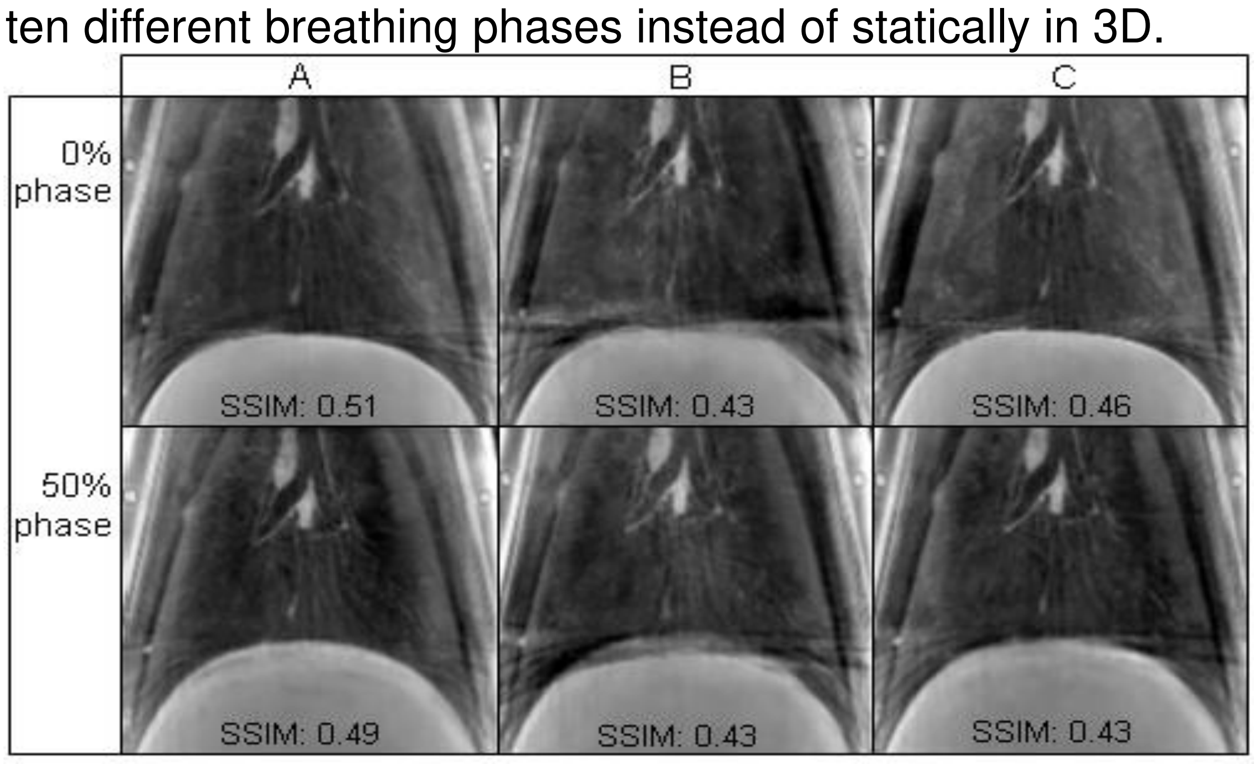

Figure 1: Coronal views with quality measure results for one of the 4DCBCTs (0% and 50% phases). The reconstructed diaphragms are compared for Amsterdam Shroud and Anzai signal projection binning methods.

RESULTS

Figure 1 depicts the 4DCBCT coronal views of the 0% and 50% phases for the three different projection binning methods.

At first, the diaphragm region was inspected, as the largest motion was simulated in the lower part of the lungs. Increased diaphragm artefacts were observed for method (B), showing streaking artefacts and irregular diaphragm boundaries. The artefacts decreased in intensity when applying a manual correction of the Amsterdam Shroud method (C). However, the best visual result was observed for method (A) using the Anzai signal to register the breathing signal measured at the diaphragm region. Less artefacts around the diaphragm region were observed in terms of streaking and sharpness of the diaphragm boundaries compared to methods (B) and (C).

Table 1 shows the structural similarity index measures for the reconstructed 4DCBCT scans and projection binning methods. The quality compared to the 3D-reconstructions was on average for the ten-phases between 44% and 49%. Method (A) using the Anzai signal showed the best image quality of the three methods.

Table 1: Quality measure results for the reconstructed 4DCBCT scans for the three projection binning methods. The average SSIM values of the ten phases plus standard deviations are noted.

	A	B	C
		SSIM (mean ± SD)	
4DCBCT 1	0.49 ± 0.02	0.46 ± 0.02	0.45 ± 0.01
4DCBCT 2	0.49 ± 0.02	0.45 ± 0.01	0.44 ± 0.01

Abbreviations: SSIM = structural similarity index measure (‘1’ represents identical images, ‘0’ represents completely non-identical images). A = Anzai method, B = Amsterdam Shroud, C = Amsterdam Shroud corrected.

CONCLUSION

The method for projection binning using the respiratory signal from the Anzai belt resulted in the best image quality for 4DCBCT reconstructions. This method can be performed automatically and is therefore the preferred approach for clinical 4DCBCT reconstruction at our proton facility.

*Mory C, Janssens G, Rit S. Motion-aware temporal regularization for improved 4D cone-beam computed tomography. *Phys Med Biol.* 2016;61(18):6856-6877. doi:10.1088/0031-9155/61/18/6856

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