

Initial investigation of dose calculation on intra-irradiation cone-beam CT images

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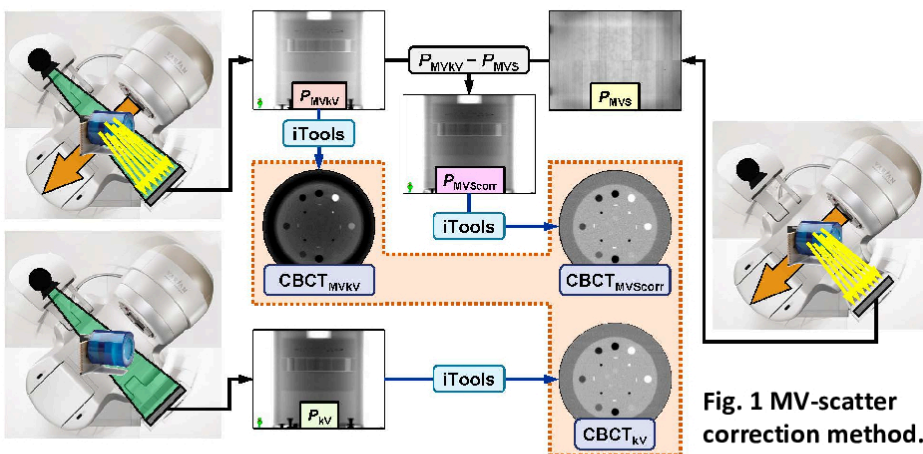


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INTRODUCTION/AIM

- CBCT images acquired during volumetric-modulated arc therapy (VMAT) delivery (**intra-irradiation CBCT images**) can be utilized for calculating dose-of-the-day.
- However, the image quality was degraded by MV scatter X-rays (MV-scatters).
- The aim of this study was **to evaluate VMAT dose calculation accuracy on the intra-irradiation CBCT images with and without MV-scatter correction.**

METHOD



MV-scatter correction method

- To correct MV-scatter on the concurrent kilovoltage (kV) projections (P_{MVkV}), the projections consist of MV-scatter only (P_{MVS}) were acquired under the same MV beam parameters and gantry angles, and then subtracted from the P_{MVkV} ($P_{MVScorr}$).

Phantom

- Anthropomorphic torso phantom (Kyoto Kagaku, CTU-41)

VMAT plans and kV imaging parameters

- Ten 1-full-arc (10 MV FFF) plans; AcurosXB (v15.6)
- 125 kVp, 1.2 mAs, Half-fan

Reconstruction algorithms (in iTools software)

- Feldkamp-Davis-Kress (FDK), iCBCT (Medium)

CBCT images

- $CBCT_{kV}$: reference normal CBCT image
- $CBCT_{MVkV}$: MV-scatter-contaminated CBCT image
- $CBCT_{MVScorr}$: MV-scatter-corrected CBCT image (FDK recon.)
- $CBCT_{MVScorr+i(M)}$: MV-scatter-corrected CBCT image (iCBCT recon.)

Evaluation index

- 95% isodose volume on $CBCT_{kV}$ was converted to the structure and recognized as "pseudo-target" (copied to the other images).
- DVH and 3D Gamma analysis (1%/1 mm/threshold 5%)**

RESULTS

CBCT-number-relative electron density (CBCT-RED) conversion table

- Multi-energy phantom (Model 1467, Gammex RMI; Fig. 2) was scanned by normal (=not concurrent) CBCT imaging (125 kVp, 1.2 mAs, Half-fan)
- CBCT-RED table was created from the reconstructed CBCT image, and applied to $CBCT_{kV}$, $CBCT_{MVkV}$, $CBCT_{MVScorr}$ and $CBCT_{MVScorr+i(M)}$.

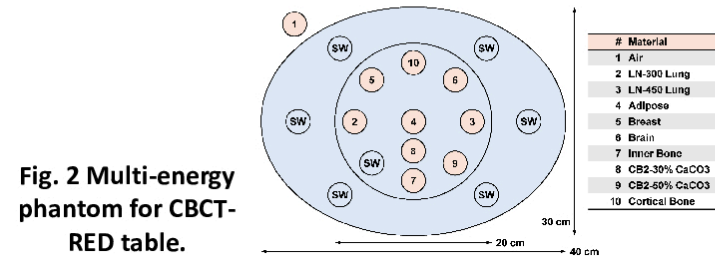


Fig. 2 Multi-energy phantom for CBCT-RED table.



Fig. 3 (a) CTU-41 phantom, (b) experimental setup.

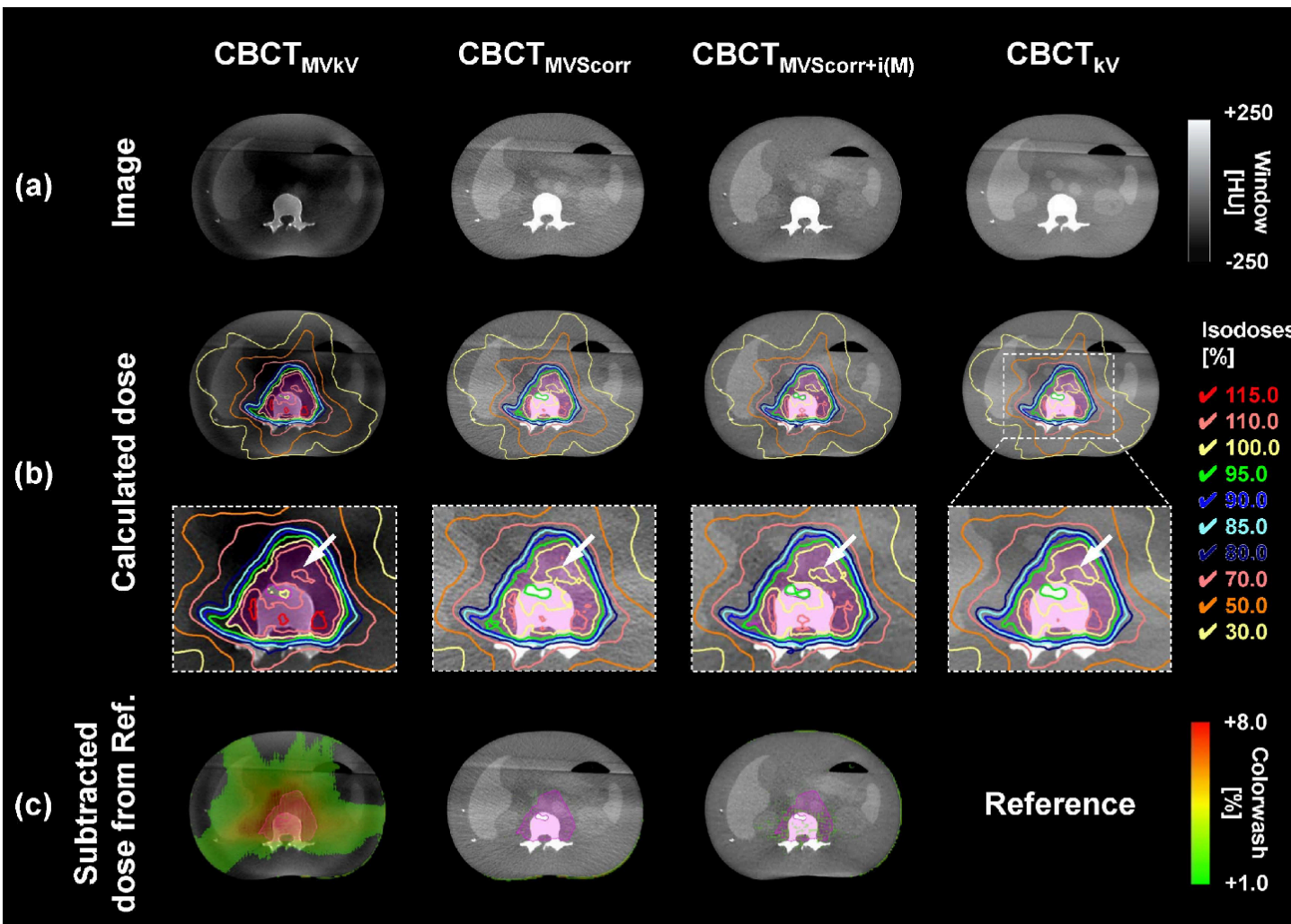


Fig. 4 (a) CBCT images, (b) calculated doses, and (c) subtracted doses from the reference one for Plan #6.

RESULTS (CONTINUED)

Dose calc. on intra-irradiation CBCT image

Fig. 4: CBCT images, calculated doses, and subtracted doses from the reference one for Plan #6

- In visual evaluation, the cupping artifact on $CBCT_{MVkV}$ was corrected on $CBCT_{MVScorr}$ and $CBCT_{MVScorr+i(M)}$ which are comparable with $CBCT_{kV}$.
- The region above 80% doses expanded and 115% dose region was appeared on $CBCT_{MVkV}$.

Fig. 5: (a) DVH for Plan #6 and (b) differences of DVH indices between $CBCT_{MVkV}$, $CBCT_{MVScorr}$ or $CBCT_{MVScorr+i(M)}$ and $CBCT_{kV}$. All differences of indices for $CBCT_{MVkV}$ were significantly larger than those for the others which were within 1.0% ($p < 0.01$)

- Calculated doses on $CBCT_{MVkV}$ were systematically elevated.

Table 1: Median 3D GPRs

- Doses on $CBCT_{MVScorr}$ or $CBCT_{MVScorr+i(M)}$ showed good agreement with that on $CBCT_{kV}$.

Table 1 Median 3D gamma pass rate (GPR) of each CBCT image compared to $CBCT_{kV}$.

CBCT type	Pass rate (1%/1 mm)
$CBCT_{MVkV}$	70.4% (range: 46.0 – 82.3%)
$CBCT_{MVScorr}$	99.5% (range: 99.3 – 99.9%)
$CBCT_{MVScorr+i(M)}$	98.2% (range: 96.0 – 98.8%)

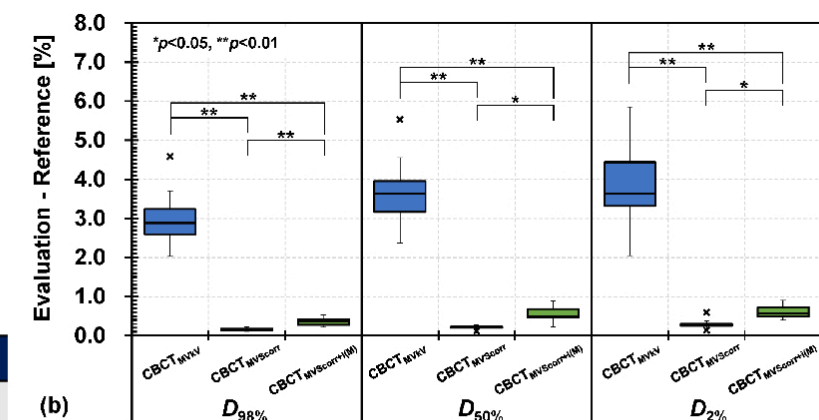
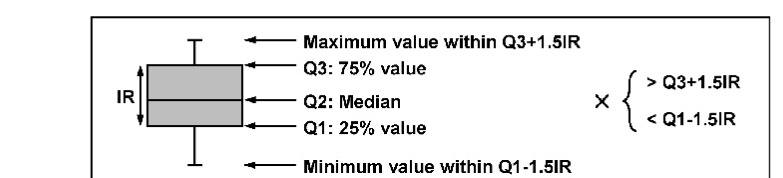
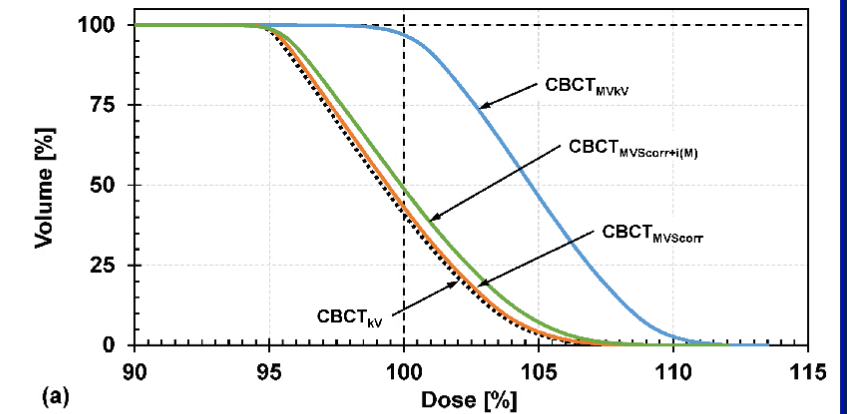


Fig. 5 (a) Dose-volume histograms for Plan #6 and (b) differences of dose-volume indices.

CONCLUSIONS

- To our best knowledge, this study was the initial investigation of the intra-irradiation CBCT images for dose calculation.
- The MV-scatters on the intra-irradiation CBCT images from VMAT deliveries were corrected by subtracting MV-scatter maps and the re-calculated doses on the images showed good agreements.
- Dose calculation on the intra-irradiation CBCT can be utilized for adaptive radiotherapy.

ACKNOWLEDGEMENTS

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