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How to Use Lead Apron to Reduce Excess Radiation Dose Caused by Over-Scan in Computed Tomography

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PURPOSE

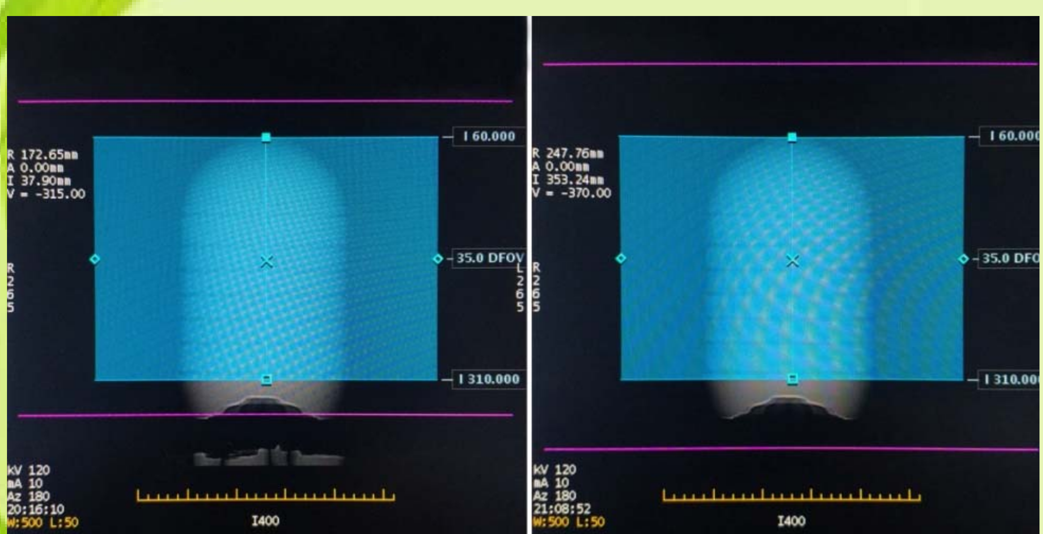
The helical scan mode is used very commonly in multidetector computed tomography and interpolation algorithm is used in reconstructing images, resulting in over-scan in the Z direction: exposures to tissues beyond the boundaries of the imaged volume. The amount of over-scan is dependent on the collimation width of the multidetector system, and in general the wider the collimation, the more the over-scan. However, not all information in the over-scan area are needed for reconstruction and may contribute to unnecessary dose to patients. One way of reducing dose in the over-scan area is to use lead apron to protect the tissues that is just outside the field necessary for reconstruction but covers the z over-scan field. So, the purpose of this study was to explore the optimal way of placing the lead apron to maximize dose reduction for the over-scans without negatively impact image quality, and its dependence on the collimation width using phantom experiments.

METHODS

We used an elliptical plastic water bottle (14cm*17cm in axial slice) to evaluate dose performances and image quality with 40mm and 80mm detector collimations and at different distances to the scanning boundary in which the lead apron was placed. The study was divided into two groups: Group A using 40mm detector coverage; and Group B using 80mm detector coverage. Based on our earlier study, the scout imaging was taken first without lead apron, then the lead apron was put on and the helical scan was taken in every group. The helical scan groups were designed as follows: group 1, without lead apron as reference standard and groups 2-7 with the lead apron first placed at the scan boundary and in 5mm increment away from the scan boundary. The scan techniques were kept the same for all scans at 120kVp, 10-740mA, 7 pre-defined noise index (in 5mm primary recon), and 5mm reconstruction slice recon.

METHODS

This operation was repeated for both the 40mm and 80mm collimations. CT dose index (CTDI) values were recorded and the image quality in terms of CT value and standard deviation (SD) of the last image at the scan boundary in the helical scan nearest to the lead apron were measured for each experiment for comparison. The images obtained without placing the lead apron were used as the reference standard. Five regions of interest (ROI, 10mm*10mm in size) at the up, down, left, right and center locations in the images were selected to measure CT value and SD. CT value rate(CT%=[CT-CT(1)]/CT(1)) and standard deviation rate(SD%=[SD-SD(1)]/SD(1)) for each ROI in matched location were used to evaluate objective imaging quality. CT(1) and SD(1) represented the CT value and SD in group 1, and the CT and SD were the measured CT and SD in group 2-7. Subjective image quality was also evaluated.



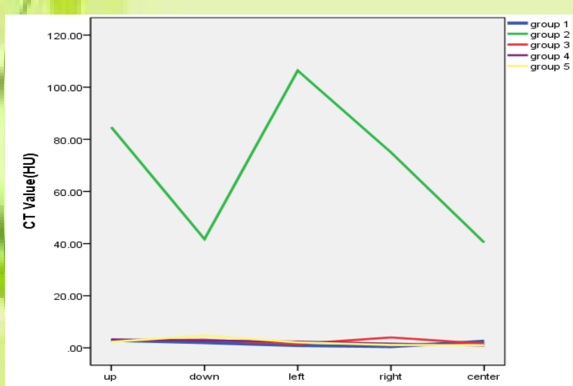
Picture 1 The z over-scan of 40mm (left , about 3cm in one side) and 80mm detector coverage(right , about 6.2cm in one side).

RESULTS

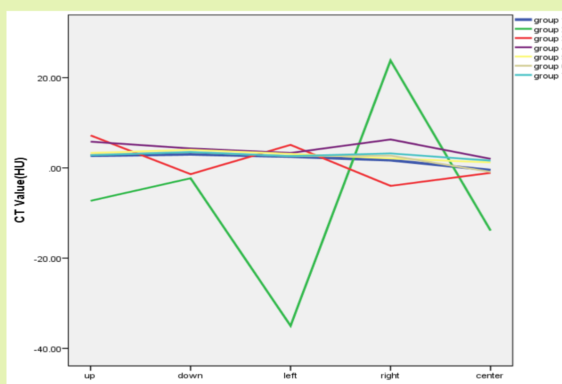
The DLP value was 54.65mGy*cm for Group A and 66.52mGy*cm for Group B for covering the same region. There was a 22% increase in radiation with the use of 80mm collimation in Group B. In both the 40mm and 80mm groups, there was a significant jump in CT value and SD in the images at the scan boundary when the lead apron was placed right at the scan boundary. The CT value and SD difference with and without the use of lead apron changed dramatically and stabilized after the lead apron was placed 5mm and 10mm away from the scan boundary in the 40mm and 80mm collimation group, respectively. The subjective image quality followed the same pattern as the objective measurements, indicating that the use of lead apron should not negatively impact the image quality in the desired areas.

Table 1 Subjective image qualitative analysis

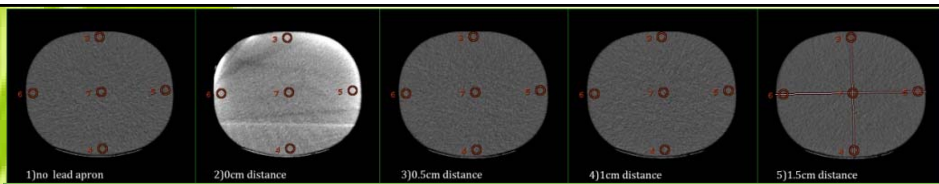
score	noise	artefacts
1	unacceptably noisy	affecting diagnosis
2	Some noise in an acceptable image	Minor artifacts not affecting the visualization
3	Minimal or no noise	no artifacts



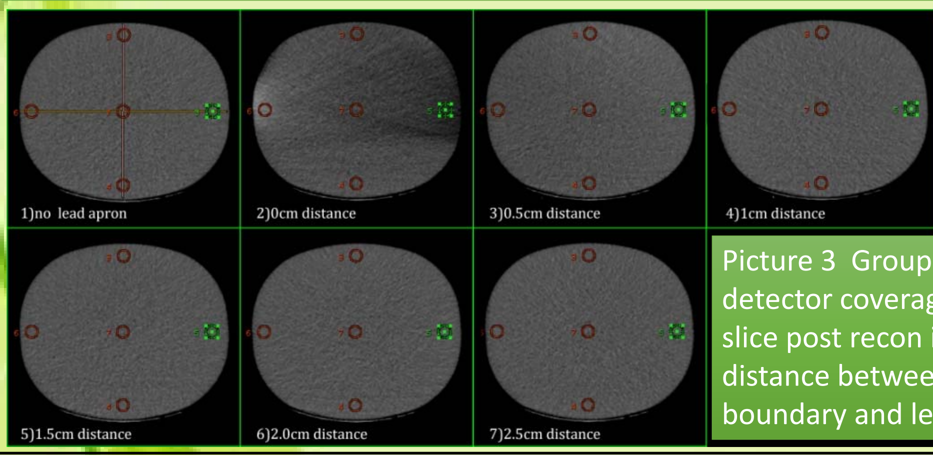
Graph 1 the CT value of five ROI in group 1-5 with 40mm detector coverage



Graph 2 the CT value of five ROI in group 1-7 with 40mm detector coverage



Picture 2 Group A - 40mm detector coverage with 5mm slice post recon in different distance between scan boundary and lead apron



Picture 3 Group B - 80mm detector coverage with 5mm slice post recon in different distance between scan boundary and lead apron

CONCLUSION

In our study we have performed a phantom experiment with different detector coverage and with different distances between scan boundary and lead apron. Our results indicated that there was dose penalty with the use of wider collimation due to over-scan. The correct use of a lead apron can greatly reduce the unnecessary radiation to patients, including in the over-scan region without negatively impact image quality in the desired areas. Placing the lead apron at least 5mm from the scan boundary when using 40mm collimation and 10mm when using the 80mm collimation is recommended.