Evaluation of the Contour 24 Coil for an MR-Only Radiotherapy Workflow

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Introduction

The Contour 24 receive coil is flexible, lightweight, and should not influence the patient's body contour during scanning. This makes it an attractive radiotherapy imaging solution compared to the rigid setups offered by a rigid coil and bridge frame.

In this study, we compare the image quality and geometry parameters calculated from MR images of an ACR MR phantom acquired using the Body 18 coil (a traditional rigid design) and the Contour 24 coil. The aim was to investigate any difference in performance of the two coil solutions. Following this, the effect of the Contour 24 coil on the patient's body contour was evaluated using MR images acquired as part of a project evaluating the synthetic CT (sCT) Dixon sequence available on the 1.5T MAGNETOM Sola RT Pro Edition, an MRI RT simulator (Siemens Healthineers, Erlangen, Germany). The Contour 24 coil was placed anteriorly over the pelvic region of eight prostate patients for the full scan protocol, which lasted approximately 20 minutes (Fig. 1).

The prostate patients included in this study also received a planning CT scan, which was used to generate the treatment plan and for dose calculation. In order to compare the body contour generated for the planning CT with the body contour generated for the sCT, the CT image data was used as the gold standard. The aim was to confirm that the Contour 24 coil had no effect on the sCT body contour by assessing its similarity to the planning CT body contour, and to demonstrate that the sCT can be used reliably for dose calculation in an MR-only workflow.

Methods

The image quality and geometry results from the weekly QA using the ACR MR phantom were studied retrospectively. A different receive coil is tested each week, providing 10

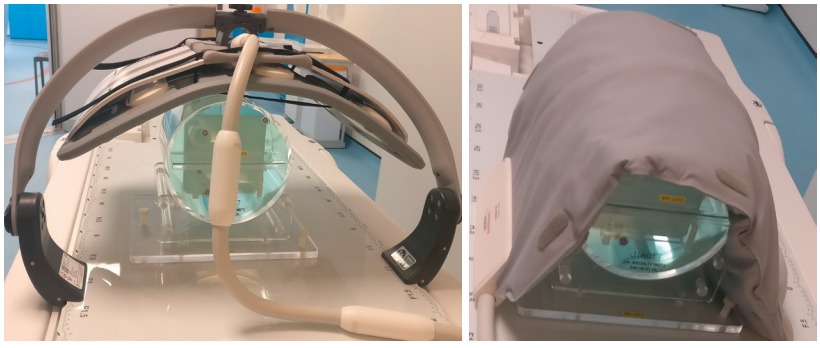
1 The Contour 24 coil is placed anteriorly over the pelvic region of the patient. The coil is flexible enough to rest comfortably over the patient like a blanket.

sets of results for the Body 18 coil and 16 sets of results for the Contour 24 coil. The experimental setups used in the QA are provided in Figure 2 and show the coil bridge that is used in conjunction with the Body 18 coil. T1- and T2-weighted axial images of the phantom are acquired according to the protocol outlined in the ACR Quality Control Manual using either the Body 18 or the Contour 24 coil and the Spine Coil located within the scanner bed. The image quality and geometry results were calculated using MR AutoQA Plus software (version 1.7.6.7, QA Benchmark LLC, Maryland, USA) on both T1- and T2-weighted images. They include high-contrast spatial resolution, slice thickness accuracy, slice position accuracy, geometric accuracy, image intensity uniformity, ghosting, signal-to-noise ratio (SNR), and low-contrast detectability. The average and standard deviation of each of these results were calculated and used to compare the performance of the coils.
The similarity between the body contours generated for an sCT and a planning CT acquired for eight prostate patients was evaluated. The body contour was generated using the Search Body tool in Eclipse's Contouring Workspace (Varian, a Siemens Healthineers Company, Palo Alto, CA, USA) with a lower threshold of -350 HU to detect the body's outline. Default post-processing parameters were used (Number of Largest Parts = 1, Disconnect Radius = 0.2 cm, Fill All Cavities = 2-D All, Close Openings Radius = 0.2 cm, Smoothing Level = 3). The planning CT body contour was copied onto the sCT dataset via a rigid registration between the planning CT and the underlying Dixon images used to generate the sCT. Both planning CT and sCT body contours were cropped superiorly and inferiorly, encompassing the region from the bottom of the ischial tuberosities to L5 (see Fig. 3). This corresponds to the area of interest over which the Contour 24 coil is placed during imaging.

The Boolean Operator tool was used to create an additional structure that included the volume common to both planning CT and sCT body contours. The volumes of the common structure, cropped CT body, and cropped sCT body contours were recorded and the Dice similarity coefficient (DSC) was calculated as follows:

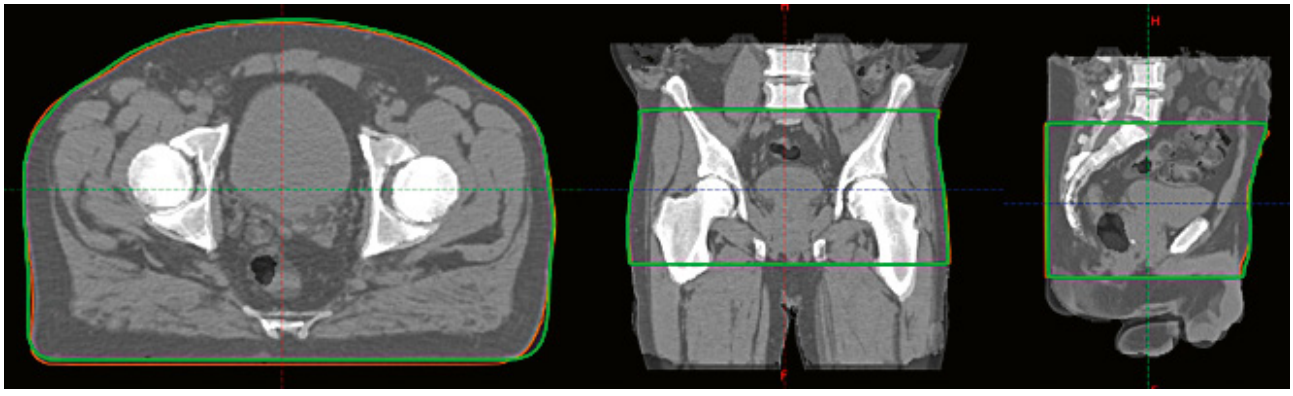
$$DSC = \frac{(2 \times Volume_{COMMON}\ [cm^3])}{(Volume_{CT\ BODY}\ [cm^3] + Volumes_{CT\ BODY}\ [cm^3])}$$

Mean and standard deviation DSC values were also calculated, and any outliers were investigated.



Body 18 + Spine Coil setup | Contour 24 + Spine Coil setup

2 Setups for the weekly QA with the ACR MR phantom for the Body 18 and Contour 24 coils. A bridge frame is used with the Body 18 coil to hold the coil over the phantom. Images are also acquired using the Spine Coil located along the length of the scanner bed.



3 Body contours generated by the planning CT (orange) and the sCT (green) were cropped to relevant patient anatomy prior to DSC calculation.

QA result	Expected result	T1-weighted images		T2-weighted images	
		Contour 24 coil	Body 18 coil	Contour 24 coil	Body 18 coil
High-contrast spatial resolution	*≤ 1 mm*	1.0 mm	1.0 mm	1.0 mm	1.0 mm
Slice thickness accuracy	*5 ± 0.7 mm*	5.0 mm	4.9 mm	4.4 mm	4.4 mm
Slice position accuracy	*0 ± 5 mm*	0.5 mm	0.3 mm	0.5 mm	0.3 mm
Geometric accuracy	*190 ± 2 mm*	190.5 mm	190.2 mm	190.6 mm	190.2 mm
Image intensity uniformity	*≥ 87.5%*	96.7%	95.4%	96.6%	96.6%
Ghosting	*≤ 0.025*	0.001	0.004	0.002	0.005
SNR	*Baseline*	341	237	301	200
Low-contrast detectability	*Spokes* *T1 ≥ 30* *T2 ≥ 25*	34	34	33	34

Table 1: Average QA results calculated from T1 and T2 data acquired with the Contour 24 and Body 18 coils.

Results

The average QA results calculated from the trending data of weekly QA are presented in Table 1. Most of the image-quality and geometry results from T1- and T2-weighted images acquired with the Body 18 and Contour 24 coils were similar, with slice thickness accuracy, slice position accuracy, geometric accuracy, image intensity uniformity, and ghosting showing improvement with the Contour 24 coil. The Contour 24 SNR was 44% (T1w) and 51% (T2w) higher than the Body 18 SNR.

DSC values calculated for each patient are listed in Table 2. The mean DSC calculated across all eight subjects was 0.979 with a standard deviation of 0.006. The difference in volume between the sCT BODY and CT BODY structures ranged from -5.57% (larger sCT BODY) to +1.12% (larger sCT BODY).

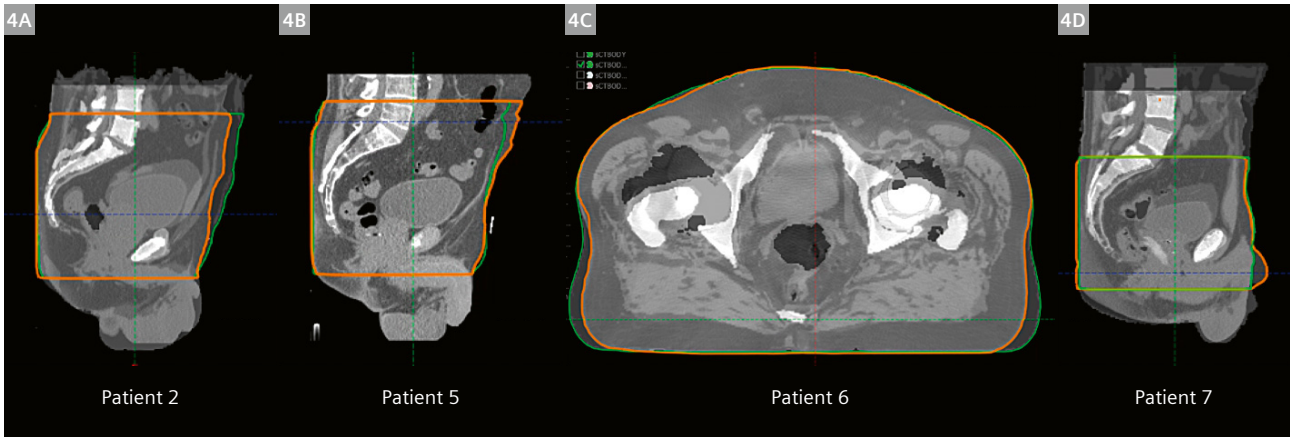
Patient Number	DSC
1	0.984
2	0.968*
3	0.982
4	0.986
5	0.977*
6	0.981*
7	0.978*
8	0.985

Table 2: Dice similarity coefficients calculated for each patient.

Discussion

Both the Body 18 and Contour 24 coils have similar image quality and geometry performance when assessed using the ACR MR phantom. The image SNR is higher in the images acquired with the Contour 24 coil, probably because of its closer proximity to the phantom. The lower SNR achieved with the Body 18 coil demonstrates the downside of having to use a bridge frame to avoid altering the patient's body contour in a rigid coil setup.

The lower DSC scores for patients 2, 5, 6, and 7 were investigated and found to be related to anatomical and positioning variations between the planning CT and sCT. Patient 2 had significant bladder distension in the sCT, causing anterior extension of the sCT body contour. Patient 5 had anteriorly located gas in the planning CT, which also caused anterior expansion of the upper abdomen and subsequently the CT body contour. Patient 6 had different



4 Patients 2, 5, 6, and 7 had lower DSC scores that were related to anatomical and positioning variations between the planning CT and sCT: **(4A)** bladder distension in sCT led to anterior extension of the sCT body contour; (**4B)** anterior gas led to anterior expansion of the upper abdomen and subsequently the CT body contour; **(4C)** this patient with bilateral hip prostheses had different posterior fat distribution between CT and MRI scans, which led to a larger sCT body contour in the posterior area of interest for the analysis; **(4D)** different anatomical positioning between CT and MRI scans led to an extended CT body contour to the inferior of the region of interest in this study.

posterior fat distribution between planning CT and MRI scans, which caused a larger sCT body contour in the posterior area of interest for the analysis. Patient 7 was positioned slightly differently between planning CT and MRI scans, causing an extended CT body contour toward the inferior of the region of interest for this study.

Patient 6 also had bilateral hip prostheses, and the images show that image quality degradation is localized to the implant and has no significant effect on the patient's overall anatomy/body contour.

Conclusion

The Contour 24 coil provided superior SNR results when calculated from T1- and T2-weighted phantom images. This is an advantage of being able to place the flexible coil directly onto the object being imaged. Better SNR is an advantage in MR imaging and provides higher quality images for contouring, sCT generation, and functional imaging in MR-only radiotherapy workflows.

Using DSC as a quantitative measure of similarity, a comparison between planning CT-generated body contours and sCT-generated body contours showed that the Contour 24 coil does not significantly alter the patient contour during MRI scanning. In addition to being a lightweight and flexible receive coil that can conform to the patient's anatomy to provide higher image SNR, the Contour 24 coil is an ideal solution for MRI scanning in radiotherapy imaging applications. The results of this study provide confidence that sCT geometry accurately reflects that of the planning CT geometry within the clinical region of interest and could be used for dose calculation in MR-only planning.

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