Assessment of Flying-Focal Spot in MPR Images of High-Frequency Objects Using a Star Phantom

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

High spatial resolution MPR (multiplanar reformation) images in some CT exams, such as temporal bone CT, is a key factor for rendering accurate clinical interpretation by the radiologist. While evaluating the spatial resolution of an in-plane CT image has become relatively easy using the ACR or Catphan® phantoms, obtaining MPR (coronal and sagittal) images of the line-pairs pattern from these phantoms is very cumbersome and, due to the line-pairs position in these phantoms, may not provide a good representation of the system's spatial resolution since some line pairs will be close to the center whereas others will be closer to the periphery (~ 10 cm way from the center).

AIM

The purpose of this study was to obtain a quantitative evaluation of the spatial resolution of the CT MPR images using a simple test object. Also, to assess the change in the MPR images' resolution of a flying focal spot system when the scanned object was moved away from isocenter.

METHOD

A star pattern phantom of 2° spoke angle was used as the test object. Temporal bone (zUHR) protocol was used on a 128-slice Definition Flash (Siemens) scanner. For coronal MPR assessment, the phantom was laid flat, and for sagittal MPR the phantom was standing 90° with its edge aligned with Z-plane. Scans were performed at isocenter and at different distances (4cm, 8cm, and 12cm) from isocenter in the vertical direction. All scans were performed using 120 kV, 200mA$_{eff}$, and a pitch of 0.85 with 16 x 0.6 collimation and a slice thickness of 0.3 mm. Images were reconstructed with an ultra sharp kernel (Ur77u/3). A plugin (Canny Edge Detector) in ImageJ software was used to define the limiting resolution, which corresponded to where the phase reversal (of black and white) occurs. By measuring the distance from the center to the phase-reversal point (r), the line-pairs per mm (lp/mm) was then defined as:

$$\frac{90lp}{2\pi r},$$

for both directions in phantom images, as shown in the figures.

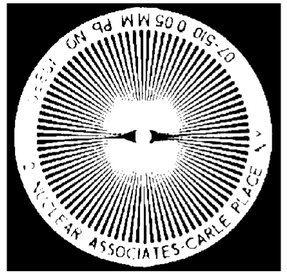
Also, an anthropomorphic phantom's temporal bone was scanned at the same vertical intervals and its image sharpness was visually evaluated.

RESULTS

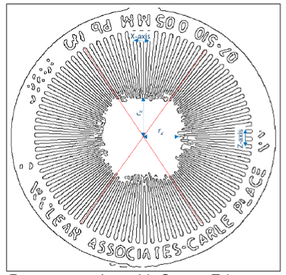
When the test object was at isocenter, the limiting resolution in all three planes was approximately 1.9 lp/mm. In coronal MPR, z-plane maintained the high spatial resolution even at vertical phantom shift of 12 cm from isocenter. X plane's spatial resolution, on the other hand, showed a loss at 8 and 12 cm shifts; to 1.3 and 1.0 lp/mm, respectively.

In sagittal MPR, z-plane spatial resolution showed a higher loss than in the coronal plane; at both 8 and 12 cm the resolution dropped to 1.5 lp/mm. Y plane resolution, like with the x-axis in coronal, dropped at distances > 4 cm in the vertical directions (from 1.9 lp/mm down to 1.2 lp/mm at 12 cm from isocenter). The results are also illustrated in the graphs to the right.

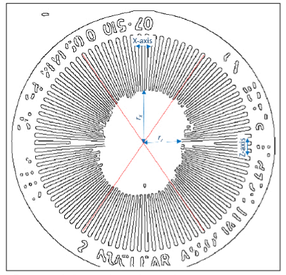
Coronal and sagittal images of the anthropomorphic phantom demonstrated a similar effect; the high frequency objects in the images showed some degradation when the phantom head was scanned at 8 cm from isocenter. See examples of the images attached.



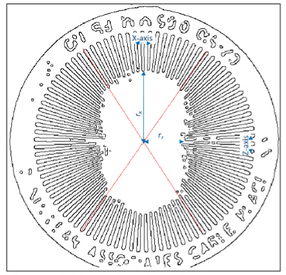
Coronal view of the star pattern at isocenter.



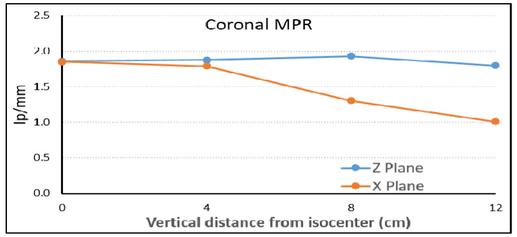
Post-processing with Canny Edge Detector (ImageJ plugin).

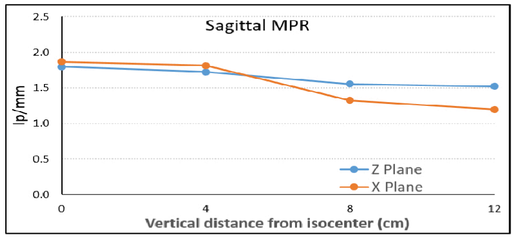


Coronal 8 cm low from isocenter.

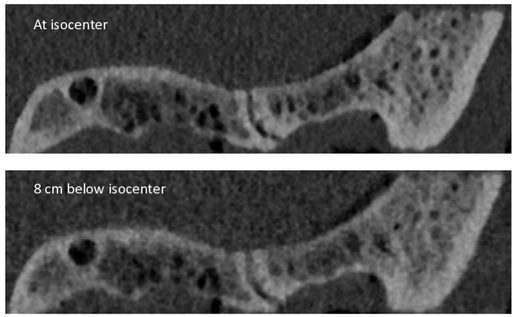


Coronal 12 cm low from isocenter.

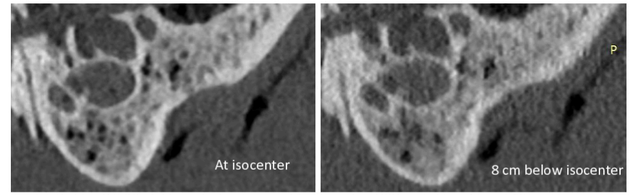




Top: resolution in the z and x axes (from coronal views of the star phantom) as a function of a vertical distance from isocenter.
Bottom: resolution in the z and y axes (from sagittal views of the star phantom) as a function of a vertical distance from isocenter



Coronal views of temporal bones (Rando phantom) at isocenter and at 8 cm below.



Sagittal MPR images of the Rando phantom's temporal bone at isocenter and at 8 cm below.

CONCLUSIONS

The use of the star phantom in evaluating the spatial resolution of CT MPR images can provide a reliable objective assessment. Edge detection software, such as the freely available plugin by ImageJ, helps obtain this objective evaluation.

The flying focal spot provides almost shift-invariant high-resolution in the z-plane of coronal MPRs. A slight degradation of Z-plane resolution may be observed in sagittal MPRs at distances > 4 cm.

In both x and y planes, however, the resolution suffers a significant loss at distances ≥ 8 cm from isocenter.

Despite the fact that the flying focal spot provides high spatial resolution images in the z-axis, it is very likely that clinical images contain high frequency objects in all orientations. Thus, images of high frequency objects away from the isocenter may still suffer from a degradation in the coronal and sagittal MPRs.

REFERENCES

McCollough CH et al. Spatial resolution improvement and dose reduction potential for inner ear CT imaging using a z-axis deconvolution technique. *Med Phys 2013; 40;: 061904-1 – 061904-9.*

CONTACT INFORMATION

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