Supplementary material

Corrected CBCT

The following figures show the DVH metrics of each individual patient group, when dose is calculated on the corrCBCT images.

Figure S.1: corrCBCT dose difference metrics for breast patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. A purple asterisk indicates that the metrics are NOT equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, LN denotes periclavicular lymph nodes, while IMN denotes internal mammary nodes. Breast denotes both breast and chest wall targets.
Figure S.2: corrCBCT dose difference metrics for the lung patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. A purple asterisk indicates that the metrics are NOT equivalent in the TOST-P test (equivalence bounds are shown as grey area). For targets, p denotes tumors in the lung, while n denotes nodal targets. Lungs are the sum of both lungs, excluding all GTVs. Spinal Cord D\textsubscript{98\%} is not shown, as doses were less than the threshold of 0.1 Gy.
Figure S.3: corrCBCT dose difference metrics for the CT-based prostate patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the prostate, p_SV the seminal vesicles, and n denotes the elective lymph node target.

Figure S.4: corrCBCT dose difference metrics for the MRCAT-based prostate patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the prostate, p_SV the seminal vesicles, and n denotes the elective lymph node target.
<table>
<thead>
<tr>
<th>Absolute dose difference [Gy]</th>
<th>D98%</th>
<th>D50%</th>
<th>D2%</th>
<th>Bladder</th>
<th>Bowel</th>
<th>Femoral Heads</th>
<th>Penile Bulb</th>
<th>Sacrum</th>
<th>Vagina</th>
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<td>Absolute dose difference [%]</td>
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Figure S.5: corrCBCT dose difference metrics for the CT-based anal/rectal patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the tumor and positive lymph nodes, while n denotes the elective lymph node target.

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Figure S.6: corrCBCT dose difference metrics for the MRCAT-based anal/rectal patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the tumor and positive lymph nodes, while n denotes the elective lymph node target.
Virtual CT

The following figures show the DVH metrics of each individual patient group, when dose is calculated on the vCT images.

Figure S.7: vCT dose difference metrics for breast patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. A purple asterisk indicates that the metrics are NOT equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, LN denotes periclavicular lymph nodes, while IMN denotes internal mammary nodes. Breast denotes both breast and chest wall targets.
Figure S.8: vCT dose difference metrics for the lung patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. A purple asterisk indicates that the metrics are NOT equivalent in the TOST-P test (equivalence bounds are shown as grey area). For targets, p denotes tumors in the lung, while n denotes nodal targets. Lungs are the sum of both lungs, excluding all GTVs. Spinal Cord D\(_{98}\)% is not shown, as doses were less than the threshold of 0.1 Gy.
Figure S.9: vCT dose difference metrics for the CT-based prostate patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the prostate, pSV the seminal vesicles, and n denotes the elective lymph node target.

Figure S.10: vCT dose difference metrics for the MRCAT-based prostate patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the prostate, pSV the seminal vesicles, and n denotes the elective lymph node target.
Figure S.11: vCT dose difference metrics for the CT-based anal/rectal patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the tumor and positive lymph nodes, while n denotes the elective lymph node target. Note one outlier outside the plot axis range (indicated by a marker and label).
Figure S.12: vCT dose difference metrics for the MRCAT-based anal/rectal patients. The top row shows the absolute dose difference, while the bottom row shows relative difference. All metrics are equivalent in the TOST-P test (equivalence bounds are shown as grey area). For the target ROIs, p denotes the tumor and positive lymph nodes, while n denotes the elective lymph node target.
DVH plots

Worst-case examples for lung, prostate and anal/rectal patients are shown to illustrate the challenges when performing CBCT-based dose calculations.

Figure S.13: Example images (a-c) and DVH curves of a lung patient, with dose deviations to target ROIs. In the DVH curves, solid lines represent the refCT dose distributions, while dotted and dashed lines show the corrCBCT and vCT doses, respectively. Target doses are slightly overestimated for GTV and CTV in the CBCT-based dose calculations, and the DVH curve for lungs somewhat different in shape. ROI colors in the DVH plot matches ROI colors in the example images. Window/Level is set to 1600/-600 HU for all images.

The lung example (Figure S.13) shows a case where anatomical changes had resulted in re-scanning and re-planning being initiated. The lack of CTV and PTV coverage is evident from the DVH, but the differences between the refCT and CBCT-based doses remains fairly limited in spite of this being an example of the largest differences to the DVH.

The prostate example (Figure S.14) shows only limited variation from the refCT to the corrCBCT and vCT based DVH curves, in spite of being a worst case example. Slight underestimation of the target doses is observed with the corrCBCT method, but well within the ±1% equivalence bound for $D_{98\%}$, $D_{50\%}$, and $D_{2\%}$.

In the anal example (Figure S.15), a large tumor is found immediately under the skin, with the original CTV delineated to the external contour of the patient. As treatment progressed, the tumor regressed as observed in the example slices. This case was particularly difficult for the vCT algorithm, on which the body outline of the patient did not fully correspond to the outline on the refCT image. The anatomical ground truth is likely to be found in the corrCBCT image for this patient. The large difference in $D_{98\%}$ of the PTV would likely be removed if the PTV was cropped to within the patient external contour.
Figure S.14: Example images (a-c) and DVH curves of a CT-based prostate patient, with slight dose deviations to target ROIs. In the DVH curves, solid lines represent the refCT dose distributions, while dotted and dashed lines show the corrCBCT and vCT doses, respectively. While only small differences are observed in the DVH, this patient represents one of the largest differences found for the prostate patients. ROI colors in the DVH plot matches ROI colors in the example images. Window/Level is set to 350/40 HU for all images.
Figure S.15: Example images (a-c) and DVH curves of a CT-based anal patient, with dose deviations to target ROIs. In the DVH curves, solid lines represent the refCT dose distributions, while dotted and dashed lines show the corrCBCT and vCT doses, respectively. Target dose deviations are observed in the vCT-based dose, which is explained by differences in images at the posterior edge of the target/patient. ROI colors in the DVH plot matches ROI colors in the example images. Window/Level is set to 350/40 HU for all images.