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Dose optimization in computed tomography of brain using CARE kV and CARE Dose 4D

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Abstract

Background: Computed Tomography (CT) scan of brain is the most widely used CT examination. Latest CT scanners have the potential to deliver very low radiation dose by utilizing tube potential and tube current modulation techniques. We aim to determine the application of CARE kV (tube potential modulation) and CARE Dose4D (tube current modulation) in CT scan of brain. Both CARE kV and CARE Dose4D are well-established innovative technology of Siemens Medical Solutions.

Methodology: A prospective hospital-based study was conducted during four months at Tribhuvan University Teaching Hospital (TUTH). The data were collected on a Siemens Somatom Definition Edge 128 slices CT scanner. Non-random purposive sampling technique was employed. Ethical approval and consent to participate were taken for every participant. Non-contrast (NC) CT images were acquired without using CARE kV and CARE Dose4D, whereas during contrast-enhanced (CE) investigation, both were turned on keeping other scanning parameters constant for each individual.

Results: A total of 72 patients, 42 males and 28 females - mean age 41y (range 16-87y) participated in this study. The Body Mass Index (BMI) was 22.0, range 20.1-25.0. The mean value of Computed Tomography Dose Index (CTDI), Dose Length Product (DLP) and Effective Dose (ED) before and after switching on both CARE kV and CARE Dose4D were 58.19±0.35 and 39.67±3.59 milli-Gray (mGy), 946.67 and 652.58 mGy-cm, and 1.98 and 1.36 milli-Sievert (mSv) respectively.

Conclusion: CARE kV and CARE Dose4D can reduce radiation dose in CT scan of brain without loss of image quality.

Introduction

Latest surveys have revealed that 60-70% of the patient doses in diagnostic radiology are received from Computed Tomography (CT) examinations.[1] These higher doses have drawn significant attention particularly in multi-detector CT.[2] The usage of CT is increasing exponentially, which can potentially lead to adverse health effects, such as genetic mutation and malignancy.[3]

In order to minimize such radiation-induced hazards, the radiation doses need to be reduced as low as possible. Different dose-reduction strategies have been introduced. Of these, we intend to use CARE kV and CARE Dose4D technique of dose modulation in this study. Both techniques are the well-established dose reduction strategies of Siemens Medical Solutions, Forcheim, Germany. Care kV is a tube potential optimization technique who can be assigned to each patient according to the patients' topography and study objectives.[4] CARE Dose4D is online, real-time anatomy adapted attenuation based tube current modulation (TCM) method with constant image quality.[5,6] Tube current (measured in milli-Amperes) is an important determinant of radiation dose and image quality.[7] Tube voltage is often an untouched scanning parameter. However, CARE kV brings a new frontier in radiation dose optimization along with TCM. A decrease in tube current not only reduces radiation exposure but also increases image noise. CARE Dose4D is a recent refinement of TCM determined in all in x, y and z-directions.[8] It modulates tube current on the basis of regional body anatomy for adjustment of x-ray quantum noise to maintain constant image noise with improved dose efficiency.[6] The principles of both these techniques are explained in more detail elsewhere.[8,9] However, in this study, we aim to evaluate the reduction of dose in CT scan of brain with care dose 4D and Care kV.

Methods

A prospective hospital-based study was conducted from April to August 2015 in Department of Radiology and Imaging, Tribhuvan University Teaching Hospital (TUTH). The data were collected on a Siemens Somatom Definition AS 128 slices CT scanner. Non-random purposive sampling technique was employed. All the patients having normal findings who provided informed consent for the CT scanning of brain and consent to participate in the study were included. Those patients who were unwilling to participate, those who refused to perform CT scanning of their brain, patients with abnormal CT findings, and examinations with artefacts were excluded from the study. Contrast enhanced procedure require both non-contrast and contrast enhanced acquisition of whole brain. Hence, we obtained plain CT images without using CARE kV and CARE Dose4D, whereas in contrast-enhanced procedure, both of them were turned on keeping other scanning parameters constant for each individual.

Patient lies supine, with head in a head rest. First of all, lateral scout image was obtained and brain images were acquired from base of skull to the vertex with the scan lines parallel to radiographic base line. The basic scanning parameters were slice thickness 5mm; table increment 5mm; kilo-Voltage 120 kV, milli Ampere second (mAs) per slice 475 mAs; Algorithm Standard; Field of View 22 cm; Window width (WW) 120/80 and Window Level (WL) 40. All the images are interpreted as excellent image quality by experienced consultant radiologist of more than 5 years. However, this report has limitation of determining the agreement level of the image interpretation. The noise levels of the images were also not taken into account. Our main focus was dose reduction strategy with excellent visual image quality.

Data Analysis

Statistical data analysis was carried out in SPSS software version 20 and Microsoft Excel 2010. Descriptive analysis and graphic representation were performed.

Ethical Consideration

Approval was granted from Institution Review Board, Research Department, Institute of Medicine (IOM), Tribhuvan University (TU). Informed consent for undergoing CT scanning procedure and consent to participate were taken from the participants.

Results

72 patients, 42 males and 28 females - mean age 41y (range 16-87y) participated in this study. The Body Mass Index (BMI) was 22.0, range 20.1-25.0. CARE kV and CARE Dose4D were switched off in non-contrast (NC) scans whereas both were turned on in contrast-enhanced (CE) scans. The mean value of Computed Tomography Dose Index (CTDI), Dose Length Product (DLP) and Effective Dose (ED) before and after switching on both CARE kV and CARE Dose4D were 58.19±0.35 and 39.67±3.59 milli-Gray (mGy), 946.67 and 652.58 mGy-cm, and 1.98 and 1.36 milli-Sievert (mSv) respectively.

Table 1 Distribution of patient data and dose parameters

Particulars	*Mean*	*Standard deviation*	*Minimum Value*	*Maximum Value*
Age	41	18.7	16	87
Body Mads index	22.0	1.9	18.1	25.0
CARE kV and CARE Dose4D are switched off in non-contrast (NC) scans[MOO1]				
CTDI NC/Off Mode	58.19	0.35	57.32	58.96
DLP NC	946.67	57.50	828.80	1169.48
ED NC	1.98	0.11	1.74	2.40
CARE kV and CARE Dose4D are switched off in contrast enhanced (CE)scans				
CTDI CE/On Mode	39.67	3.59	27.97	46.70
DLP CE	652.58	62.86	512.50	807.70
ED CE	1.36	0.13	1.07	1.69

*CTDI Computed Tomography Dose Index; DLP Dose Length Product; ED Effective Dose.

The mean value of Computed Tomography Dose Index (CTDI) was 58.19±0.35 before CARE kV and CARE Dose4D were not utilized, whereas CTDI decreased to 39.67±3.59 when both were applied during scanning. CTDI decreased by 31.82%. Similarly, the mean value of Dose Length Product (DLP) before and after switching both CARE kV and CARE Dose 4D were 946.67 and 652.58 mGy-cm respectively. DLP was reduced by 31.06% after applying these two techniques. Effective Dose (ED) was also decreased by 0.62 mSv (31.31%). The decrease in CTDI, DLP and ED are further elaborated in Figure 1, 2 and 3 respectively.

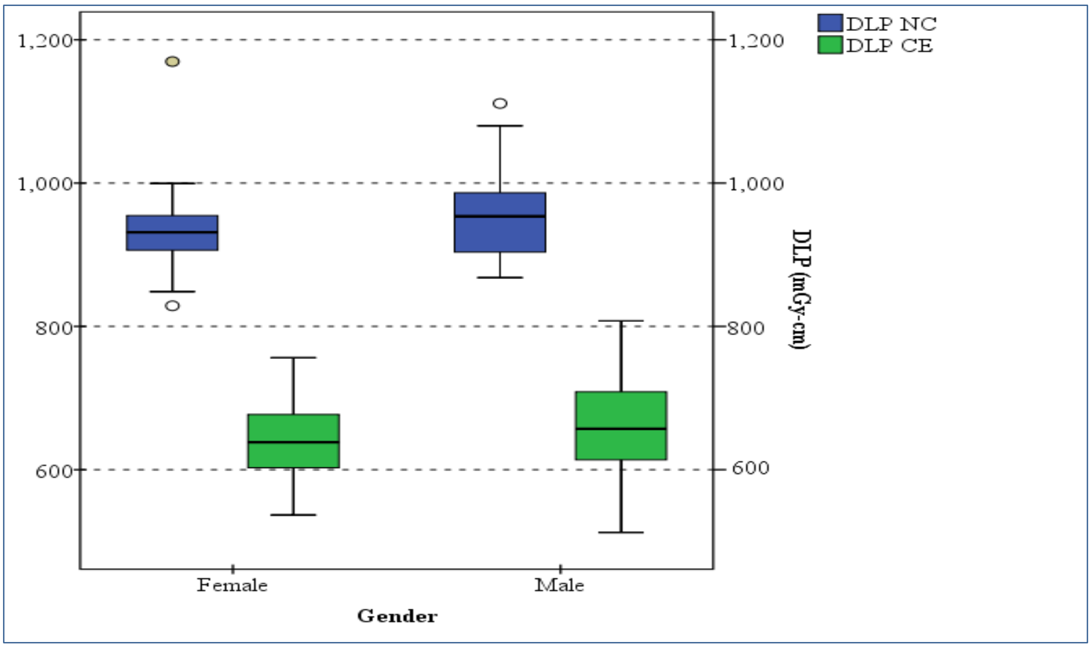

Figure 1. Box Whisker Plot showing CTDI (mGy) in female and male patients. In non-contrast (NC) scans, both CARE kV and CARE Dose 4D were not applied whereas in contrast-enhanced (CE) scans, both were used. Small circles are the outlier values that could not be represented by the boxes.

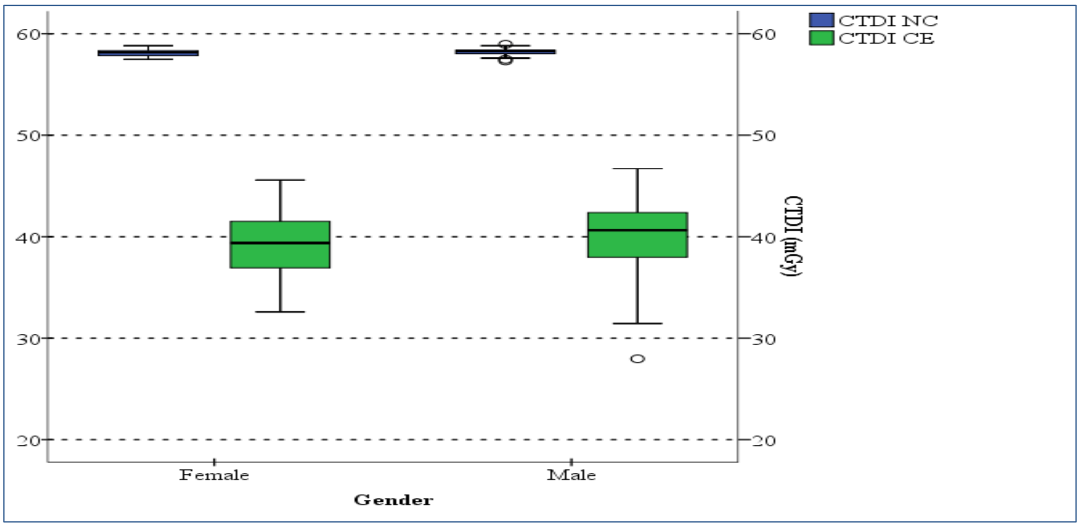

Figure 2. Box Whisker Plot showing DLP (mGy-cm) of female and male patients. In non-contrast (NC) scans, both CARE kV and CARE Dose4D were not applied, whereas in contrast-enhanced (CE) scans, both were used. Small circles are the outlier values that could not represented by boxes.

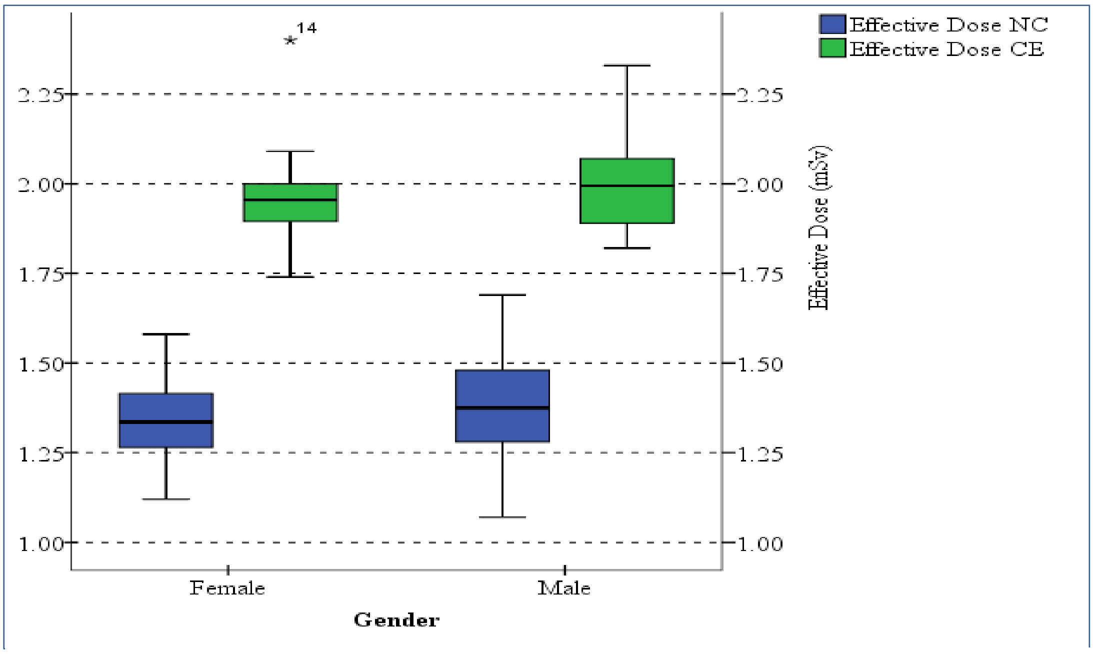

Figure 3. Box Whisker Plot showing effective dose (mSv). In non-contrast (NC) scans, both CARE kV and CARE Dose4D were not utilized whereas in contrast enhanced (CE) scans, both were used. Star represents an outlier value.

Milliampere-seconds (mAs) was however greater when CARE kV and CARE Dose4D were turned on. The mAs value was fixed at 410 mAs before they were applied whereas the mean value of mAs was 459.34±39.89, (maximum 536 and minimum 321) when both were employed.

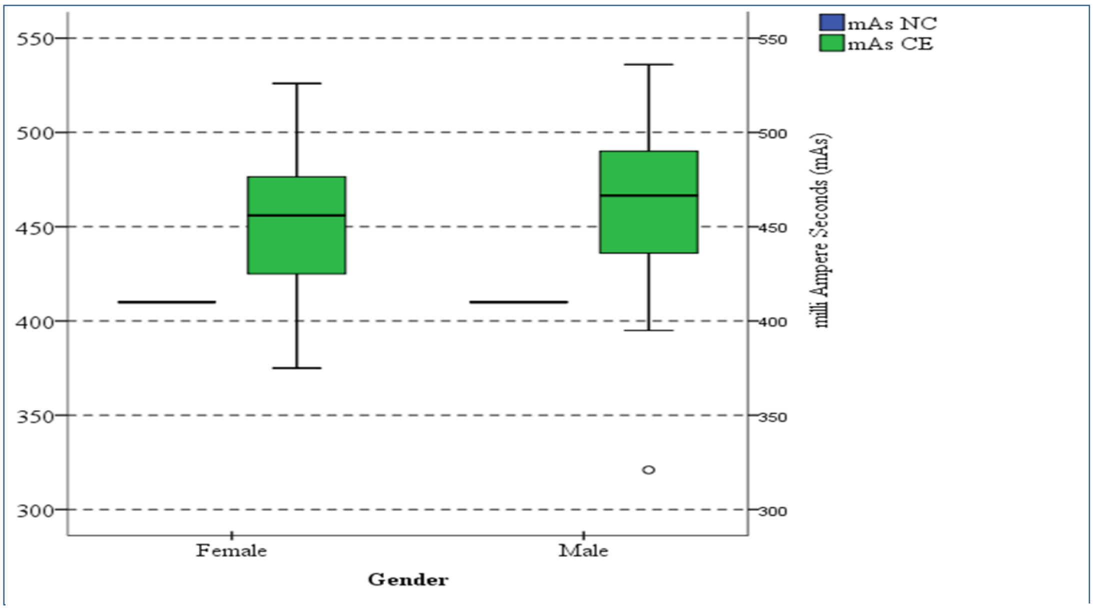

Figure 4. Box Whisker Plot, showing milli-Ampere second (mAs) for female and male patients. In non-contrast (NC) scans, CARE kV and CARE Dose4D were not applied, whereas in contrast-enhanced (CE) scans, both were used.

The tube potential was decreased to 100 kVp from standard 120 kVp when CARE kV was applied, accounting for 16.6% decrease in kilo-voltage by employing it alone.

Discussion

The present hospital-based study was performed to highlight the dose optimization in CT scan of brain by utilizing CARE kV and CARE Dose4D that could significantly reduce radiation dose to the patients. The results showed a huge drop in radiation dose when these two technologies were utilized. CT Dose Index (CTDI), Dose Length Product (DLP) and Effective Dose(ED) were decreased 31%. However, the image quality was reported to be excellent by a radiologist, 5+ years of experience. Song *et.al.*[10] also performed similar study in contrast-enhanced liver CT. In their study, they used CARE kV and Sinogram-Affirmed Iterative Reconstruction (SAFIRE). They concluded the mean dose reduction of 47%. Gnannt *et.al.*[11] also used automated tube potential in 40 testicular cancer patients undergoing contrast-enhanced arterio-venous chest and portal-venous abdominal CT. They reported 12% decrease in radiation dose compared to conventional 120 kVp protocol. Greess *et.al.*[8] showed the usage of online tube current modulation in CT scan of children led to radiation dose reduction from 10-60%, depending on child's geometry and anatomical regions, preserving the image quality constant. Yu *et.al.*[12] also demonstrated the application of CARE kV in CT Angiography and abdominopelvic CT examinations. They stated mean dose reduction of 36% in angiography scans and of 25% in abdominopelvic scans. Tube potential was decreased from 120 kVp to either 80 or 100 kVp. Froemming *et.al.*[13] also performed CT urography with kV selection and tube current modulation in excretory phase and they concluded that the combination of automated kV selection, tube current modulation and iterative method of image reconstruction results in radiation dose reduction without ruining image quality. Wang *et.al.*[14] depicted that BMI dependent tube voltage/current selection in cardiac CT angiographic investigations provided consistent image quality and helped in radiation dose reduction. Lee *et.al.*[15] stated that compared to tube current modulation alone, both tube voltage and tube current modulation reduce radiation dose maintaining good image quality in contrast-enhanced liver CT. Graser *et.al.*[16] confirmed that combined x-, y- and z-axis tube current modulation leads to a significant reduction of radiation exposure in CT colonography without loss of image quality. Considering other scholar's literature papers, our study also supported their results. CT scan operators should be aware of dose reduction techniques of tube potential and tube current modulation methods and implement them into daily scanning practice. CARE kV and CARE Dose 4D are the dose modulation techniques incorporated in Siemens CT scanners.
There are similar types of protocols in other manufacturers as well. They are named differently but they work very much similarly for dose optimization while scanning patients in CT scan. This study was performed in brain. Doses could be reduced in CT examinations of other parts, such as chest, abdomen, orbit, extremities etc. We recommend similar type of studies performed in other body parts as well.

Conclusion

In summary, CARE kV and CARE Dose4D can reduce radiation dose dramatically in CT scan of brain without loss of image quality. Utilization of these techniques is strongly recommended for dose optimization in other parts of body. In this study, CTDI, DLP and effective dose were all decreased by approximately 31%.

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