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Implementation of magnetic resonance imaging in the radiotherapy workflow

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Abstract

Computed tomography (CT) has traditionally been the standard imaging modality used for radiotherapy treatment planning (RTP). However, the immense soft tissue contrast of magnetic resonance (MR) imaging makes it desirable to use MR imaging as an aid to improve the accuracy of tumor and normal tissue delineations for radiotherapy (RT). In CT imaging, there is a direct link between the voxel intensity and the electron density data, which is necessary for RT dose calculation. MR does not possess this link, so MR images have been fused with CT images for RTP. However, this type of image fusion introduces a set of errors. To base the RTP on MR alone, the electron density information has to be generated from the MR data through the creation of a pseudo-CT (pCT). Another issue related to MR-based RT is the presence of geometric distortions in MR imaging. Geometric distortions can decrease the geometric accuracy of the MR images, which would affect the accuracy of the RTP.

In this thesis, a Siemens Biograph mMR scanner (Siemens Healthineers) was set up for MR-based RT. RT specific MR-equipment was purchased, installed and tested. This equipment included a laser bridge, a flat table overlay, torso and head/neck coil holders, MriPlanner software (Spectronic Medical AB) for atlas-based pCT generation and the GRADE phantom (Spectronic Medical AB) for measurements of the geometric distortion. After the work with this thesis, all the RT-specific equipment is installed and tested, and the scanner is ready for MR-based RT.

Through retrospective RTP of ten prostate cancer patients, the dosimetric accuracy of the atlas-based pCTs generated through the MriPlanner software was compared to bulk density-based pCTs generated in the RTP system RayStation (RaySearch Laboratories AB). The original planning CT was used as the reference for dosimetric accuracy. For these ten patients, the atlas-based pCTs was found to be of higher dosimetric accuracy compared to the bulk density-based pCTs.

The geometric distortion was measured over a 44-day period through imaging and analysis of the GRADE phantom. The measurements of the geometric distortion over time showed some variations which suggest that monitoring the geometric distortion is necessary to ensure a sufficient geometric accuracy. Further studies are recommended for both the GRADE phantom measurements and the pCT generation, both to get more familiar with the software and to ensure a sufficient accuracy before clinical applications.

Sammendrag

Tradisjonelt er computertomografi (CT) den mest brukte bildemodaliteten for planlegging av strålebehandling. Magnetisk resonansavbildning (MR) gir langt bedre bløtvevskontrast enn CT, noe som gjør det attraktivt å bruke MR til å identifisere både tumor og normalvev. CT-avbildning innehar en direkte link mellom signalintensiteten og elektrontettheten. Å kjenne denne elektrontettheten er nødvendig for beregning av stråledose. I MR finnes det ingen slik link, så MR-bilder blir gjerne fusjonert med CT-bilder for bruk i stråleterapiplanlegging. Denne typen fusjon introduserer et sett med feilkilder til planleggingen, og det kan derfor være hensiktsmessig å basere planleggingen på MR-bildene alene. Dermed er det nødvendig å generere elektrontetthetsinformasjon basert på MR-bildene, gjennom å lage en såkalt pseudo-CT (pCT). En annen problemstilling relatert til MR-basert stråleterapi er risikoen for geometriske forvrengninger i bildene. Denne typen forvrengninger kan påvirke nøyaktigheten av geometrien i bildene, noe som vil kunne påvirke nøyaktigheten i stråleterapiplanleggingen.

I denne oppgaven har en Siemens Biograph mMR scanner (Siemens Healthineers) blitt klargjort for MR-basert stråleterapi. Stråleterapispesifikt utstyr har blitt kjøpt inn, installert og testet. Dette utstyret inkluderer en laserbro, en flat bordtopp, torso- og hode/nakke-spoleholdere, MriPlanner (Spectronic Medical AB) programvare for dannelse av atlas-basert pCT og GRADE-fantomet (Spectronic Medical AB) for målinger og analyse av geometriske forvrengninger. Etter arbeidet med denne oppgaven er scanneren klargjort for MR-basert stråleterapi.

Gjennom retrospektiv stråleterapiplanlegging av ti pasienter med prostatakreft, ble den dosimetriske nøyaktigheten av atlas-basert pCT sammenlignet med "bulk density"-basert pCT som ble generert i stråleterapiplanleggingssystemet RayStation (RaySearch Laboratories AB). Den originale planleggings-CTen ble brukt som referanse for dosimetrisk nøyaktighet. Atlas-basert pCT ble funnet å være den mest nøyaktige metoden for disse ti pasientene.

Den geometriske forvrengningen ble målt over en periode på 44 dager, gjennom avbildning og analyse av GRADE-fantomet. Målingene viste variasjoner som tyder på at det er nødvendig å overvåke de mulige forvrengningene for å garantere tilstrekkelig nøyaktighet. Videre studier av geometrisk forvrenging og pCT-dannelse bør utføres, både for å bli bedre kjent med programvaren og garantere tilstrekkelig nøyaktighet før MR-basert stråleterapi tas i bruk i klinisk rutine.

Preface

This thesis is submitted as the conclusion of the master's degree program in Applied Physics and Mathematics at the Norwegian University of Science and Technology (NTNU).

I would like to thank my supervisors, Kathrine Røe Redalen and Oddbjørn Sæther, for involving me in such an interesting project and for continuous support and feedback throughout these months. The opportunity to learn through a more hands-on experience with new equipment has been both highly motivating and educational. I would also like to thank phd-student and medical physicist at St. Olavs hospital, Kajsa Fridström, for showing me the works of RayStation and VMAT radiotherapy planning. A thank you to Stina at the RaySearch support team for generating the Phyton script used for beamset transfer, and all the patience and will to solve every problem I encountered in RayStation. A big thank you also goes to Spectronics Medical AB for generating an online access which I used to analyse the phantom measurements and generate atlas-based pseudo-CTs.

Lastly, I would like to thank my family and friends, and all the people I've spent the last years in Trondheim with.

Rørvik, 27.02 2019
Vilde Skorstad Bondø

Contents

Abbreviations

bd-pCT - Bulk density-based pseudo CT
CT - Computed tomography
CTV - Clinical target volume
DE - Dual energy
DSB - Double strand break
DVH - Dose volume histogram
EBRT - External beam radiotherapy
FHL - Femoral head left
FHR - Femoral head right
FOV - Field of view
G_{PE} - Phase encoding gradient
G_{RO} - Readout gradient
G_{SS} - Slice selection gradient
GTV - Gross tumor volume
Gy - Gray
HU - Hounsfield unit
LET - Linear energy transfer
LINAC - Linear accelerator
LQ - Linear quadratic
MLC - Multi leaf collimator
Mp-pCT - MriPlanner-based pseudo CT
MR - Magnetic resonance
OAR - Organ at risk
opCT - Original planning CT
PTV - Planning target volume
pCT - Pseudo-CT
QA - Quality assurance
RF - Radio frequency
ROI - Region of interest
RT - Radiotherapy
RTP - Radiotherapy treatment planning
SDA - Statistical decomposition algorithm
SE - Spin echo
SNR - Signal-to-noise ratio
SSB - Single strand break
TE - Echo time
TR - Repetition time
TSE - Turbo spin echo
T2W - T2-weighted

UTE - Ultrashort echo time
VMAT - Volumetric modulated arc therapy
WE - Water equivalent

1 Introduction

Alongside chemotherapy and surgery, radiotherapy (RT) is a commonly used for cancer treatment. External beam radiotherapy (EBRT) is a non-invasive and well established treatment alternative available for most solid cancers. Extensive treatment planning is performed before the initiation of an EBRT treatment, where the aim is to ensure a sufficient dose delivered to the tumor while minimizing the dose to surrounding normal tissues and possible organs at risk (OARs). Photons are the most common choice for EBRT, although other particles might also be utilized.

Magnetic resonance (MR) imaging is characterized by an immense soft tissue contrast compared to other imaging modalities. The soft tissue contrast leads to increased differentiation between healthy and pathological tissue, and thereby enables a more precise delineation of both the tumor volumes and OARs. Another strength of MR related to RT is the ability to combine different MR sequences to obtain additional contrasts for tumor characterization and thereby more information about tumor per scan. One shortcoming of MR is however the lack of a direct link between the image voxel intensity and the electron density information. The electron density values gives an understanding of the amount of interactions between the photons and the imaged structures. As the dose to a structure is deposited through these interactions, electron density information is vital for the EBRT treatment planning. Computed tomography (CT) possesses this direct link between the voxel intensity and electron density information, and is therefore the standard image modality used for radiotherapy treatment planning (RTP) today. Since CT lacks the soft tissue contrast of MR, the use of MR as a supplement to CT for RT purposes is increasingly popular. Combining MR and CT by performing an image registration is an effective way of obtaining both the electron density information and the improved soft tissue contrast, to increase the accuracy of the tumor and OAR delineations. The image registration does however also introduce a set of errors related to this superpositioning of the images. As these techniques require separate imaging set-ups, the patient has to be moved between the image acquisitions. This movement can often result in errors due to differences in patient positioning and in some cases changes in tumor location due to internal movements such as bladder and rectal filling.

RT dose calculations based solely on MR imaging were first reported around the millennium when MR became a common addition to CT for tumor delineation [1]. RTP based on MR alone, so called MR-only RT, could remove

the systematic errors related to the MR/CT image registration, create a better RTP workflow, decrease the number of scans required per patient and lessen the exposure to ionizing radiation. For MR-only RT, the electron density data is determined based solely on the MR images through creation of synthetic CT images, often also referred to as a pseudo-CT (pCT). There are several approaches to pCT creation, where an atlas-based and a bulk density-based approach are examined in this thesis.

One of the major concerns related to MR-only RT is the presence of geometric distortions in the MR images. Such distortions would affect the geometric accuracy of the images and could result in incorrect geometries of important structures. The geometric distortion can be separated into hardware-related distortion and tissue-related distortion, where the hardware-related distortion is caused by non-linearity of the gradients and inhomogenities in the static magnetic field [2]. The tissue-related distortion is most often caused by magnetic susceptibility effects and the amount of generated distortion can vary depending on the tissues [2]. Normally, the imaged region of interest (ROI) is located at the center of the field of view (FOV) of the MR image, where the effect of the geometric distortion is minimal. The effect of the distortion can normally be further minimized by registration of the MR images to corresponding CT images, where there are no such distortions. However, if the treatment plan is based on MR alone, the FOV of the MR scan is much larger. Since the amount of geometric distortion tends to increase with the distance from the isocenter of the MR scanner, the distortion needs to be corrected for to provide an accurate geometry of the entire patient contour [2]. Any discrepancies in the patient contour could introduce severe errors to the dose calculations and also affect the accuracy of the patient set-up [2]. The amount of geometric distortion should therefore be known and monitored to confidently base the RTP on MR imaging alone.

This master thesis was carried out to set up a pipeline for MR-based RT at St. Olavs hospital. This process includes different aspects, where the specific aims of this thesis was to;

1. Setup an MR scanner with equipment required for MR-based RTP.
2. Compare two methods for pCT generation for prostate cancer and compare the dosimetric accuracy of these methods through retrospective RTP.
3. Study the geometric distortion on the scanner over time through use of the RT-specific GRADE phantom (Spectronic Medical, Sweden).

2 Theory

In this section a brief background into the main theories, techniques and technologies that construct the grounds for this work will be presented.

2.1 External beam radiotherapy

After surgery, RT is the most effective curative treatment for cancer [3]. Around 60% of all RT treatments are given with curative intent, often in combination with surgery and chemotherapy, but RT can also often be an important contribution in palliative cases [3]. Although other particles can also be utilized, photons are the common choice for EBRT today and EBRT using photons is therefore the only treatment form that will be described in this section.

2.1.1 Interactions between photons and biological material

This section is based on "Radiobiology for the radiologist" by Hall and Giaccia [4]. Photons are uncharged particles that are indirectly ionizing, meaning that these particles do not produce chemical or biological damage themselves. A photon creates damage by transferring energy to the material it travels through, by creating fast-moving charged particles. There are different processes in which the energy can be transferred, depending on the initial photon energy. The Compton process dominates at the energy levels utilized in EBRT. In a Compton process an incoming photon interacts with an electron that has a very low binding energy compared to the photon energy, often referred to as a "free" electron. During the interaction, some of the photon energy is transferred to the electron as kinetic energy. The electron is released from the atom and can interact with other atoms, while the photon continues to move with the remaining energy, but in a deflected path. If the remaining photon energy is sufficiently high, the photon can interact with a new electron. The amount of energy that is transferred during each interaction varies, but normally several photons will interact with several atoms when a photon beam is absorbed in tissue.

When any form of radiation is absorbed in a biologic material, there is always a possibility of direct interaction with some critical target in a cell, resulting in biological damage. This form of damage creation is called direct action of radiation, and is the dominating process when the radiation primary consists of particles with a high linear energy transfer (LET). High LET particles are characterized by strong interactions and therefore only travel a

short distance before all their energy is lost. Examples of high LET particles include α-particles and neutrons. Photons are small, uncharged particles and therefore usually create damage through interactions with other atoms or molecules inside a cell. This form of damage creation is called indirect action of radiation, and the interactions are usually between the photons and water molecules. The interactions between radiation and water produces a series of free radicals through a process called radiolysis of water. Free radicals are atoms or molecules containing an unpaired electron in their outer shell, making these atoms/molecules very reactive. The free radicals are therefore able to create biological damage through interactions with other structures inside the cell. Direct and indirect action of radiation is illustrated in Figure 1. A simplified overview of radiolysis of water can be presented as:

Incident photon
↓
Fast electron (e^-)
↓
Free radical
↓
Biological effects

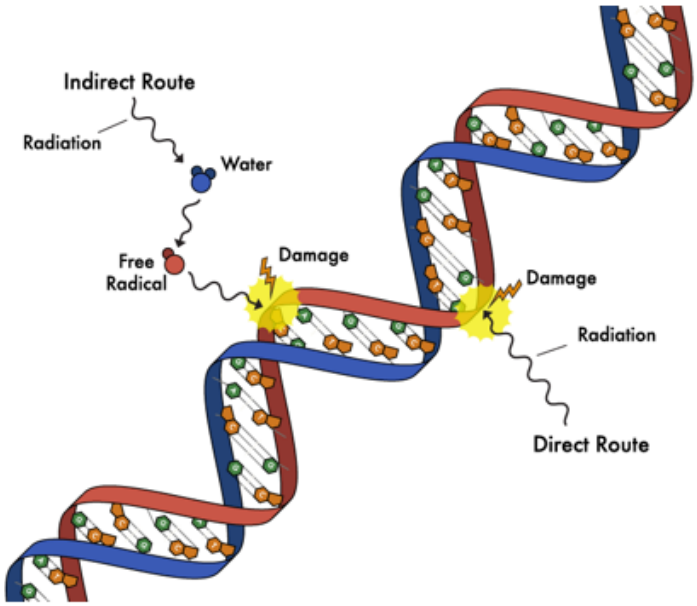


Figure 1: This Figure illustrates direct and indirect action of radiation, where DNA is irradiated. A small illustration of the generation of a free radical through the radiolysis of water is also included. Figure from [5].

The goal of RT is to kill the cancerous cells directly or to inactivate the cell and remove its capability to divide. There are four main outcomes when ionizing radiation comes in contact with a cell [6]:

1. The radiation can pass through the cell without any interaction, and therefore cause no harm
2. The radiation can interact with the cell, but in a way where the cell can repair itself and no real harm has occurred
3. The radiation can interact with the cell and possibly create a mutation, affecting the cells ability to divide correctly
4. The radiation can cause damage that kills the cell

Exactly how or where the DNA damage has to occur in order to kill the cell is debated, and there are different models describing cell survival. The linear-quadratic (LQ) model, which is a commonly used model, postulates that both strands of a DNA molecule have to be damaged to inactivate the cell. Such double strand breaks (DSBs) can be caused by a single interaction or by two single strand breaks (SSBs) located close enough to one another on opposite DNA strand [5]. DSBs and SSBs are illustrated in Figure 2. The absorbed radiation dose to tissue is measured in Gray (Gy), where 1 Gy $= 1\ \frac{\mathrm{J}}{\mathrm{kg}}$. A radiation dose of 1 Gy produces around $2 \cdot 10^5$ ionizations per irradiated cell, resulting in about 1000 SSBs and 40 DSBs [5].

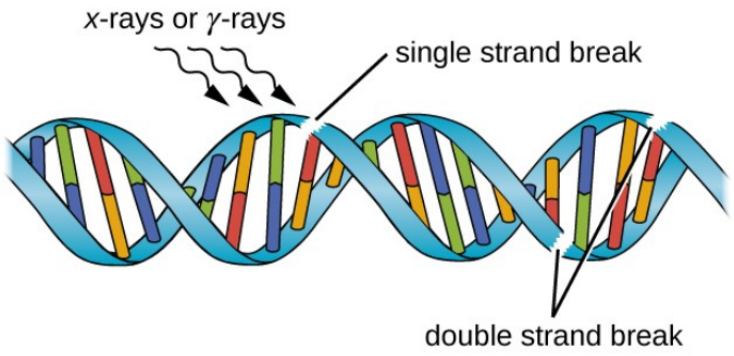


Figure 2: Illustration of a single strand DNA break and a double strand DNA break. The LQ-model postulates that DSBs are necessary to inactivate a cell, but a DSB can also be caused by two SSBs on located close to each other on opposite strands. Figure from [7].

2.1.2 Volumes in radiotherapy

There are three main target volumes in RTP. The first and smallest volume is the gross tumor volume (GTV) which describes the position and extent of the tumor that can be seen, imaged or examined by touch. The second volume is the clinical target volume (CTV) that contains the GTV plus a margin for sub-clinical disease spread which cannot be completely imaged. The last treatment volume is the planning target volume (PTV) which contains the CTV plus a margin that accounts for uncertainties in planning or treatment delivery. These are illustrated in Figure 3. There might also be multiple CTVs in cases where the cancer has spread to other structures such as lymph nodes [3].

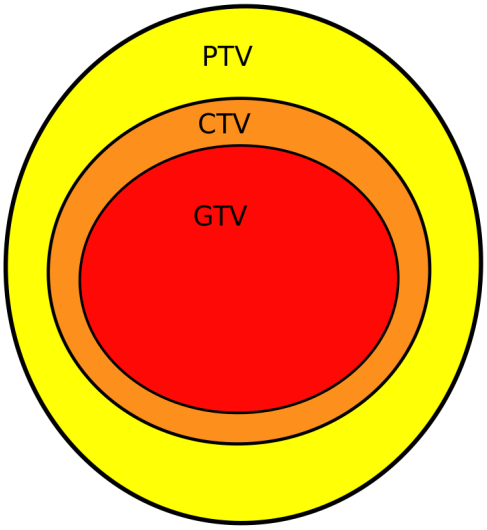


Figure 3: Illustration of the three main target volumes in RT, the gross tumor volume (GTV), the clinical target volume (CTV) and the planning target volume (PTV).

In addition to target volumes, there are also volumes of normal tissue that are important to avoid. These volumes are often referred to as OARs and a detailed delineation of these volumes is necessary to minimize the adverse effects of the treatment and thereby maximize the organ function and the quality of life post treatment. It is possible to add a margin accounting for systematic and random errors around the OARs, similar to the PTV around the CTV, but the resulting volume will often be large and can result in dilemmas regarding the dose delivered to the tumor volumes versus the organ [3]. Usually this additional margin is only applied in cases where the tissue is very sensitive to radiation, where a small loss of tissue due to

radiation damage results in severe damage to the patient. The spinal cord is an example of a tissue where the inclusion of such an extra margin could prove beneficial [3].

2.1.3 External beam radiotherapy for prostate cancer

The goal of EBRT is to deliver a sufficiently high dose to a defined target in order to destroy the targeted cells and thereby cure the cancer or provide symptom relief in palliative cases. In EBRT used for prostate cancer, a photon beam is created by a linear accelerator (LINAC) and applied from outside the patient. To minimize the damage to the tissue surrounding the tumor, the photon beam energy is optimized to maximize the energy deposit at the depth of the tumor. The beam is also reshaped to mimic the shape of the target volume before the irradiation of the patient. The reshaping occurs as the photon beam enters the multileaf collimator (MLC), a structure consisting of many thin metal leafs that absorb radiation. All leafs in the MLC can be moved individually, depending on the shape of the target volume. The MLC and a reshaped beam is illustrated in Figure 4 and 5. Despite these efforts there will still be interactions between the beam and healthy tissue, especially with the tissue located above and below the tumor, as seen in a straight line from the LINAC.

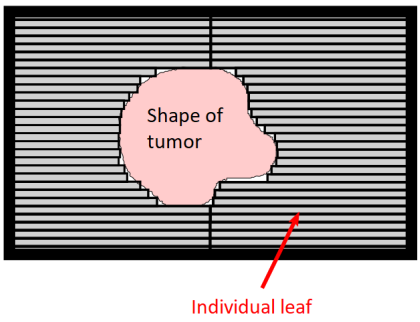


Figure 4: A simple illustration of the MLC as seen from below. The individual leafs can move independently of each other to reshape the photon beam to match the shape of the target.

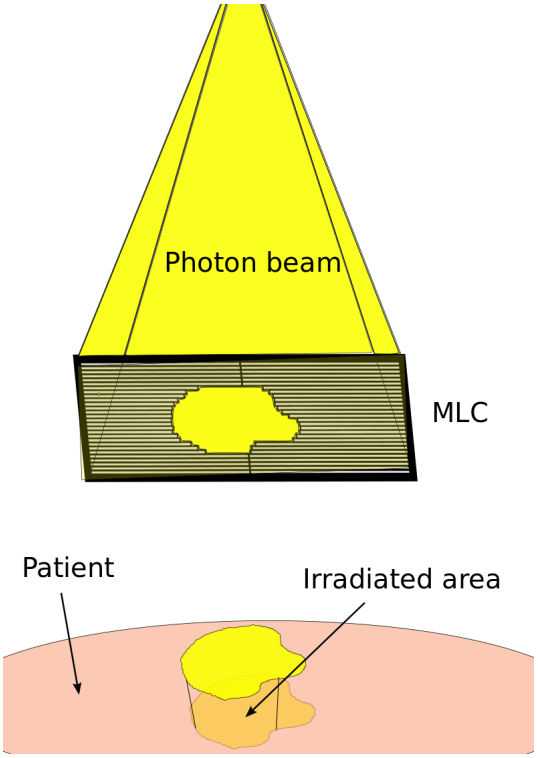


Figure 5: Illustration of the effect of the MLC, where the photon beam is shaped to match the shape of the tumor volume. The outside casing of the LINAC, other components of it and effects like photon scattering in air and tissue are not included in this illustration, but are present in real life.

Traditionally, the EBRT treatment of prostate cancer offered at Norwegian hospitals consisted of 66-70 Gy total dose given as 2 Gy fractions [8]. With newer techniques offering a more conformal dose distribution and evidence of a stronger dose-response relationship, one has been able to increase the total dose to 78 Gy or more. As prostate cancer cells are known to divide slower than those of many other types of cancer, it is suggested that altering the treatment by decreasing the number of fractions but increasing the dose given per fraction, a so called hypofractionated treatment regime, will result in equal or better treatment response [8]. Multiple studies have shown a significant relation between the total dose given and the development of distant metastasis, and some of these studies included total doses larger than 82 Gy [8]. Side effects related to EBRT treatment of prostate cancer include both acute and chronic reactions to the radiation in surrounding normal tissues including the urinary bladder, the rectum and the hips. The risk of such side effects increase with the radiation dose and the size of the treatment volume [8]. With the increased dose levels, the accuracy of the treatment de-

livery becomes even more crucial for sparing normal tissue. To spare normal tissue, techniques for more precise ROI delineation combined with minimizing the uncertainties related to organ movement and patient positioning, are becoming more important than ever.

2.1.4 Volumetric modulated arc therapy

Volumetric modulated arc therapy (VMAT) is a newer treatment technique where the radiation beam rotates around the patient while simultaneously irradiating the patient. The aim is to deliver a conformal prescription dose to the target while minimizing the dose to normal tissues. VMAT generally spares a higher amount of normal tissue compared to older conventional treatments, which commonly use two or more fields applied from specific angles. This sparing of normal tissue is achieved by modulating the photon beam intensities through the MLC positions, gantry speeds and dose rates simultaneously at selected control points along the rotation arcs [9]. Figure 6 shows a VMAT treatment plan and a conventional four field treatment plan side by side. The rapid modulation of the photon beam can however increase the uncertainties in the mechanical operation of the LINAC, resulting in differences in dose distribution between the planned and the delivered treatment [9]. To ensure that the LINAC is able to deliver the treatment as planned, quality assurance (QA) is performed before the start of any VMAT treatment in the clinic.

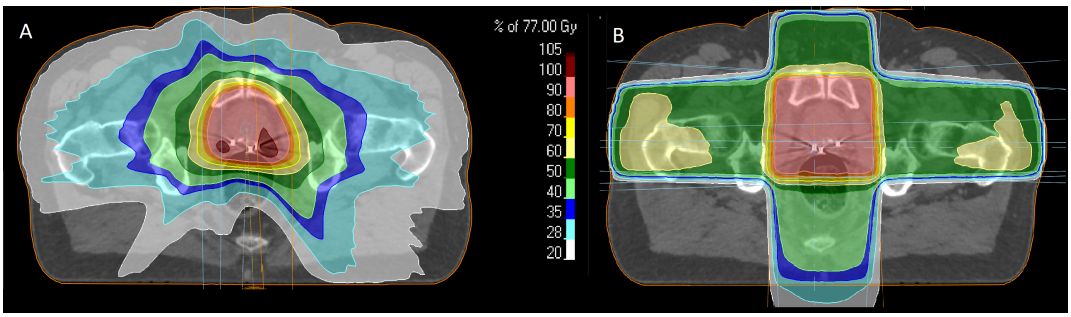


Figure 6: A VMAT treatment plan (A) and a conventional four field treatment plan (B) illustrated on the same CT image from one patient included in this thesis. In A there is a large area receiving 20% of the total dose (white area) compared to B. In B the 40% and 50%-isodoses (two shades of green) covers large areas. In A, the sparing important normal tissues, such as the rectum and the bladder, can be accomplished while also delivering a sufficient dose to the tumor. The treatment in B cannot spare the bladder and the rectum to the same extent.

2.2 Computed tomography (CT)

Only a brief explanation of CT imaging will be provided in this thesis, with emphasis on characteristics relevant in EBRT treatment planning.

CT imaging is based on the same principle as x-ray imaging, where a beam of photons is directed towards the anatomical area of interest. Different tissues and structures can be separated based on their distinct electron density which is revealed through the difference in attenuation of the photon beam. The degree of photon attenuation depends on the thickness, density and atomic number of the structure, where an increase in any of these variables increases the numbers of particles available or photon interaction. This is illustrated in Figure 7. As a result, dense structures such as bone and metals show a higher degree of attenuation compared to less dense substances such as air.

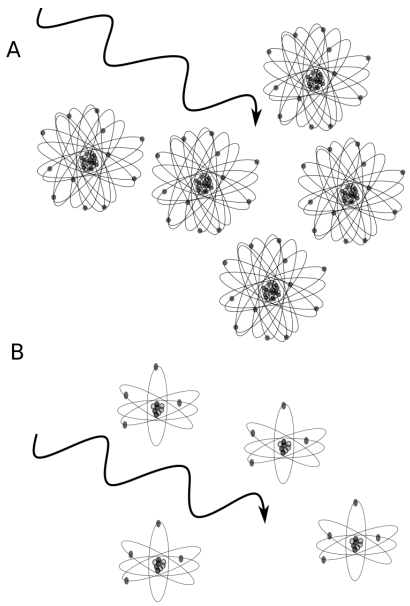


Figure 7: The probability of photon interaction increases with the density, atomic number and thickness of the substance. This Figure illustrates that the probability of photon interactions are higher in a material of high density and atomic number (A) compared to a material of lower density and atomic number (B).

Each voxel in a CT image is assigned a Hounsfield unit (HU) based on the signal intensity of the voxel. HUs are universal, dimentionless quantities which describes the attenuation of the photon beam in each voxel. The HU

is reflected in the intensity of each voxel, where an increased attenuation results in increased brightness for the voxel. Figure 8 shows a transverse CT image which is typically used for prostate RTP. The HU system is based on the attenuation coefficients of water and air, μ_{water} and μ_{air}, at standard pressure and temperature (1 Atm and 0°C), where the HU of water equals 0 and the HU of air equals -1000. Equation 1 shows the formula used for HU calculation of a material with attenuation coefficient μ. HU values of a few different tissues and structures are included in Table 1.

$$HU = 1000 \cdot \frac{\mu - \mu_{water}}{\mu_{water} - \mu_{air}} \tag{1}$$

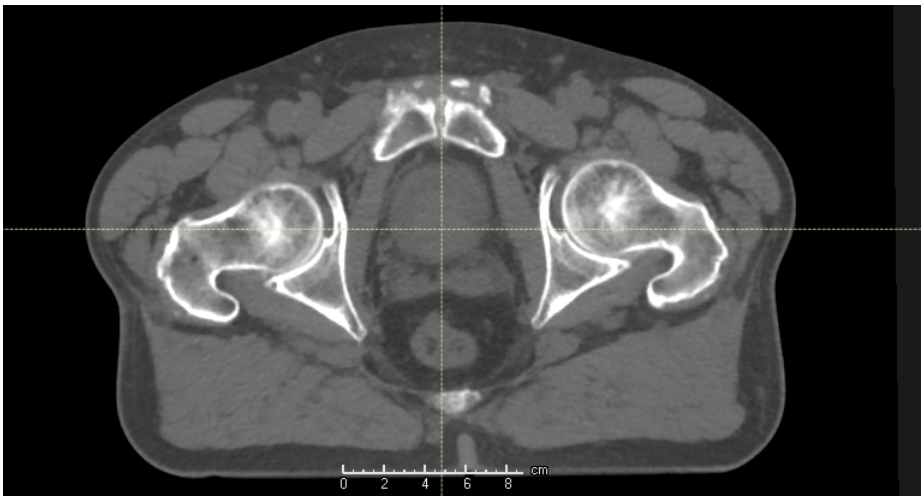


Figure 8: Example of a transverse CT image used for prostate RTP. The femurs are highly visible, as their photon attenuation is very different from the surrounding structures. Soft tissues are however harder to separate based on the CT image alone.

Structure	**HU**
Bone, calcium, metal	$>$ 1000
Grey matter	35
White matter	25
Water	0
Fat	-30 to -70
Air	$<$ -1000

Table 1: Some commonly used HU values. These values are from [10]

2.3 Magnetic resonance (MR) imaging

2.3.1 General introduction to MR

This subsection is adapted from the author's project thesis, which was carried out at NTNU during spring 2018 [11]. The project thesis assessed the use of diffusion-weighted MR for radiotherapy response prediction.

The most common method of diagnosing prostate cancer today is an elevated value of prostate specific antigen that initiates an ultrasound guided biopsy of the prostate. This biopsy is taken from an arbitrary part of the prostate. This method has been found to be less than satisfactory in regards to both sensitivity and specificity by the Norwegian directorate of health [8]. Instead, multiparametric MR, including T2 weighted (T2W), diffusion weighted and contrast enhanced MR imaging, is considered a more accurate way of diagnosing and staging a tumor [8].

Where CT images the attenuation of a photon beam in tissue, MR utilizes a characteristic of nuclei with uneven numbers of protons or neutrons, known as magnetic moment or spin. In medical imaging the hydrogen nucleus (^{1}H) is most commonly used. As there are two hydrogen atoms per water molecule, hydrogen nuclei are abundant particles in human tissues. When interacting with an external magnetic field, B_0, the magnetic moment μ of each hydrogen nucleus will precess at a frequency proportional to the magnetic field strength, known as the Larmor frequency, f:

$$f = \frac{\gamma}{2\pi} B_0$$

where γ is the gyromagnetic ratio, which is a nuclei dependent constant. For ^{1}H $\frac{\gamma}{2\pi}$ equals 43.58 MHz/T. ^{1}H has spin $\frac{1}{2}$, which means that there are two possible energy states of the nuclei when exposed to B_0. These energy levels are often referred to as "spin up" and "spin down", where spin up is aligned with B_0 and is the lower energy state, and spin down is anti-parallel and is the higher energy state. Spin up and spin down protons will cancel each other out, so the only measurable magnetization results from the fact that there is a slightly higher number of spins in the lower energy state (spin up) compared to the spin down state. This difference is known as the net magnetization vector, M, and is the basis of the MR signal.

To create a signal, the net magnetization has to be shifted from the direction of B_0 by an addition of energy known as a radiofrequency (RF)-pulse. The RF pulse is in fact a transient magnetic field, that flips the net magnetization

vector away from B_0, creating an angle between B_0 and M known as the flip angle α.

$$\alpha = \gamma B_1 t_p$$

where γ is the gyromagnetic ratio, B_1 is the strength of the transient magnetic field, and t_p is the duration of the RF pulse.

There are two main relaxation processes in MR. T1 relaxation is the process of recovering longitudinal magnetization, which means moving the net magnetization vector back from the transverse plane to realign with the B_0-field. T2 relaxation is a combination of static and dynamic dephasing effects, resulting in dephasing of the spins in the transverse plane which ultimately will result in signal loss. T2 is defined as the time it takes for approximately 37% ($\frac{1}{e}$) of the signal to be lost to dephasing effects after M entered the transverse plane. T1 and T2 values differ for different tissues, and are part of what creates contrast in MR. As T2 effects are always present, T2 is always $\leq$ T1.

Echo time (TE) and repetition time (TR) are variables that control the so called image weightings in MR. Different image weightings change the brightness of the different tissues and fluids in the images. TE is the time between the application of an initial pulse and the maxima of the following echo. TE controls the amount of T2 relaxation that occurs, where a short TE minimize the T2 effects. TR is the time between the excitation pulses, and determines the amount of longitudinal (T1) relaxation that can occur between the excitations. TE and TR are illustrated in Figure 9. A short TE and short TR results in a T1 weighted image where fat will appear bright while water is dark. A long TE and long TR results in a T2 weighting where water will appear bright and fat darker.

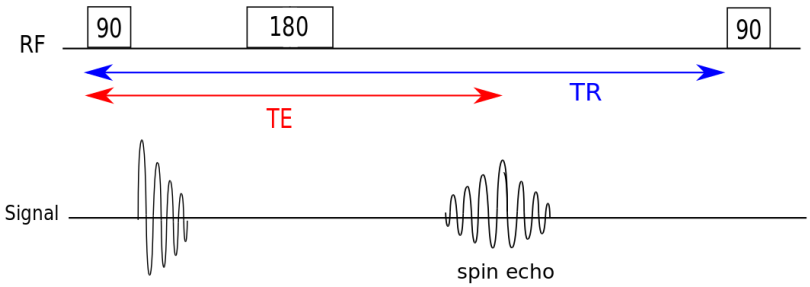


Figure 9: MR sequence showing RF pulses, the resulting signal and the variables TE and TR.

One of the fundamental MR sequences is the spin echo (SE) sequence. This sequence consists of a 90° pulse which after a time TE/2 is followed by a 180° pulse. The initial 90° pulse flips the spins to the transverse plane, where they dephase as a consequence of T2 relaxation. The 180° pulse reverses the static dephasing effects, and produces an echo with a maximum intensity occurring TE/2 after the pulse. After this maximum, the spins will again start to dephase, and the signal will eventually be lost again. The SE sequence is illustrated in Figure 10.

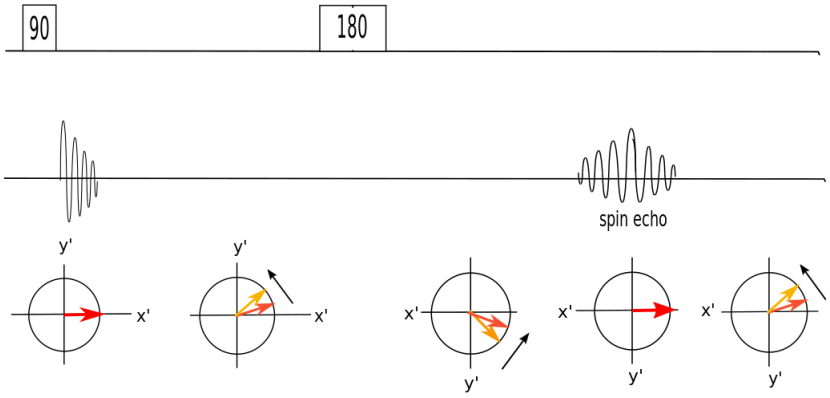


Figure 10: SE sequence showing the dispersion of the spins as a result of T2 relaxation effects and reversal following the 180° pulse, resulting in echo formation.

Spatial localization of the signal is essential for image creation. Gradients are magnetic fields applied along the three dimensions in order to excite spins in selected areas, to spatially locate the MR signal. The combination of gradient fields and B_0 creates a new effective magnetic field B_{eff}.

$$B_{eff} = B_0 + Gz_1$$

Here G is the gradient strength and z_1 is a gradient direction, normally chosen to point in the direction of either x, y or z. B_{eff} makes the magnetic field strength, and thus the Larmor frequency of each spin vary with position along the chosen gradient axis, as illustrated in Figure 11. As spins only react to RF pulses that match their Larmor frequency, the application of an RF pulse along a gradient direction only excite the spins that match the frequency of the RF pulse, while the spins located higher or lower along the gradient will not react. This is the basis of localization in MR.

The application of gradients is repeated along the three axes throughout a sequence. The first gradient to be applied is the slice selection gradient, G_{SS},

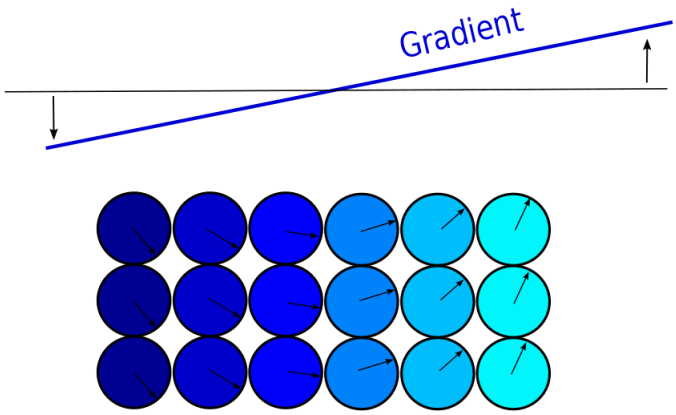


Figure 11: This very simple illustration shows how the application of a gradient (blue line) changes the Larmor frequency of the spins (circles) along the gradient axis. In this illustration, the lighter the color, the higher the frequency.

which is often applied along the z-axis (length of the body). The slice selection gradient selects which spins are excited by the simultaneously applied RF pulse. The second gradient to be applied is the phase encoding gradient, G_{PE}, which is changed for each acquisition in order to create a better resolution in the final image. Last is the readout gradient, G_{RO}, which is applied during the read out phase, where the echo is measured. Figure 12 illustrates the order of the gradients in a spin-echo sequence.

Signal detection in MR is based on induction. If a coil is placed in an alternating magnetic field, a current will be induced in the coil. The rotating magnetic field from the spins, while in the transverse plane, will induce a current in the receiver coils located around the patient. As the signal from the spins changes, the strength of the induced current will also change. It is the strength of this current that is recorded and used as the basis for signal intensity in images. The signal strength is mapped in a 2D system called k-space, where all the different phase encoding steps are placed in the y-direction and the x-direction contains the current strength for different sampling points along an echo. K-space has a bright spot in the middle, and more blurry and dark edges, resulting from the fact that the middle of K-space is where the highest signal intensities are mapped. To create the final image a Fourier transform is applied along both axes of K-space.

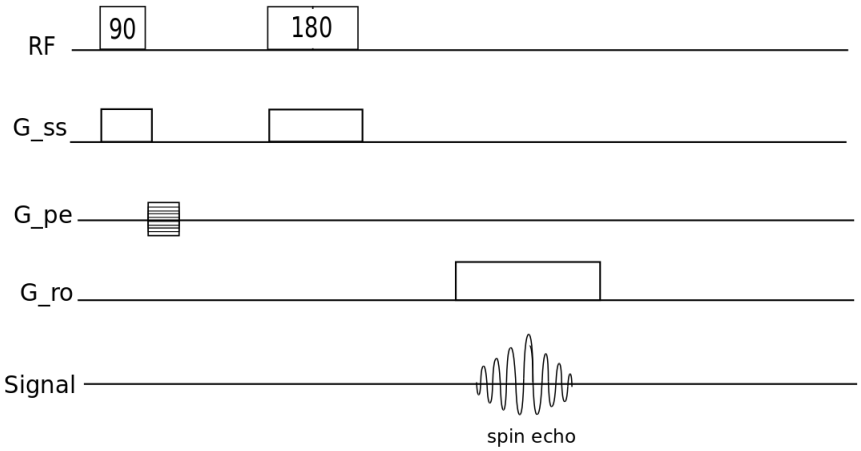


Figure 12: Simplified illustration of the spin echo sequence with the application of gradients. The phase encoding gradient, G_{pe}, is changed for each acquisition.

2.3.2 Geometric distortion

Geometric distortion is one of the main concerns related to MR-only RT. CT is generally regarded the gold standard for geometric accuracy, while the presence of geometric distortion in MR means that the geometric accuracy of the images can be compromised. Precise geometric information is crucial in all image applications where a millimeter accuracy is necessary, such as RT volume delineation and dose calculation [12]. In such applications, CT images are often combined with the MR images in an effort to correct for any geometric distortions and thereby ensure adequate geometric accuracy [12]. Figure 13 shows a simple illustration of geometric distortion, while Figure 14 shows an example of distortion correction in MR.

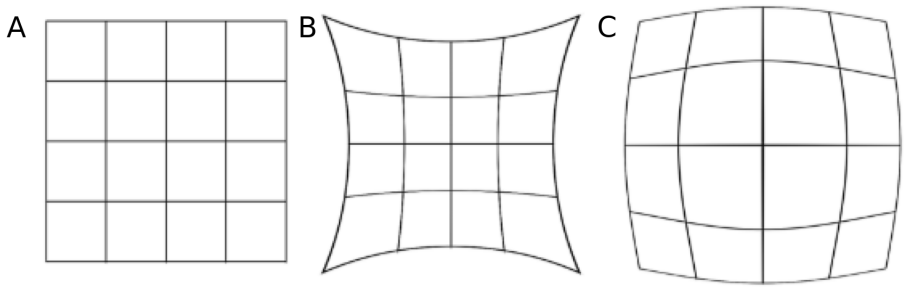


Figure 13: Illustration of two types of geometric distortion. A) is the non-distorted image and B) and C) shows two types of distortion. This illustration is adapted from [13].

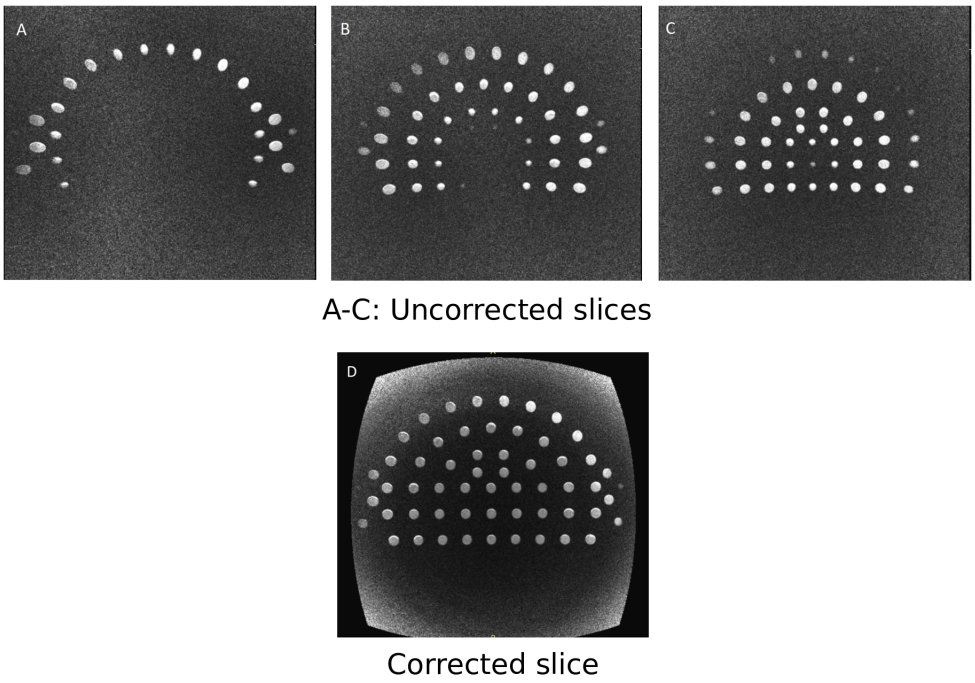


Figure 14: Example of geometric distortion correction in MR. Image A-C show a few of the first slices in an MR scan of a phantom, without distortion correction. Based on images A-C it seems like the outermost layer of spheres is located in front of the others, meaning that the spheres located closest to the center of the MR scanner is closer to the middle of the phantom. Image D shows the distortion corrected version of the images where the deformation of the slice is visible in sides where the image is now curved. From image D it is clear that the different spheres are actually located in the same plane.

Geometric distortions are caused by a variety of factors related to both the MR hardware and the magnetic properties of the patient. As mentioned, MR utilizes magnetic field gradients to generate a relationship between the precession frequency and the location of each spin. This means that any imperfection in the B_0 field or the linearity of the gradients can result in errors related to the localization of each spin for image creation [12]. Figure 15 provides an illustration of gradient nonlinearity. The hardware-related distortions are known and automatic post-processing distortion correction algorithms for gradient nonlinearity is incorporated in the software of all major MR vendors [12]. Although these algorithms can reduce these system-related distortions, the distortions are not completely removed [12, 14].

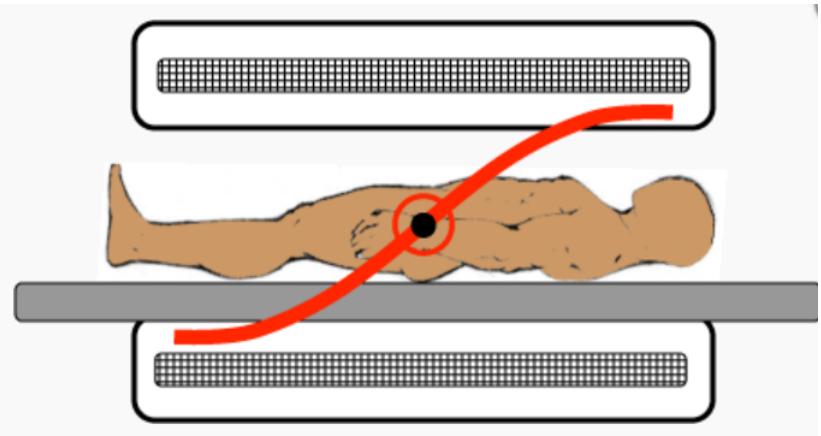


Figure 15: Illustration of gradient nonlinearity. The gradient (red) is not continuously rising, but bends off a bit at both ends. Without sufficient distortion correction, this nonlinearity would result in geometrical errors in the regions where the gradient is flattening out. The isocenter of the scanner is illustrated as a black dot located on the middle of the gradient line. This illustration is courtesy of Allen D. Elster [15].

The patient-related geometric distortion results from susceptibility effects caused by the different magnetic properties of different tissues, chemical shift effects related to slight differences in magnetic shielding in areas of fat and water and the presence of structures filled with air or metal such as implants [12, 14]. As geometric distortions tend to increase in magnitude with the distance from the isocenter of the scanner, the distortions are a concern when imaging large regions such as the pelvic area for RTP. The geometric accuracy of an MR scan has to be controlled and found acceptable before MR-only RT can be offered to the patient.

2.3.3 Radiotherapy-specific MR requirements

There is shift in focus when MR is used for RTP compared to the regular use as a diagnostic tool. When using MR for RTP, the patient has already been diagnosed and the focus of the imaging is then to determine the extent and location of the tumor in relation to other structures [16].

MR images used for RTP should be acquired with the patient in the exact treatment position, including any immobilization devices that are used during treatment [17]. The MR environment is not compatible with all types of immobilization devices, so as the technology moves towards more dedicated MR-RT systems, there is a substantial amount of MR safe devices being released [17]. The inclusion of immobilization devices may increase the distance between the patient and the receiver coils. Coil bridges are also needed to avoid any direct contact between the coils and the patient, as such contact would result in anatomical displacements that are incompatible with RTP [17]. The addition of coil bridges might further increase the distance between the patient and the receiver coils. Such an increased distance results in a decreased signal to noise ratio (SNR) and thereby a decreased image quality [18]. The SNR can be improved through an increase in acquisition time, but generally MR sessions are already quite time consuming and an increased acquisition time is usually not desirable.

The addition of a flat table overlay is another RT-specific MR requirement. The flat overlay replicates the surface of the patient table from a LINAC or CT and is also needed to place certain RT positioning aids. Standard MR tables are slightly curved, which somewhat shifts the patient positioning and introduces uncertainties in MR/CT registration or treatment delivery if the treatment plan was based on MR imaging alone. An example of the positioning shift between a curved MR and flat CT patient table is shown in Figure 16.

Even in the case of CT-based treatment positions suited for replication inside an MR scanner, maintaining such a position over a period of time will usually be demanding for the patient [17]. As MR examinations are usually much longer than CT examinations, this can prove to be a significant issue [17]. The duration of MR scans can also cause problems as MR is very sensitive to motion, so the best approach might be to use a limited and prioritized set of MR sequences to limit the scan time.

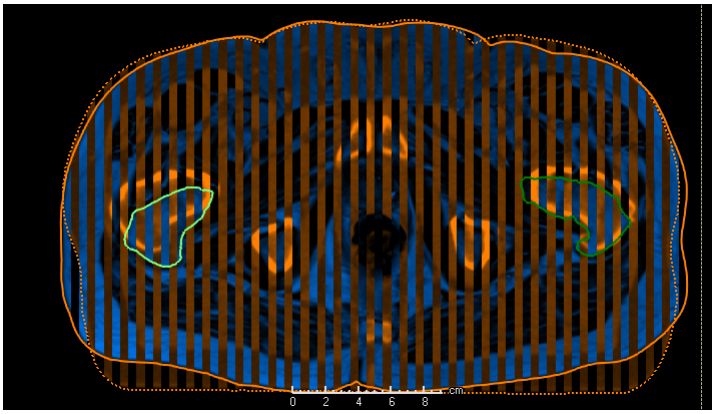


Figure 16: Comparison of an MR (blue) and a CT (orange) image of the same patient illustrating the difference in positioning between a curved patient table (MR) and a flat patient table (CT). The continuous line marks the external contour of the MR, while the dashed orange line marks the external contour from the CT. The two green contours marks the femoral heads delineated on the MR, while the same bones are visible on the CT in a light shade of orange.

An RT laser positioning system, often in the form of a laser bridge, also has to be installed to further aid in the positioning of the patient. The lasers generate a basis for patient positioning, as the reference lasers are aligned with skin markers on the patient. Such lasers-based patient positioning is already the standard at treatment facilities. The laser bridge is used to provide the same references for patient positioning for both the MR imaging and the treatment delivery, in an effort to obtain the same patient geometry and positioning at both locations.

Generally, the phantoms used for MR QA are not optimized for measurements of distortion in large volumes. As the geometric distortion tends to increase with the distance from the isocenter, and an accurate delineation of the external patient contour is important for RTP, having a phantom suited for QA measurements of larger volumes is key [16]. Thus, the addition of a larger phantom built for RT can therefore be expedient to study the geometric distortion present in MR imaging for RTP.

2.3.4 Pseudo-CT

As previously mentioned, MR lacks the direct connection between signal intensity and electron density information. Electron density information is crucial in EBRT treatment planning, as the interaction between the photon beam and the different tissues will alter the dose delivered to a tumor. In an effort to derive electron density information from MR it is common to generate pCTs. There are two main approaches to pCT generation that will be mentioned in this thesis, these are bulk density-based and atlas-based approaches, respectively.

The bulk density assignment approach is perhaps the most straight forward approach to pCT generation. The pCT is generated through segmentation of the MR into distinctive structures such as air, bones and soft tissues, and then assigning each structure a HU number. Generation of bulk density based pCTs (bd-pCTs) is usually a manual process, as the T2 relaxation of different tissues can be similar and therefore makes an automatic segmentation based on image intensity very difficult [19]. For instance, the T2 relaxation time of spins in cortical bone is very short (in the range of 0.5-2 ms [20]) which generates a very low signal. Because of its low hydrogen concentration, air more or less only introduces noise, which means that it can be very hard to separate air and cortical bone based on the signal intensity alone [19]. In an attempt to receive a higher signal from the solid structures and thereby differentiate between air and bone, the ultrashort echo time (UTE) sequence has been generated. UTE is a specialized MR sequence where TE is extremely short in order to receive a higher signal from structures such as bone. The utilization of UTE does however introduce an extra MR sequence and thereby increases the total scan time per patient [19].

Atlas-based pCTs are generated through utilization of image data from other patients that underwent both MR and CT scans. The image data generates an atlas, which consists of one or more sets of MR and CT images where the MR and the CT are registered to one another [19]. The atlas can be based on CT images from a single patient or images from multiple patients superpositioned into the same coordinates. To generate the pCT, the MR image of the patient has to be matched to MR image(s) of the atlas patient(s). A deformation is generated after this matching, which describes how the MR images from the atlas needs to be altered in order to best match the MR of the patient of interest. Since the MR of each atlas patient is registered to the CT from the same patient, the CT can be shaped according to the deformation generated through the MR matching. The atlas-based pCT is

then generated through a transfer of the HU values from the deformed atlas CT to the MR of the patient. One of the major advantages of the atlas-based method is that the pCT generation can be automated through the use of algorithms. However, any atypical shape such as surgical implants or missing tissue could cause problems for automatic matching. There are different methods for generation of the HU values of the pCT. In the case of multiple atlas patients, the pCT intensity, μ, of a voxel at location x_0 can for instance be assigned the mean of all the atlas patient CT image intensities in the corresponding position:

$$\mu(x_0) = \frac{1}{N_a} \sum_{i=1}^{N_a} y_i(x_0) \tag{2}$$

where N_a is the number of patient CTs included, and y_i is the intensity of the CT intensity of the atlas patient [19].

This section is based on [21]. For this thesis, the atlas-based method used for pCT generation is based on the statistical decomposition algorithm (SDA). The SDA first applies an automated segmentation algorithm which through machine learning is able to recognize certain structures in the MR image. After this, the patient's MR is registered to all atlas MRs and the algorithm generates the deformation. From this deformation multiple candidate pCTs are generated, based on the deformed atlas CTs. The HU values for the final pCT are generated through a voxel-by-voxel calculation of the weighted median HU value from all the candidate pCTs

$$G(\beta) = \sum_{i=1}^{N} W_i |c_i - \beta| \tag{3}$$

where the weighted median constitutes the value β which minimizes G(β) for a set of candidate pCTs c_1, c_2, ..., c_N and a set of weights W_1, W_2, ..., W_N. The weights are also calculated through machine learning, where the algorithm promotes the HU values of the candidate pCTs which most closely match the patient MR image.

3 Methods and materials

3.1 Equipment for MR-based radiotherapy

A Siemens Biograph mMR PET/MR scanner (Siemens Healthineers, Erlangen, Germany) was chosen to be the first scanner prepared for MR-only RT at St. Olavs hospital. This scanner has a magnetic field strength of 3 T, a patient bore size of 60 cm, and is capable of an MR FOV of 50 cm. Some specialized equipment is required for to set the MR scanner up for MR-only RT. The following equipment was purchased to enable MR-only RT on this scanner:

1. DORADOnova MR3T laser bridge (LAP GmbH Laser Applikationen, Lueneburg, Germany), moving laser system
2. Medibord flat overlay (Medibord Ltd, Nottingham, UK), thickness 20 mm
3. Torso and a head/neck coil holders made specifically for the Siemens Biograph mMR and the Mediboard overlay
4. MriPlanner software (Spectronic Medical AB, Helsingborg, Sweden) for atlas-based pCT generation
5. GRADE phantom (Spectronic Medical AB, Helsingborg, Sweden) for geometric distortion QA

Figure 17 shows the mentioned equipment, except the GRADE phantom, installed at the Siemens Biograph mMR scanner at St. Olavs hospital.

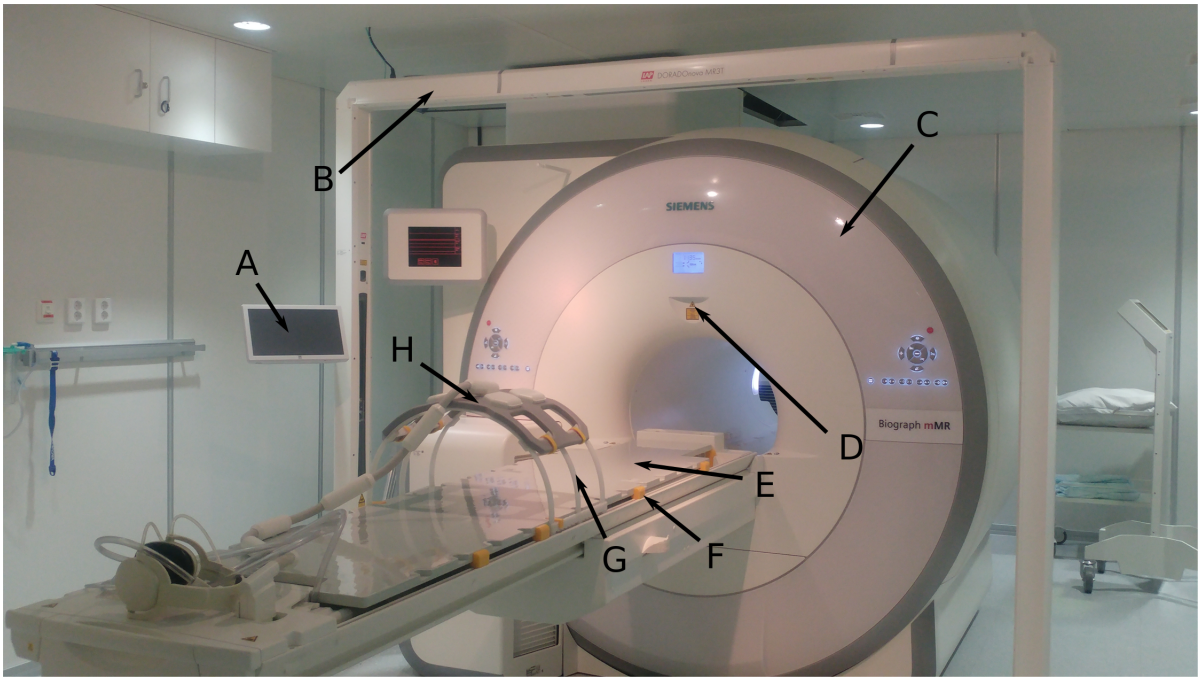


Figure 17: Picture of the Siemens Biograph mMR scanner with the equipment needed for MR-based RT installed. A) Tablet used to control the laser bridge, B) laser bridge, C) Siemens Biograph mMR scanner, D) scanner isocenter-location laser, E) Mediboard flat overlay, F) blocks used to secure the flat overlay on top of the standard curved patient table, G) torso coil holder, H) MR receiver coil placed on coil holder.

3.2 Patient selection

The patient group consisted of 10 prostate cancer patients. All patients included in this thesis were originally treated with a four field RT treatment, and therefore had ROIs delineated on the original planning CT (opCT). In addition to the CT images each patient also had a set of T2W MR images which were utilized for RTP in this thesis. The use of both CT and MR led to the exclusion of patients with large differences in bladder and/or rectal filling between these scans. The difference in filling resulted in a displacement of the prostate and/or alterations in the distance to surrounding ROIs between the MR and CT. As the RT beam set was transferred to the opCT to generate a dose comparison with the pCT, such a large shift in patient geometry or ROI location would make this comparison difficult. Figure 18 shows an example of a patient that was excluded due to a large difference in rectal filling between the MR and CT scan.

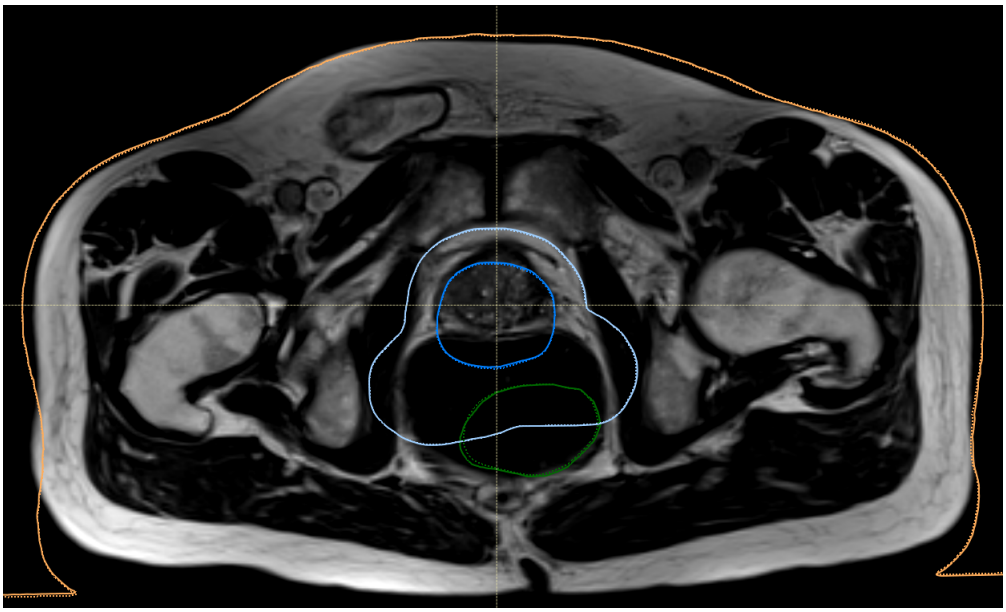


Figure 18: Example of MR scan from an excluded patient. Here the green structure delineates the rectum size and location in the CT scan, the orange shows the external contour from the CT, while the two blue shades show two target volumes, also mapped from the CT. Because of the large shift in rectum size and location, the CT based treatment volumes were not found to be of adequate accuracy for the MR, and so the patient was excluded.

3.3 Pseudo-CT generation

The overall objective of this part of the thesis was to generate pCTs by two different methods and and use these pCTs for retrospective treatment planning. The beam sets from the new treatment plans were also transferred to the opCT for dose calculations based on the true HU values. The first method for pCT generation is the bulk density approach, where the pCT was created using the RTP software RayStation (RaySearch Laboratories AB, Stockholm, Sweden). The second method is an atlas-based method, where the pCTs were generated through the MriPlanner software. All RTP was performed in RayStation. Figure 19 presents an overall workflow for the generation of the pCTs.

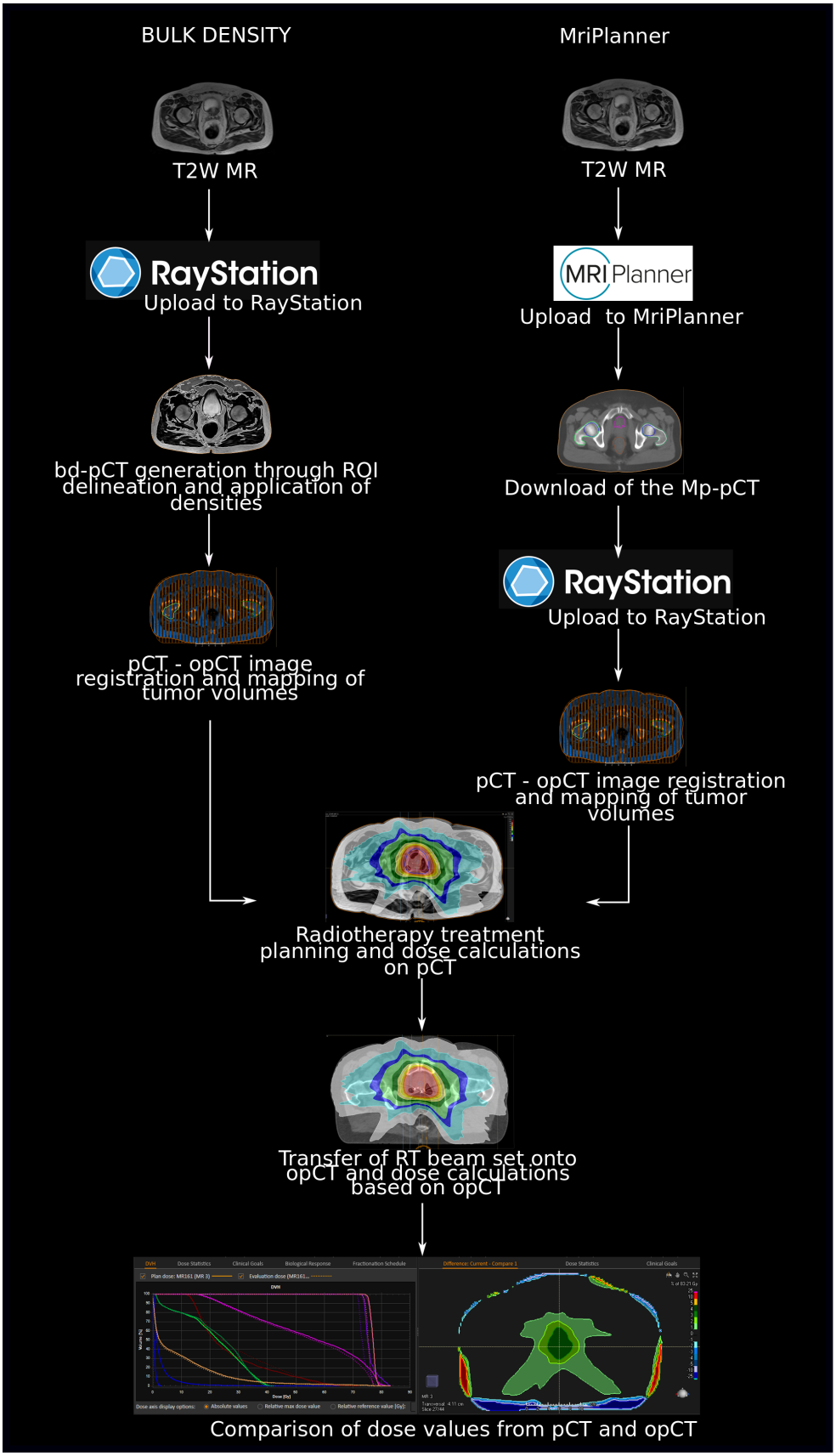


Figure 19: Illustration of the workflow for the pCT generation and dose comparison. Mp-pCT - MriPlanner-based pCT, opCT - original planning CT, bd-pCT - bulk density-based pCT.

3.3.1 Bulk density approach

In addition to the external contour, only four OARs were delineated and assigned a density for the generation of the bd-pCT. The four OARs were the bladder, the colon/rectum and the visible part of the two femurs (femoral heads, necks and the greater trochanter). Figure 20 shows an image of the femur with these areas indicated. It should be mentioned that the OARs were delineated manually by a student without any experience, and to simplify the delineations only the fluid inside the bladder and the inside of the rectum was delineated, and not the walls of these organs.

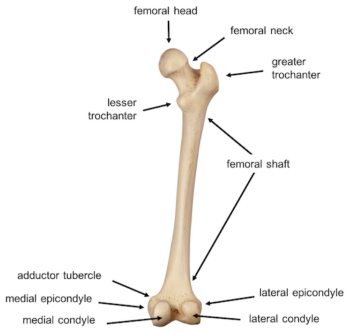


Figure 20: Image of the femur showing the femoral head, neck and the greater trochanter which are the regions included in the pCTs. Image from [22].

The density values were set manually and covered every pixel in the delineated ROI volume. The entire external contour volume of the patient was set to equal water, with a density of 1.000 g/cm^3. Each segmented structure would overwrite this value if the structure was assigned a separate density. The bladder and the rectum were not assigned separate values and were therefore water equivalent (WE). To set the rectum as WE is a common way to avoid dose build-up in any air-filled parts of the rectum in regular CT-based RT, and this common methodology was chosen her. The femurs were assigned a density value of 1.350 g/cm^3 after a brief examination of CT data from two prostate patients that were not included in the thesis.

The superior-inferior length of the imaged area of the CT was large compared to the area imaged in the MR, as shown in Figure 21. In an effort to digitally increase the area where a density was assigned in the bd-pCT, to better match the superior-inferior length of the CT, additional pieces of WE density was added. These pieces of additional density were applied above and below the existing bd-pCT, where each piece was 5 cm in length. The shape of each WE piece was matched to the first or last slice of the existing

bd-pCT, depending on the placement of the piece. The delineated OARs with the addition of the water pieces are illustrated in Figure 22.

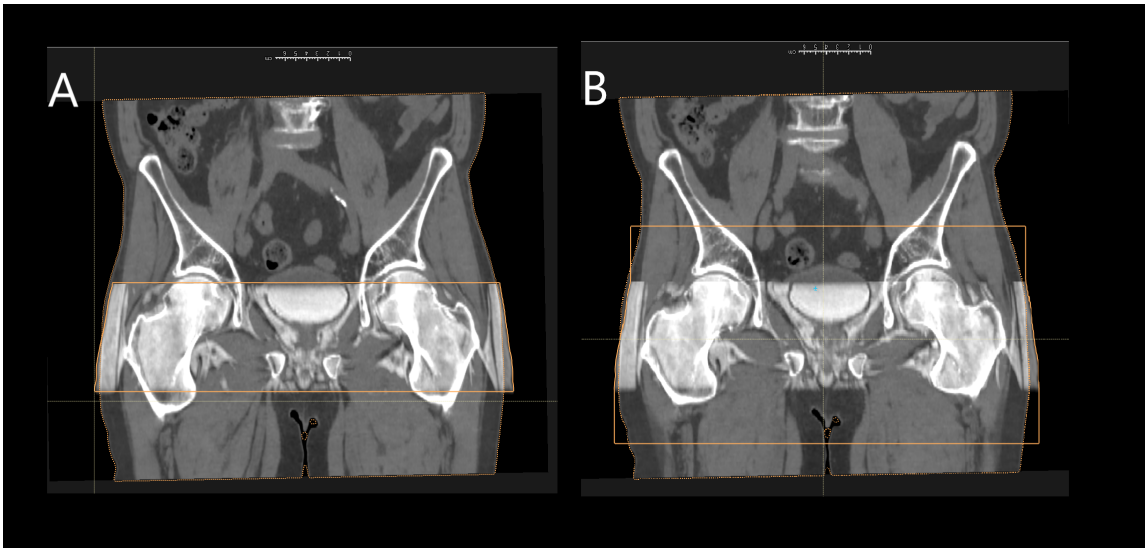


Figure 21: Images showing the different regions from the MR and the CT, where the MR is laid on top of the CT image. The area where the MR image is overlaid can be recognized as the area with the bright appearance of fatty tissue located around the hips. A) Here the external contour of the MR is illustrated in orange. B) The external contour of the MR with the additional density added is also shown in orange. These images are screen shots from the image registration process in RayStation.

Adipose tissue appeared very bright in the T2W MR and a grayscale based tissue delineation was implemented in an effort to separate and assign the appropriate density value to this tissue. To avoid other bright appearing OARs being wrongfully identified as adipose tissue, a list of exclusions was also implemented via the ROI algebra tool in RayStation. The algebra tool created the grayscale based ROI, and then subtracted the areas delineated as the bladder, the femurs and the prostate from the original volume. The resulting delineated volume was then assigned a density of 0.950 g/cm^3, which is the standard value for adipose tissue in RayStation.

As the delineation of adipose tissue was mainly grayscale based, there were probably some structures that were incorrectly defined as adipose tissue. To examine the impact of this delineation each patient had a bd-pCT generated with and without the inclusion of adipose tissue. The same approach was also applied to study the effect of the additional water, and in total four dif-

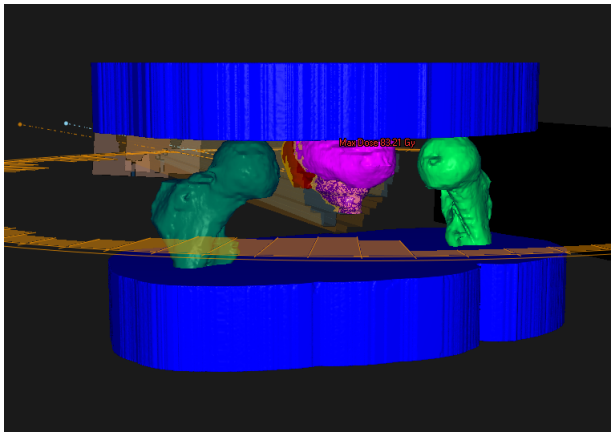


Figure 22: 3D illustration of the ROIs with the additional density, illustrated in blue, added above and below the existing bd-pCT. Here the density data from the original external contour of the bd-pCT is removed to better illustrate the OARs. This Figure also contains an orange circular structure that is involved in the VMAT planning procedure, as this is a screen shot from the RTP in RayStation.

ferent bd-pCTs were created per patient. An overview of the four bd-pCTs is included in Figure 23.

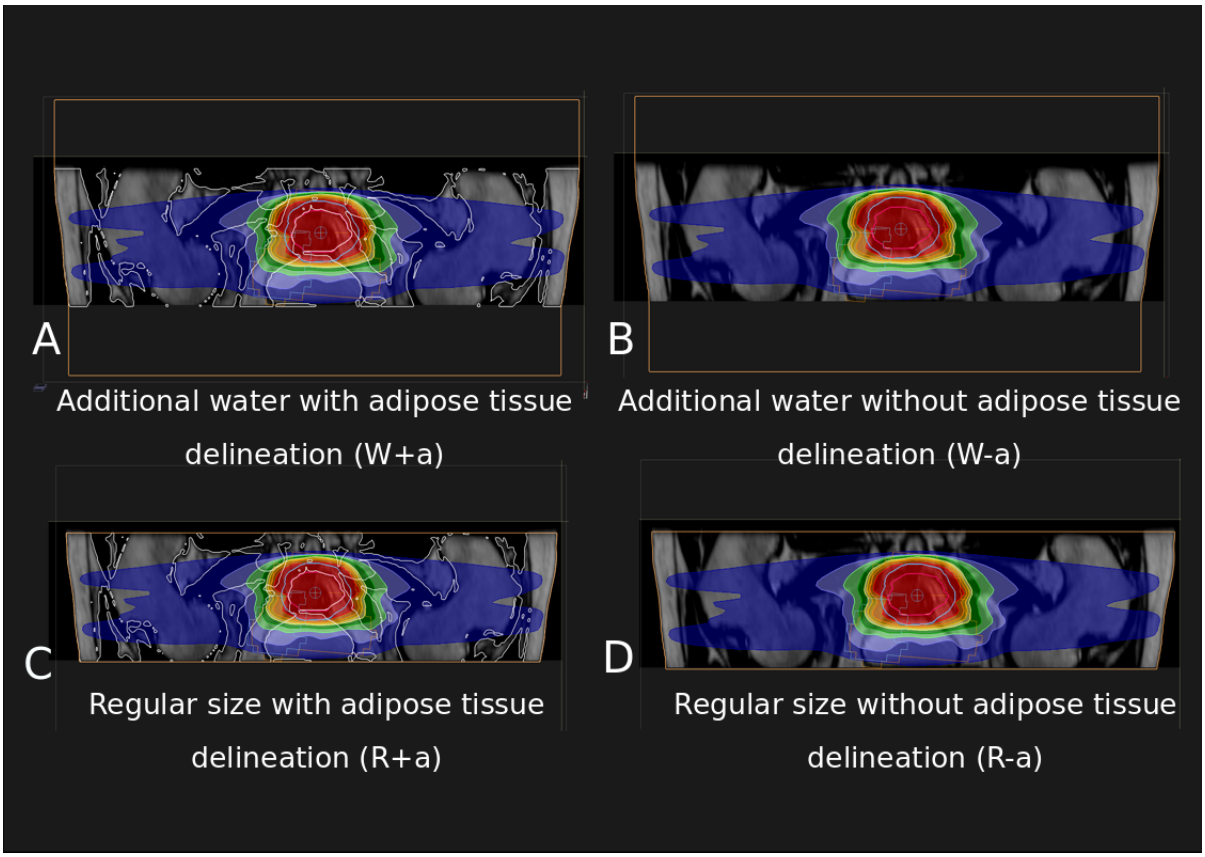


Figure 23: Illustration of the four types of bd-pCT with a dose distribution overlay. The orange contour marks the external contour of the pCT, and the white lines delineate the adipose tissue. Image A shows the bd-pCT with additional water and delineation of adipose tissue. B shows the bd-pCT with additional water, but without adipose tissue. C shows the bd-pCT without additional water, but with the delineation of adipose tissue. D shows the bd-pCT without the additional water and without delineation of adipose tissue.

3.3.2 MriPlanner pCT generation

MriPlanner is a black box software, where axial T2W MR images are uploaded to a cloud based software and the pCTs are automatically generated and available for download after one to two hours. The MriPlanner software is so far only CE certified for pCT generation of the prostate. In addition to assigning continuous HUs to the pCT, the software also delineates the external contour, the colon/rectum, the bladder and the femoral heads. As the bd-pCT included the delineation of the femoral neck and greater trochanter in addition to the femoral heads, the automatically delineated femoral heads were extended manually to also include the remaining part of the femur present in the Mp-pCT.

The MriPlanner based pCTs (Mp-pCTs) were also registered to the opCTs to allow for the mapping of the target volumes in the same manner as the MR images for the bd-pCT generation. To test the accuracy of the MriPlanner alone, there was no experimentation with delineation of adipose tissue or additional water. For the same reason, the automatically generated ROI delineations were used instead of a mapping of the MRI-based delineations generated for the bd-pCT.

3.4 Radiotherapy treatment plan creation

To avoid the need for a second round of target delineations, an image registration was performed between the opCT and MR images, which allowed for mapping of the PTVs and CTVs from the CT onto the MR. The primary image matching was grayscale based and applied automatically by RayStation before a manual optimization, mainly based on the pelvic bone and the femur, was applied if the grayscale match was not found sufficient.

All patients were retrospectively planned with 35 fractions of 2.2 Gy (77 Gy total), in consensus with the standard treatment at the radiotherapy department at St.Olavs hospital. The patients included in this study were all older cases, whom had originally received a four field RT treatment. The previous RT protocol that the patients underwent involved two PTVs and two CTVs, differentiating between volumes receiving a prescribed dose of 70-78 Gy and 0-70 Gy. With the help from an experienced medical physicist, the volume receiving 0-70 Gy was altered in order to move the treatment planning towards the standards for VMAT planning. The PTV and CTV that were originally assigned 70-78 Gy were left unaltered and assigned 77 Gy in the VMAT plans.

The CTV 70-78 Gy only contained the prostate, while the CTV 0-70 Gy included the prostate, the seminal vesicles and a small margin around these. To separate the seminal vesicles from the prostate as is common for VMAT RT treatments, the 70-78 Gy volume with an additional uniform margin of 0.5 cm was subtracted from the 0-70 Gy volume through the use of ROI algebra in RayStation. The additional margin excluded the normal tissue, located between the prostate and the seminal vesicles, from the CTVs to reduce the dose. The two resulting CTVs were then named CTV77 and CTV70 where the number describes the dose prescribed to the volume. To generate the corresponding PTVs, margins were added as explained in Table 2.

Table 2: Table showing the margins that were added around the CTVs to generate the PTVs in RayStation.

PTV	**Target**	**Left-Right (mm)**	**Anterior-Posterior (mm)**	**Superior-Inferior (mm)**
PTV77	Prostate	5	7	7
PTV70	Seminal vesicles	10	10	10

As the treatment plans were only generated for evaluation purposes, each

plan only had to fulfill a list of clinical goals to be accepted. As soon as all goals were met, there were no further optimization. The clinical goals used for the treatment planning in this thesis is based on the clinical goals used for prostate VMAT treatments given at St.Olavs hospital, and are listed in Table 3. Achieving a sufficient dose to the PTVs without exceeding the maximum doses for the OARs was the most common issue related to the treatment planning, and for one of the ten patients the goal for PTV70 was not met for the bd-pCTs without additional water (64.89 Gy with addition of adipose tissue and 64.73 Gy without), but this patient was still included as the goals were met for the treatment plans based on the three remaining pCTs.

Table 3: List of the clinical goals that each treatment plan had to fulfill. The table includes both the minimum doses to the target volumes and the maximum doses to the OARs.

Target	**Minimum dose to percentage of volume (Gy)**
CTV77	73.15 at 100%
CTV70	66.50 at 100%
PTV77	73.15 at 98%
PTV70	66.50 at 98%
Organ	**Maximum dose to percentage of volume (Gy)**
Rectum	50 Gy at 50% 60 Gy at 35% 66 Gy at 25% 70 Gy at 20% 73 Gy at 15%
Bladder	66 Gy at 50% 70 Gy at 35% 74 Gy at 25% 78 Gy at 15%
Femurs	51 Gy at 2%
External contour	80.85 at 1%

The creation of each treatment plan started with the implementation of some standard objectives and weightings, which are listed in Table 4. The weighting of the objectives was altered or additional objectives created in cases where the standard set-up did not generate a treatment plan that fulfilled

all the clinical goals.

The RT beam sets were based on 6 MV photons delivered through dual arcs spanning in a clockwise motion from 182.0 to 178.0 degrees, and in a counterclockwise motion from to 182.0 to 178.0 degrees. The collimator angle was set to 5 degrees, and a constraint of 0.50 cm/deg was placed on the leaf motion.

Table 4: List of objectives used as a standard starting point for the treatment planning in RayStation. In cases where the generated treatment plan did not fulfill the list of clinical goals, the weighting of the objectives were altered or additional objectives were included.

ROI	**Objective**	**Weighting**
CTV77	Uniform dose 77.00 Gy	3
PTV77	Minimum dose 73.15 Gy	100
	Maximum dose 80.85 Gy	100
CTV70	Minimum dose 67 Gy	3
PTV70	Minimum dose 66.5 Gy	100
	Max dose 73.5 Gy	100
Rectum	Dose-fall-off from 77 Gy to 25 Gy, distance 2.0 cm	3
External	Dose-fall-off from 77 Gy to 30 Gy. distance 3.5 cm	3
	Maximum dose 80.85 Gy	100
Femoral heads	Maximum dose 51 Gy	3
Bladder	Dose-fall-off from 77 Gy to 25 Gy, distance 2.0 cm	3

3.4.1 Dose data comparison

The beam sets from the treatment plans were transferred from the Mp-pCT and bd-pCT to the opCT to test the dosimetric accuracy of the generated pCTs compared to the opCT. To compare the dose data ROI by ROI, the ROIs were mapped from the pCTs to the opCT, a process that was made possible by the initial image registration where the target volumes where mapped from the opCT to the pCTs.

As the bd-pCTs were generated by assigning densities to the delineated ROIs, the densities had to be removed as the ROIs were mapped onto the opCT to avoid overwriting the HU data in the opCT. A problem with this procedure was that a removal of the density information from the bd-pCT caused RayStation to also delete the beam set associated with the treatment plan,

as the bd-pCT was no longer treated as a pCT and therefore could not be the basis for a treatment plan. RaySearch, the developers of RayStation, created a Phyton script to solve the issue of removing the density information without deleting the beam set. The script transferred the beam set from the bd-pCT onto the opCT and computed the dose to each ROI through a simulated irradiation of the opCT. This script is included in Appendix A.

Unlike the bd-pCT, there was no need for a script when computing the dose from the Mp-pCT based treatment plan on the opCT, as both the Mp-pCT and the opCT contains continuous HU values for each voxel and are treated as CTs by RayStation. The built-in RayStation solution "Compute on additional sets" was used for the beam set transfer and the dose computation.

After the completion of the dose calculations on the opCT, the doses from the opCT and the pCT were compared ROI by ROI, and the dose volume histogram (DVH) statistics for the variables D_{99}, D_{98}, D_{95}, D_{AVG}, D_{50}, D_2 and D_1 were presented by RayStation. The numbers in subscript indicate the percent of the total volume, so D_{98} for instance describes the dose delivered to 98% of the total volume, and D_{AVG} is the average dose to the entire volume of the ROI. D_{98}, D_{AVG} and D_2 were chosen to study further, as this choice of variables covered a large variety of the volume percentages and can be of interest clinically.

Finally, the dose difference in Gy between the pCTs and the opCT was calculated ROI by ROI for each patient. The significance of the addition of water to the two bd-pCTs and of the delineation of the adipose tissue was studied by comparison of the four bd-pCTs. The mean of the absolute value of the dose deviations was calculated for all pCTs in an effort to find the most dosimetrically accurate pCT to the opCT. The dosimetric difference between the bd-pCT with the lowest mean deviation from the opCT and the Mp-pCT was also tested for statistical significance. The signed-rank Wilcoxon test was used for all statistical tests, and applied through the "signrank" function in MATLAB (MathWorks, Massachusetts, USA). This test was chosen as it does not require normally distributed data.

3.5 Phantom studies of geometric distortion

Since geometric distortion can decrease the geometric accuracy of MR, the presence of such distortion is an important concern related to MR-only RT. To ensure sufficient geometric accuracy, and thereby treatment accuracy, it is therefore important to monitor the presence of geometric distortions on a regular basis. Phantoms can be used to study the geometric distortion, and at St. Olavs hospital the GRADE phantom was purchased for the distortion testing.

The GRADE phantom is a large field-of-view phantom with associated evaluation software designed for geometric QA in an MR-based RT workflow. The inside of the phantom consists of around 1200 spheres, which are placed at specific locations throughout the phantom volume. The evaluation software utilizes these spheres to study the amount of geometric distortion present in each MR slice. An illustration of the GRADE phantom is included in Figure 24. The distortion analysis is performed automatically after a set of MR images are uploaded to a cloud based software and a report of the distortion is generated. Figure 25 illustrates the steps involved in the distortion analysis.

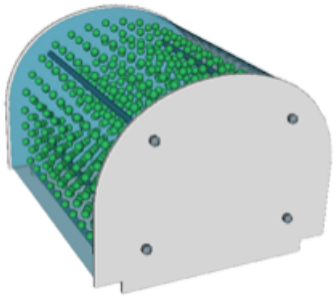


Figure 24: Illustration of the GRADE phantom where around 1200 spheres are used to examine geometric distortion. Illustration from [23].

In all imaging sessions the phantom was placed on the flat MR overlay and positioned using the laser bridge by fitting the crosshair markings on top of the phantom to the laser bridge. This crosshair marking on top of the phantom is imaged in Figure 26. The MR isocenter positioning laser was also used to ensure the placement of the middle of the phantom at the center of the MR bore.

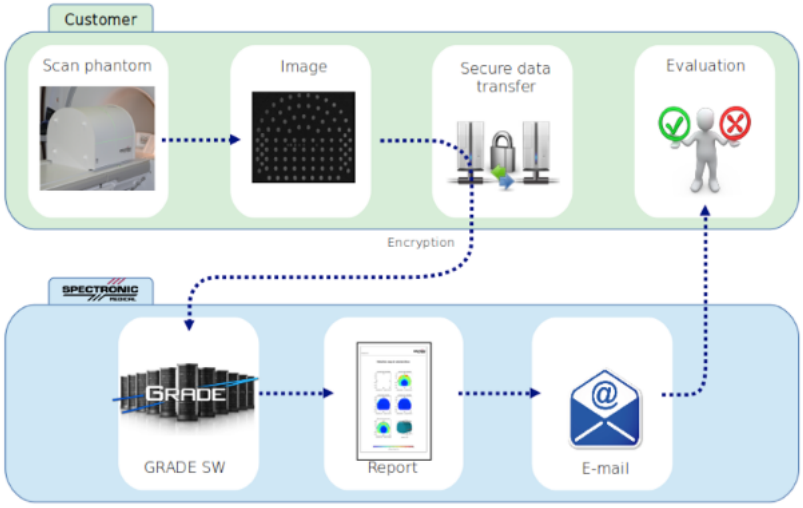


Figure 25: Flowchart describing the process used for examinations of geometric distortion using the GRADE phantom and the associated analysis software. The images were not transferred automatically as illustrated in the Figure, as the transfer software was not installed locally at St. Olavs hospital, but the MR images were uploaded to the cloud manually. Illustration from [23].

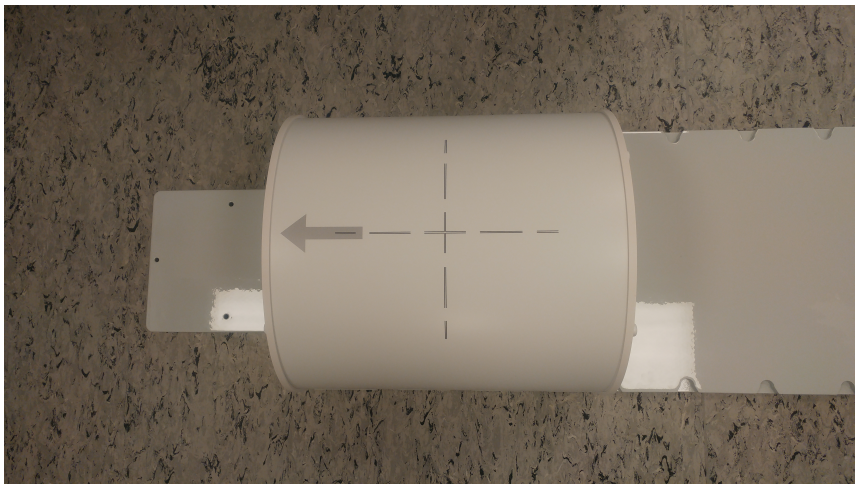


Figure 26: Image of the GRADE phantom placed on top of the flat MR overlay. The arrow symbol on the top of the phantom indicates which end of the phantom is inserted into the scanner first. The crosshair markings located next to the arrow is used to place the phantom, by aligning the cross with the laser cross produced by the laser bridge.

All images were acquired on the Siemens Biograph mMR 3T PET/MR imaging system, as mentioned above. After some trial and error, a 2D T2W turbo spin echo (TSE) sequence, which is a SE sequence where the echo is refocused by 180° pulses multiple times, was chosen as the main test sequence. Details about the main MR sequence is included in Table 5. All images were acquired using only the body coil, and the vendor 3D distortion correction was applied during all imaging sessions. Automatic shim routines were also used for all scans. This standard sequence included an additional 30 mm anterior shift of the FOV, which was implemented to move the phantom from the edges and closer to the center of the FOV.

Table 5: Technical parameters for the T2W TSE MR sequence used for geometric distortion testing.

Slice thickness	2.5 mm
Number of slices	128
TR	4000 ms
TE	85
Number of averages	1
Echo number	1
Number of phase encoding steps	525
Echo train length	21
Pixel bandwidth	490
Flip angle	130
Field of view	500 x 500 mm
Image matrix	512 x 512

To study whether there were variations in geometric distortions over time, repeated measurements were conducted over the 44 day measurement period. In total, there were seven imaging sessions, producing a total of 18 phantom scans. Table 6 gives an overview of the imaging sessions.

Table 6: Table presenting an overview of the different imaging sessions and which MR sequences that were utilized during each of them.

Day number	**MR sequence**	**Laser bridge for set-up**
1	T2W with 30 mm shift	X
24	T2W with 30 mm shift	
	T2W at isocenter	
29	T2W with 30 mm shift	X
	T2W with 30 mm shift after new laser-based set-up	X
35	T2W with 30 mm shift	X
	T2W with 30 mm shift	
	T2W with 30 mm shift with new laser-based set-up	X
	New 3D T2W sequence with 30 mm shift	X
37	T2W with 30 mm shift	X
	T2W with 30 mm shift	X
	T2W with 30 mm shift	X
41	T2W with 30 mm shift	X
	T2W at isocenter	X
	T2W with 30 mm shift	X
44	T2W with 30 mm shift	X
	New 3D T2W sequence with 30 mm shift	X
	New 3D T2W sequence at isocenter	X

As illustrated in Table 6, some scans were conducted without the use of the laser bridge for positioning, where the phantom was positioned manually by measuring the distance from the sides of the phantom to the sides of the flat overlay, as illustrated in Figure 27.

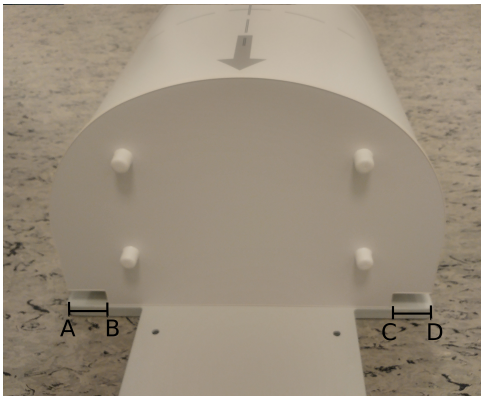


Figure 27: Image of the GRADE phantom placed on top of the flat MR overlay. Points A and D marks the sides of the flat MR overlay, and points B and C marks the bottom edges of the phantom. For the manual placement of the phantom, the distances A-B and C-D were matched along the entire side of the phantom.

Five main points of interest were identified, these were:

1. Variation over time
2. Effect of different imaging sequence
3. Effect of anterior shift of FOV vs. isocenter positioning
4. Random variation within the same imaging session
5. Effect of manual placement vs. laser-based placement

The measurement on day 1 was simply a test of the sequence, and was also used to study changes in geometric distortion over time.

The measurements on day 24 were conducted during a period where the laser bridge was not functioning and the manual set-up was used to position the phantom. During this imaging session, the standard sequence with and without the 30 mm anterior shift was scanned.

On day 29 there were two scans utilizing the standard T2W sequence, where

the phantom was removed from the scanner between the two measurements, to examine the effect of a laser-based re-set-up of the phantom.

Three measurements of the same sequence were acquired on day 35, where the phantom was removed from the scanner and positioned manually before the second scan. The laser bridge was used to position the phantom for the first scan. The third measurement was acquired directly after the second, to compare two scans with an identical setup. One scan was conducted using a new T2W sequence that was added to examine whether the amount of distortion would be dependent on the choice of sequence. This second T2W sequence was a 3D TSE sequence (SPACE) which is described in Table 7.

Table 7: Technical specifications of the second T2W, 3D SPACE, MR sequence that was used to study whether the geometric distortion was dependent on the choice of MR sequence.

Slice thickness	1.600 mm
Number of slices	176
TR	1300 ms
TE	91
Number of averages	1
Echo number	1
Number of phase encoding steps	223
Echo train length	81
Pixel bandwidth	490
Flip angle	110
Field of view	500 x 500 mm
Image matrix	320 x 320

The three measurements conducted on day 37 were acquired immediately after one another to examine any random effects causing variation in the geometric distortion, as the phantom was not moved between the measurements.

On day 41 the effect of the 30 mm anterior shift of the FOV was examined, along with the random effects of two consecutive measurements of the same sequence.

During the last imaging session, on day 44, a measurement of the new 3D

T2W sequence was acquired to be compared with the measurement on day 35. In addition a measurement of the same new sequence without the 30 mm shift was tested. One measurement of the regular T2W sequence was also acquired to compare with the new sequence, and to examine the difference in the geometric distortion over time.

4 Results

4.1 Setup of radiotherapy specific equipment

The purchased RT-specific MR equipment was installed and tested through the work in this thesis. The equipment was found to be functioning, and all the equipment required for MR-only RT is therefore ready for clinical use or further testing.

4.2 Pseudo-CT

Figure 28 shows the Mp-pCT and the opCT with the automatically delineated OARs. Figure 29 shows the bd-pCT and the opCT with the manually delineated OARs volumes. As seen in these figures, the delineations mapped from the pCT do not entirely match the contour of the corresponding volume in the opCT. This effect is most easily observable for the femurs.

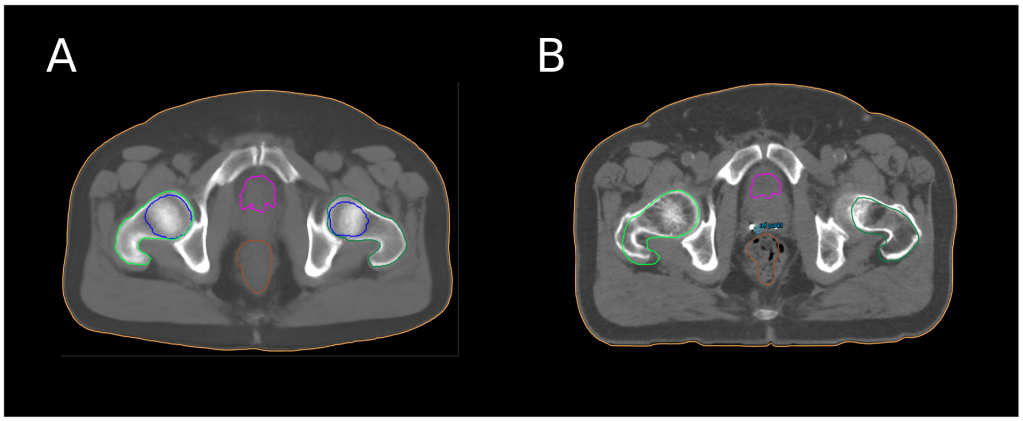


Figure 28: Image of the Mp-pCT (A) and the opCT (B) with the automatically delineated OAR volumes. The orange line delineates the outer patient contour (which has not been mapped from the pCT onto the opCT), pink delineates the bladder, brown delineates the rectum, the blue circles mark the femoral heads while the two shades of green mark the manual delineation of the femurs.

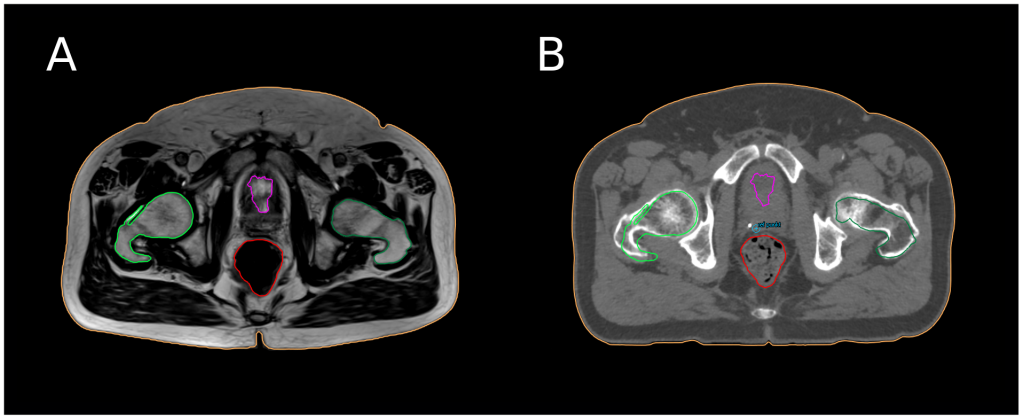


Figure 29: Image of the bd-pCT (A) and the opCT (B) with the manually delineated OAR volumes. The orange line delineates the outer patient contour (which has not been mapped from the pCT onto the opCT), pink delineates the bladder, red delineates the rectum and the two shades of green delineates the two femurs.

Figures 30 to 38 shows boxplots of the dosimetric difference (D_{98}, D_{AVG} and D_2) between the pCT and opCT for the four types of bd-pCTs and the Mp-pCT. Dosimetric data for all patients and all pCTs are included in Appendix B.

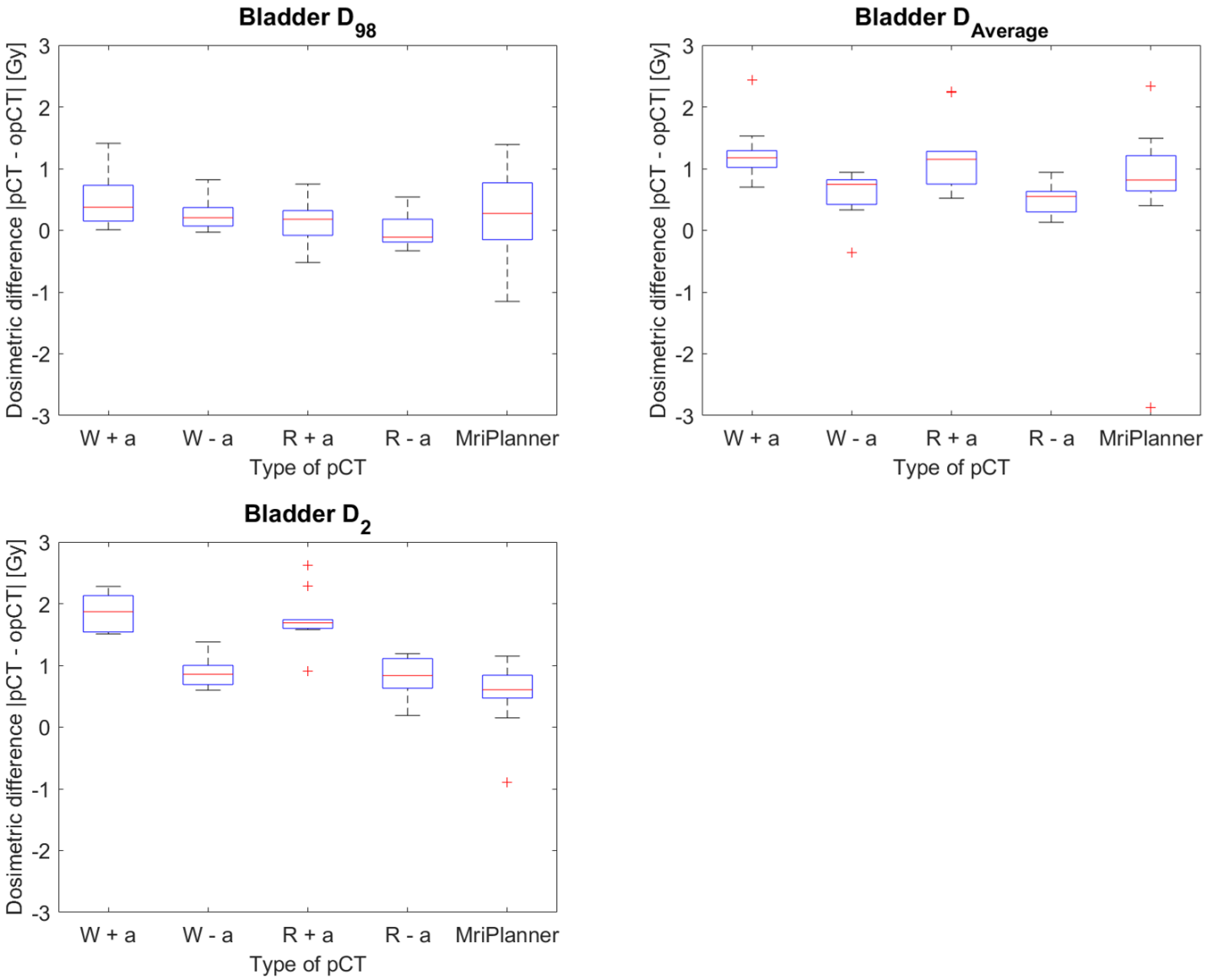


Figure 30: Boxplots showing the dosimetric difference for the bladder between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, ± a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

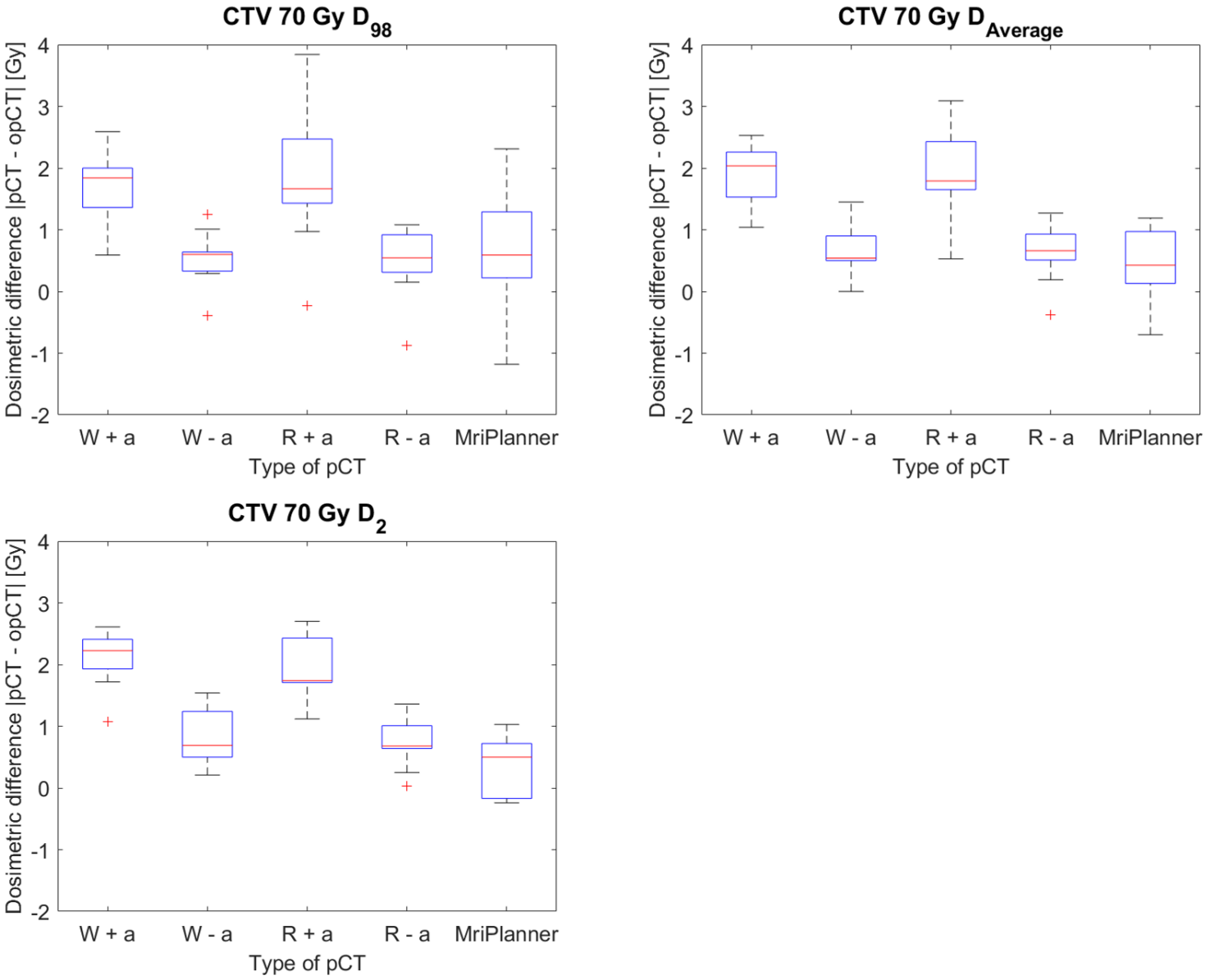


Figure 31: Boxplots showing the dosimetric difference for the CTV70 between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

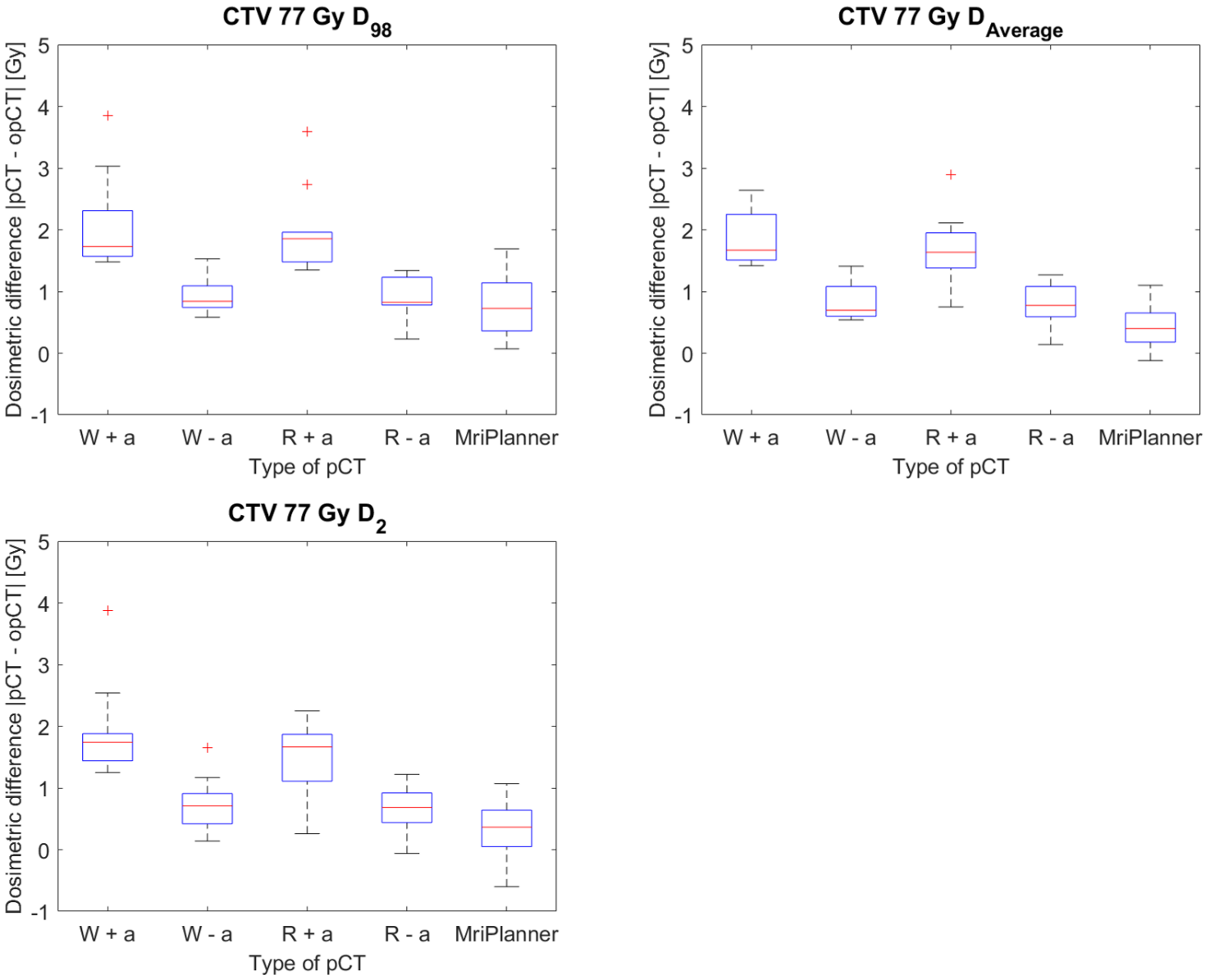


Figure 32: Boxplots showing the dosimetric difference for the CTV77 between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, ± a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

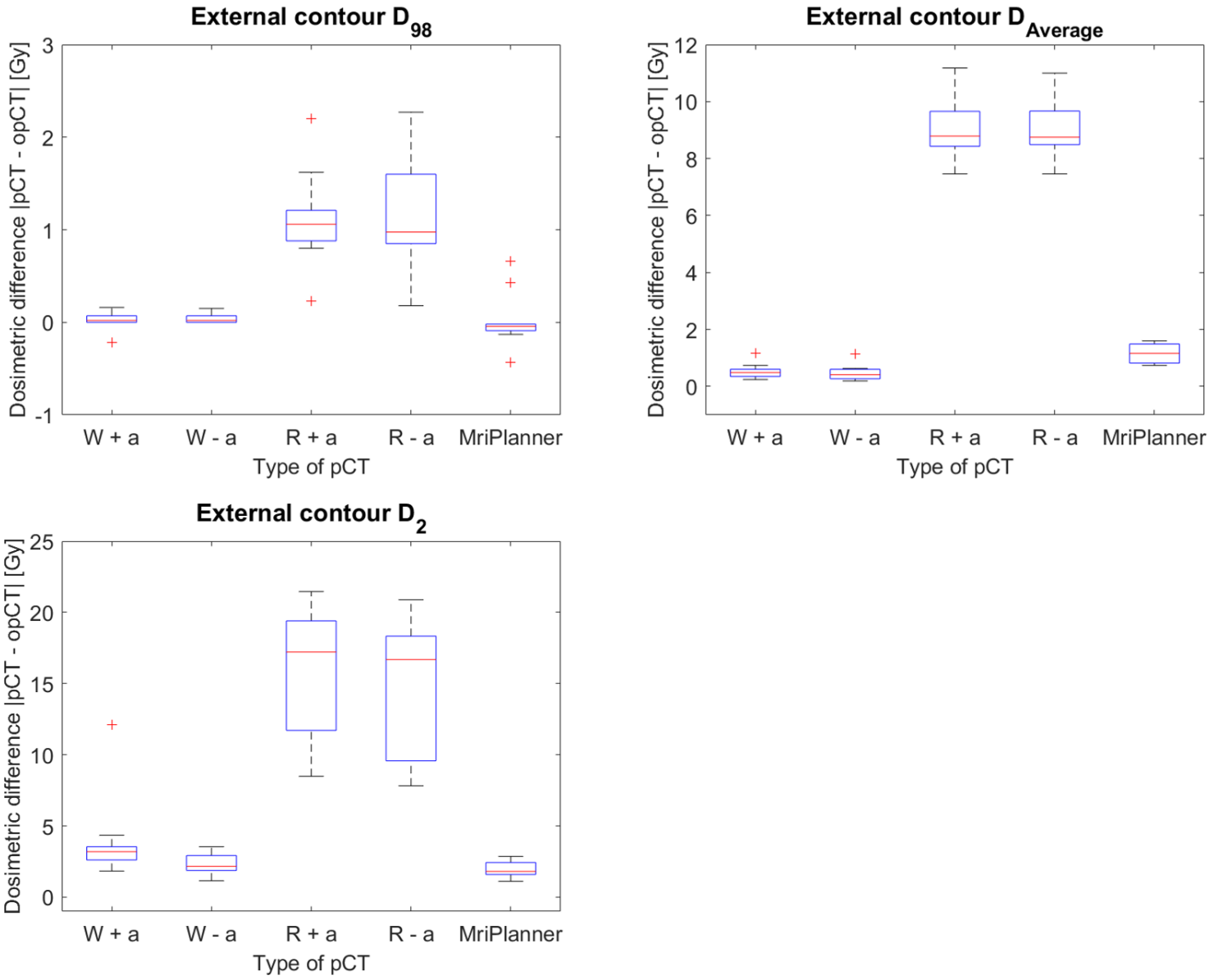


Figure 33: Boxplots showing the dosimetric difference for the external contour between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue. Note the different y-axes.

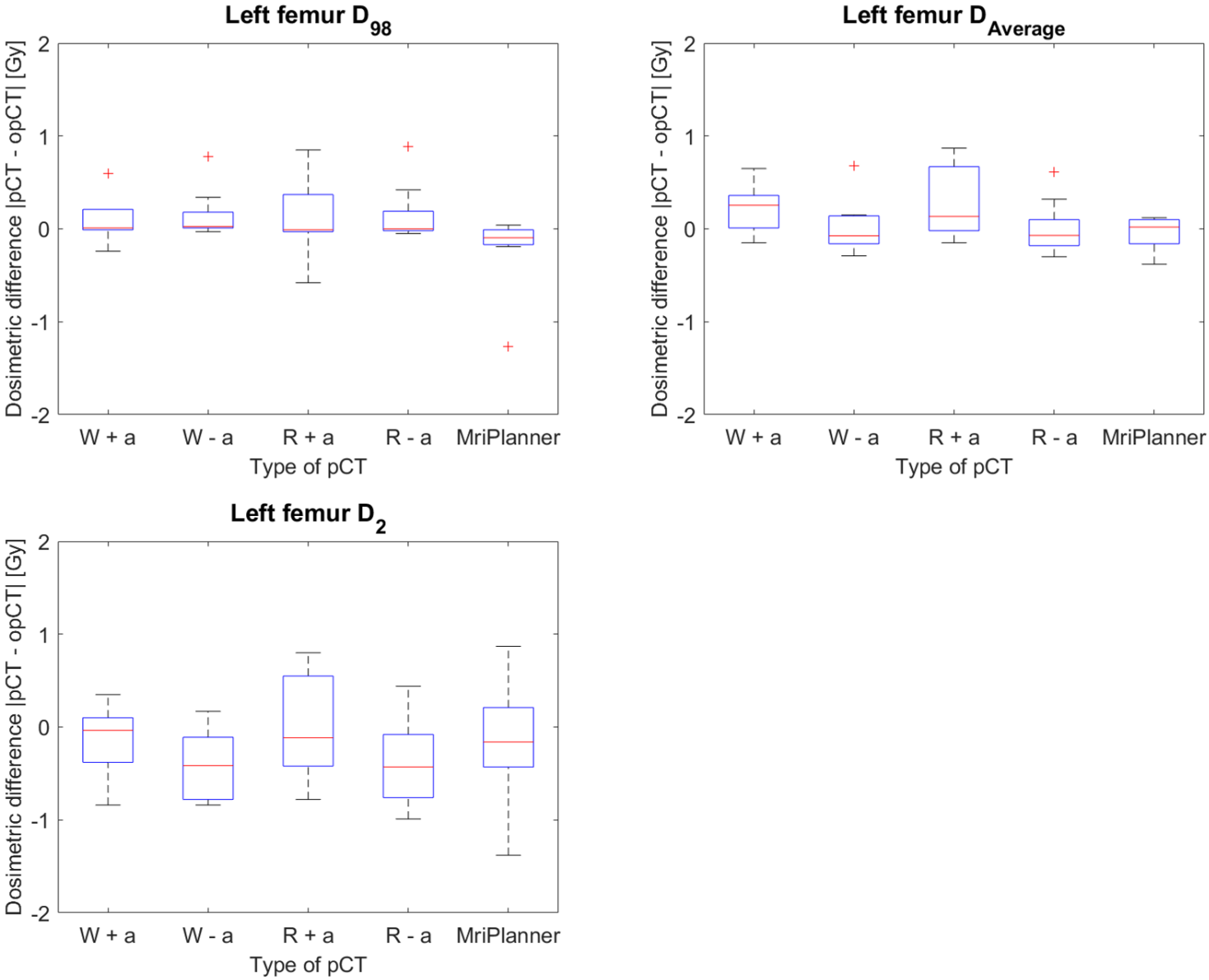


Figure 34: Boxplots showing the dosimetric difference for the left femur between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

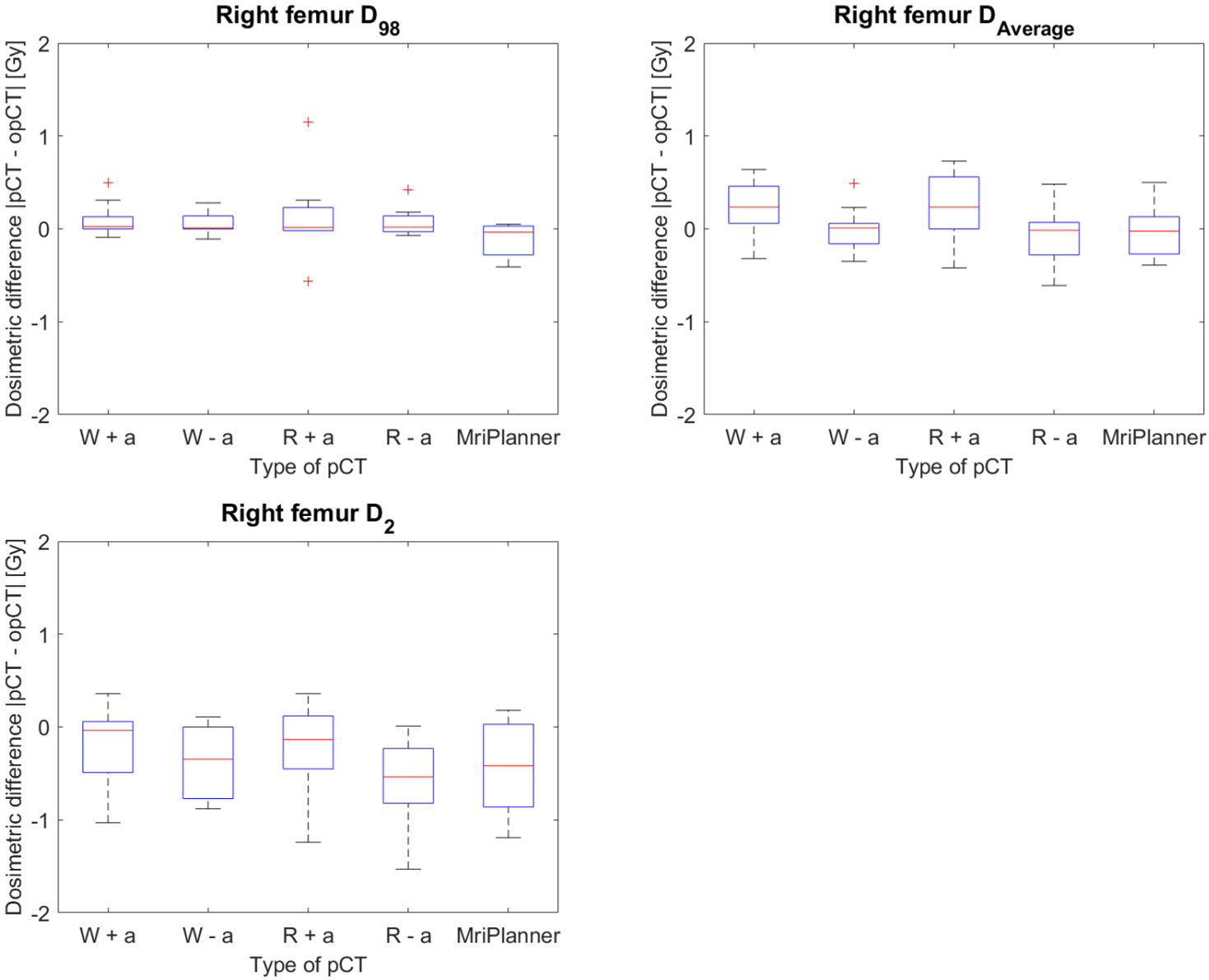


Figure 35: Boxplots showing the dosimetric difference for the right femur between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

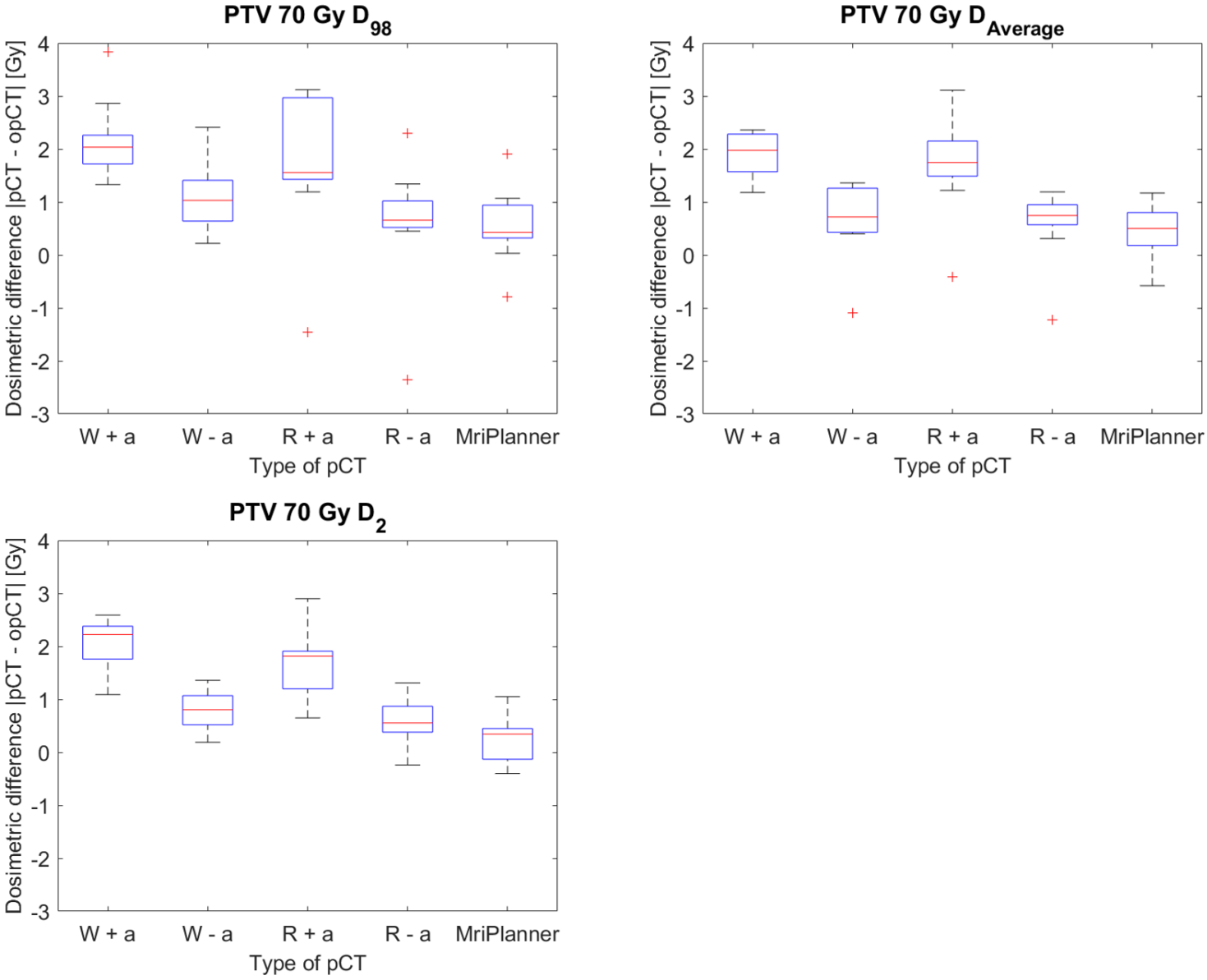


Figure 36: Boxplots showing the dosimetric difference for PTV70 between each type of pCT and the opCT in Gy. Where the top right figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. Here W signifies additional water, ± a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

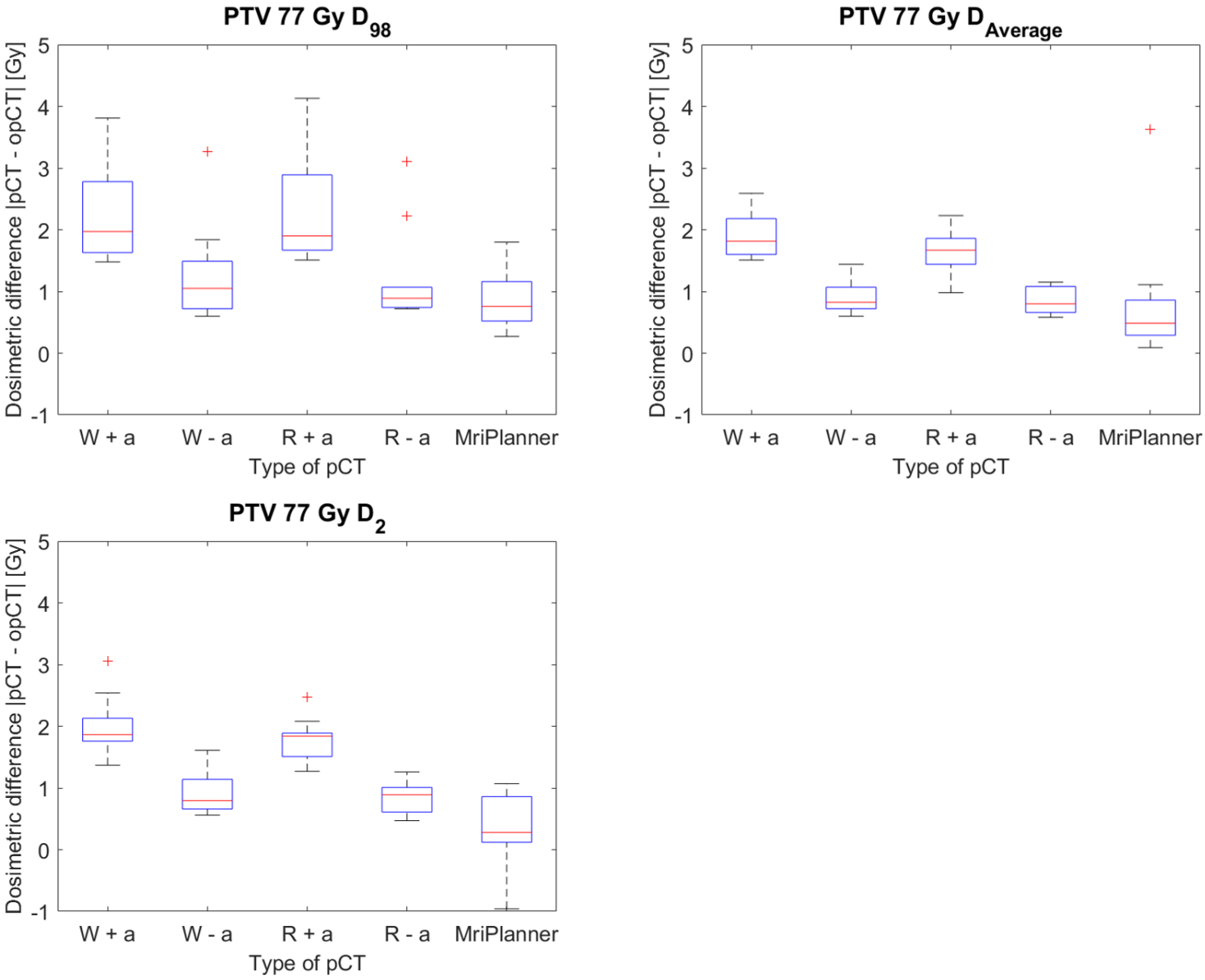


Figure 37: Boxplots showing the dosimetric difference for the PTV77 between each type of pCT and the opCT in Gy. The top left figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

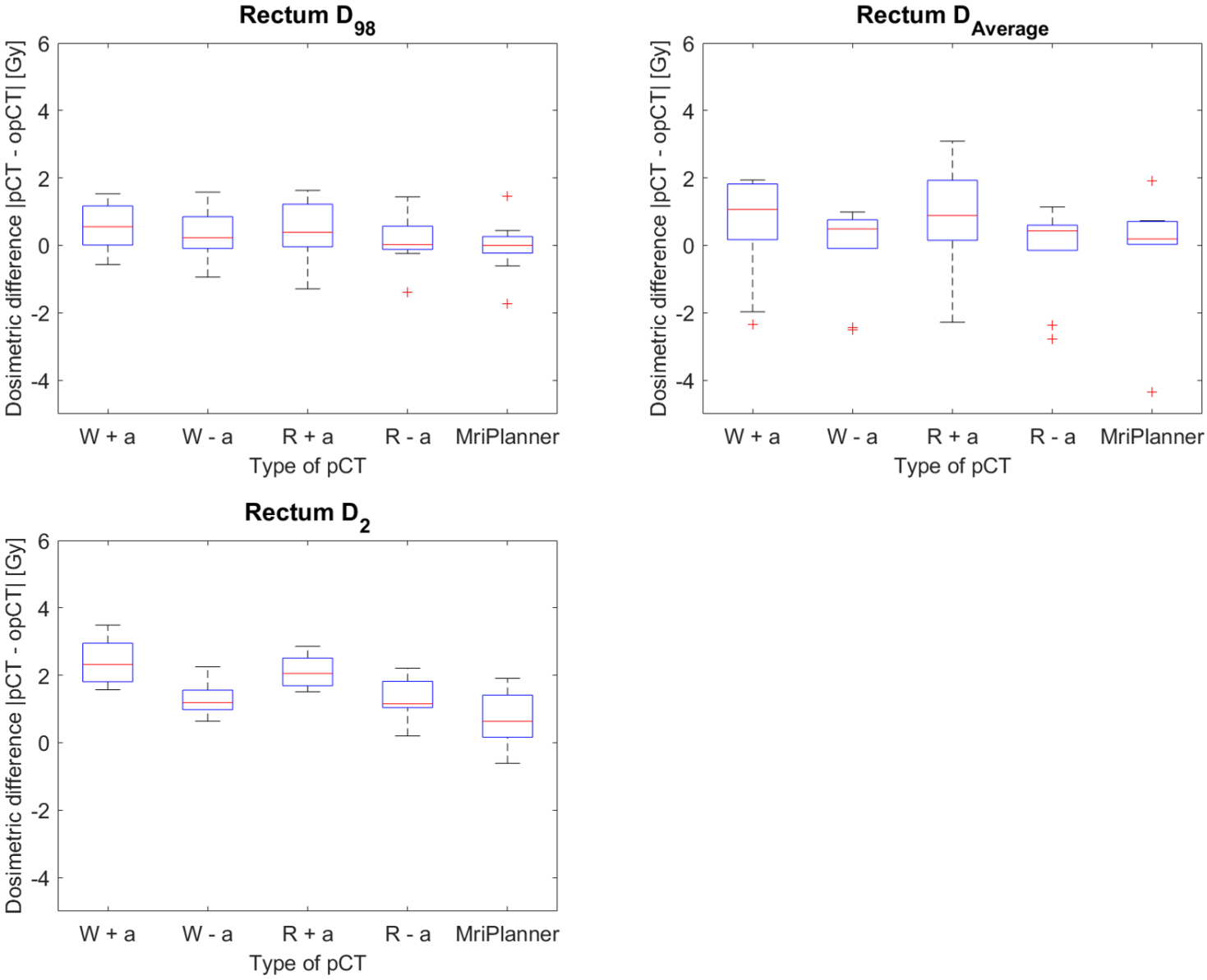


Figure 38: Boxplots showing the dosimetric difference for the rectum between each type of pCT and the opCT in Gy. Where the top right figure shows the dosimetric data for D_{98}, top right shows the same data for D_{AVG} and the bottom left figure shows the data for D_2. Here W signifies additional water, $\pm$ a the delineation of adipose tissue and R the regular size of the pCT, meaning no additional water. So R - a is the pCT without additional water or delineation of adipose tissue.

4.2.1 Effect of delineation of adipose tissue

Figure 39 shows an MR image with delineation of adipose tissue, where the exclusion of the femoral heads and the bladder is visible. To examine the effect of the delineation of adipose tissue through statistical testing, the bd-pCTs were separated based on the addition of water and the two resulting bd-pCT pairs were compared (W+a vs. W-a and R+a vs. R-a). The p-vales resulting from this comparison are presented in Table 8.

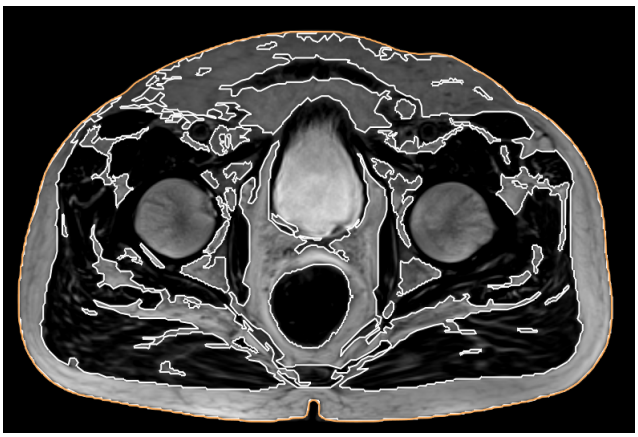


Figure 39: An MR image with delineations of areas defined as adipose tissue delineated in white. The orange line marks the external contour and sometimes overlaps the white line. One can see that the bladder and femurs are excluded from the delineation, although their grayscale value alone would be placed within the range for adipose tissue.

Table 8: Table presenting the p-values from the signed-rank Wilcoxon test comparing dosimetric values from bd-pCTs with and without the delineation of adipose tissue. Each bd-pCT is compared with the bd-pCT of the same size (with or without the additional water), meaning W+a vs. W-a and R+a vs. R-a. Values significant on a 5% level are presented in bold.

ROI	**Additional water**	$\mathbf{D_{98}}$	$\mathbf{D_{avg}}$	$\mathbf{D_2}$
Bladder	x	**<0.01**	**<0.01**	**<0.01**
		0.061	**<0.01**	**<0.01**
CTV70	x	**<0.01**	**<0.01**	**<0.01**
		<0.01	**<0.01**	**<0.01**
CTV77	x	**<0.01**	**<0.01**	**<0.01**
		<0.01	**<0.01**	**<0.01**
External contour	x	0.750	0.084	**<0.01**
		0.430	0.313	**<0.01**
Femur left	x	0.914	**<0.01**	**<0.01**
		0.720	**<0.01**	**0.049**
Femur right	x	0.477	**<0.01**	**0.025**
		0.961	**<0.01**	**<0.01**
PTV70	x	**<0.01**	**<0.01**	**<0.01**
		<0.01	**<0.01**	**<0.01**
PTV77	x	**<0.01**	**<0.01**	**<0.01**
		<0.01	**<0.01**	**<0.01**
Rectum	x	0.080	**<0.01**	**<0.01**
		0.104	**<0.01**	0.084

4.2.2 Effect of additional water

Figure 40 shows the effect of assigning additional water to the external contour on the dose calculated on the bd-pCT and on the opCT.

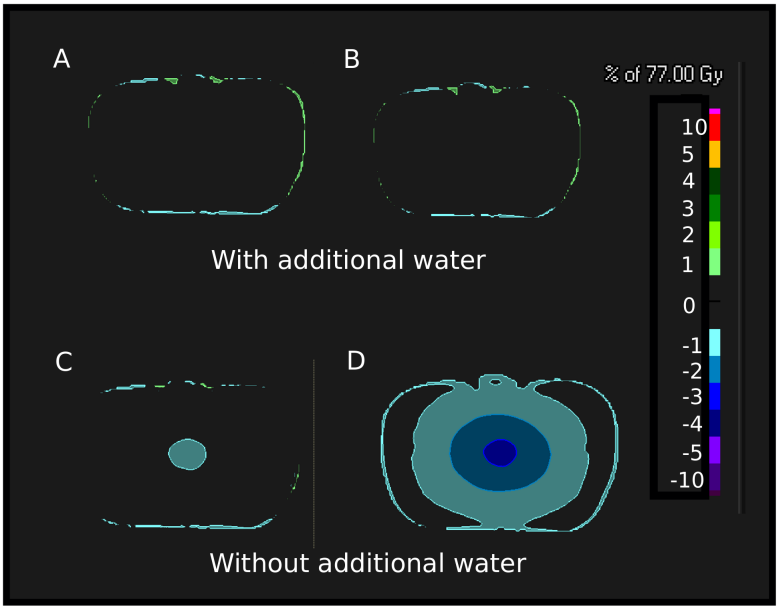


Figure 40: This figure illustrates the effect of assigning additional water to the external patient contour. A and C visualize the dosimetric difference in the last slice of the external patient contour from the MR image, while B and D show this difference in the first slice of the opCT after the end of the original MR patient contour. A and B shows the dosimetric difference in the case where water is added to the external patient contour, while in C and D only the original external patient contour from the MR.

The bd-pCT with the additional water and delineation of adipose tissue was compared with the bd-pCT without additional water but with delineation of adipose tissue (W+a vs. R+a), and the two bd-pCTs without the delineation of adipose tissue were also compared (W-a vs. R-a). The p-values from this comparison are presented in Table 9.

The bd-pCT without both the additional water and the delineation of adipose tissue (R-a) resulted in the smallest absolute mean deviation from the opCT of the four bd-pCTs when the external contour was not included. When the external contour was included, the bd-pCT with the additional water and without the delineation of adipose tissue (W-a) resulted in the smallest mean deviation. Tables of the absolute mean deviations are included in

Appendix C.

Table 9: Table presenting the p-values from the signed-rank Wilcoxon test comparing dosimetric values from bd-pCTs with and without additional water. Here W+a is compared with R+a, and W-a is compared with R-a. Values significant on a 5% level are presented in bold.

ROI	**Adipose tissue delineation**	$\mathbf{D_{98}}$	$\mathbf{D_{avg}}$	$\mathbf{D_2}$
Bladder	x	**<0.01**	0.557	0.492
		<0.01	0.344	0.695
CTV70	x	0.940	1.000	0.322
		0.311	0.570	0.432
CTV77	x	0.539	0.496	**0.037**
		0.512	0.426	0.391
External contour	x	**<0.01**	**<0.01**	**<0.01**
		<0.01	**<0.01**	**<0.01**
Femur left	x	0.981	0.762	0.221
		0.793	0.223	0.441
Femur right	x	0.516	0.361	0.426
		0.848	**0.014**	**0.035**
PTV70	x	0.557	1.000	0.106
		0.061	0.203	0.100
PTV77	x	0.676	0.215	0.141
		0.594	0.426	0.770
Rectum	x	0.492	1.000	0.607
		<0.01	0.264	0.752

4.2.3 MriPlanner versus bulk density pseudo-CT

The dosimetric data from the W-a and R-a bd-pCTs were compared with the corresponding data from the Mp-pCT. The p-values from this comparison are included in tables 10 and 11, respectively.

Table 10: Table presenting the p-values from the signed-rank Wilcoxon test comparing dosimetric values from the bd-pCT without additional water and without the delineation of adipose tissue (R-a) with the dosimetric values from the Mp-pCT. Values significant on a 5% level are presented in bold.

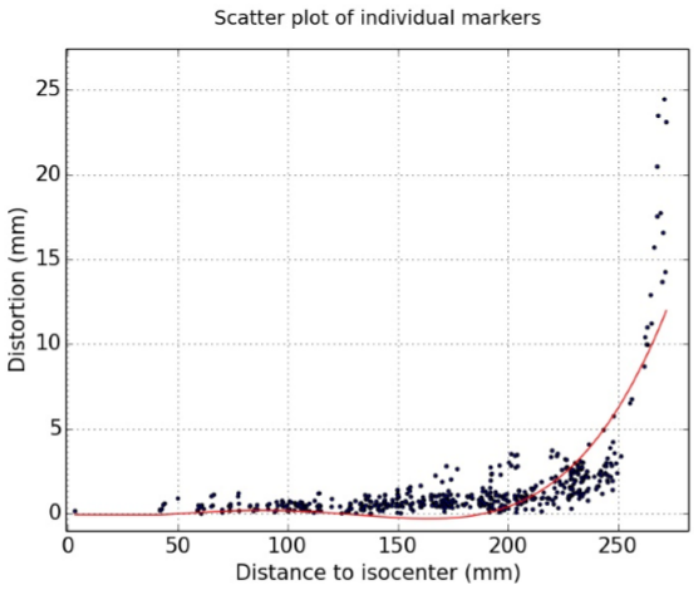
ROI	$\mathbf{D}_{98}$	$\mathbf{D}_{avg}$	$\mathbf{D}_{2}$
Bladder	0.322	0.240	**<0.01**
CTV70	0.490	**0.037**	**<0.01**
CTV77	0.557	**<0.01**	**0.041**
External contour	**<0.01**	**<0.01**	**<0.01**
Femur left	**<0.01**	0.645	0.625
Femur right	0.074	0.826	0.275
PTV70	0.375	0.106	**0.018**
PTV77	**0.049**	0.102	**0.029**
Rectum	0.432	0.232	0.106

Table 11: Table presenting the p-values from the signed-rank Wilcoxon test comparing dosimetric values from the bd-pCT with additional water and without the delineation of adipose tissue (W-a) with the dosimetric values from the Mp-pCT. Values significant on a 5% level are presented in bold.

ROI	$\mathbf{D}_{98}$	$\mathbf{D}_{avg}$	$\mathbf{D}_{2}$
Bladder	1.000	0.275	0.113
CTV70	0.902	0.232	**0.014**
CTV77	0.432	**<0.01**	**0.014**
External contour	0.361	**<0.01**	0.275
Femur left	**<0.01**	0.537	0.492
Femur right	0.080	0.678	1.000
PTV70	**0.049**	0.174	**<0.01**
PTV77	**0.012**	0.123	**<0.01**
Rectum	0.322	0.186	0.082

4.3 Measurements of geometric distortion

Figures 41 and 42 results from one of the automatically generated reports following the upload of one GRADE phantom measurement using the standard T2W MR sequence. The values in the table in Figure 41 were collected for all measurements from all imaging sessions and are included in Appendix D.



	Distance to isocenter (mm)				
	< 100	100-150	150-200	200-250	≥ 250
Worst observed distortion (mm)	1.21	1.21	2.84	5.75	24.44
Mean observed distortion (mm)	0.44	0.48	0.86	1.84	13.88

Figure 41: Screenshot from the first page of the report automatically generated after the upload of an MR scan of the phantom to the Spectronic cloud based software. The report includes a scatter plot and a table, where the scatter plot reports the measured geometric distortion in slices at different distances from the isocenter of the MR scanner. The table presents the mean and worst observed distortion in different distance intervals from the isocenter.

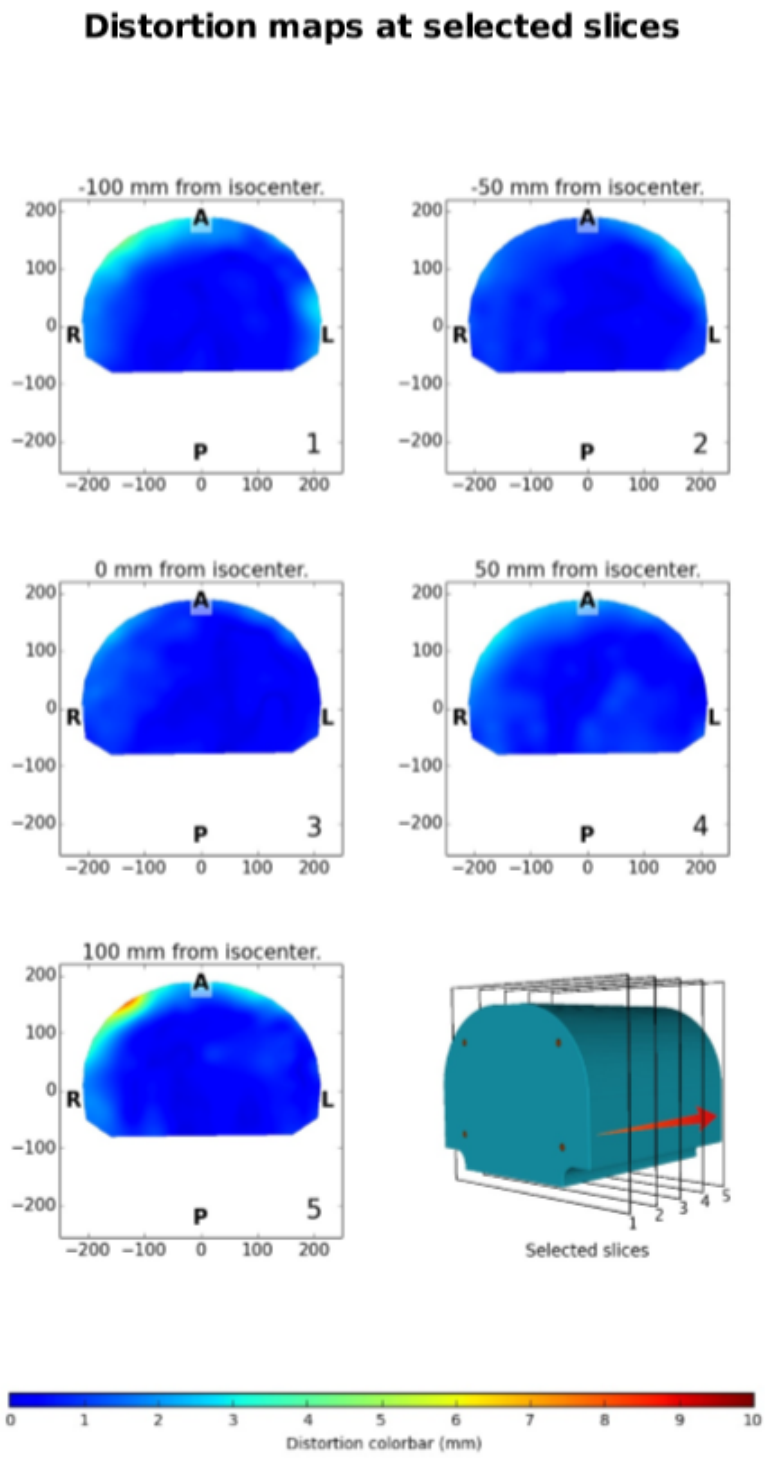


Figure 42: Screenshot from the second page of the automatically generated report following an upload of an MR scan of the phantom to the Spectronic cloud based software. This figure shows the measured geometric distortion in different distances from the isocenter of the scanner, as well as a colorbar which describes the number of mm that each color in the figure represents.

4.3.1 Measured distortion over time

The length (superior-inferior) of the imaged area in the MR used for the pCT generation was measured to equal around 10.83 cm for all patients. As illustrated in the scatter plot in Figure 41, the geometric distortion increases rapidly in slices located around 200 mm from the isocenter of the scanner. To better visualize the geometric distortion in slices located within the distances of clinical interest, only the first three distance intervals (up to 200 mm) are included in the plots of the geometric distortion.

Plots of the worst and mean observed geometric distortion from every imaging session are included in Figure 43. All measurements were acquired using the standard T2W sequence.

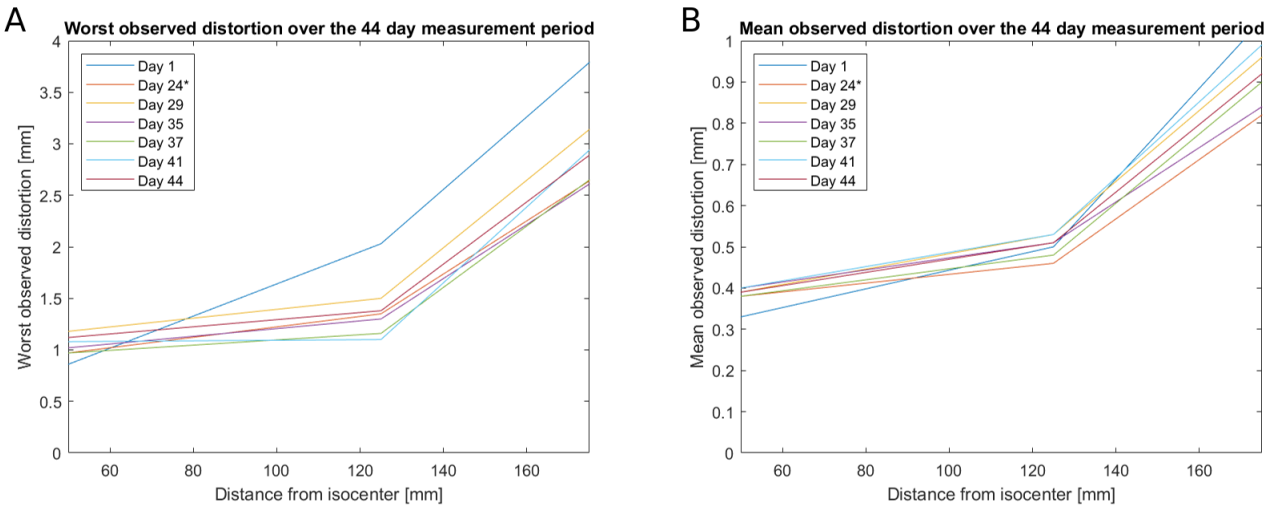


Figure 43: The worst (A) and mean (B) observed geometric distortion for one measurement per imaging session over the 44 day period. The measurements were acquired using the same standard T2W sequence. *Day 24 is measured using a manual set-up, for all other measurements the laser bridge was used to set up the phantom.

4.3.2 Measured distortion from consecutive measurements

The worst and mean observed geometric distortion from two sets of consecutive measurements are included in Figure 44. All measurements were acquired using the standard T2W sequence without moving the phantom.

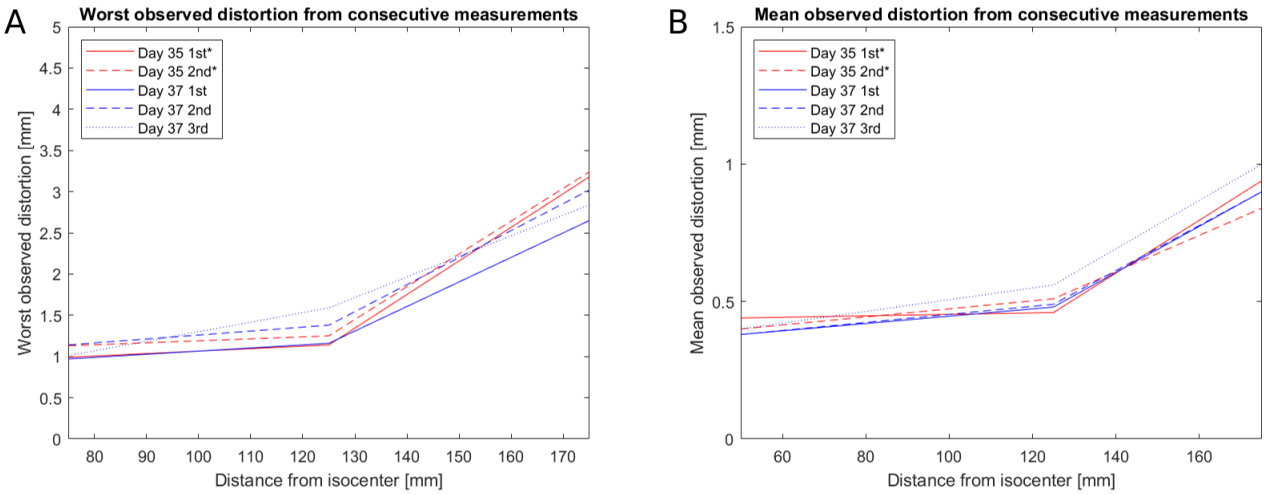


Figure 44: The worst (A) and mean (B) observed geometric distortion from two sets of consecutive measurements. *The measurements from day 35 are based on a manual set-up.

4.3.3 Comparison of two MR sequences

The worst and mean observed geometric distortion from two sets of measurements including both a 3D T2W sequence and the standard T2W sequence are included in Figure 45.

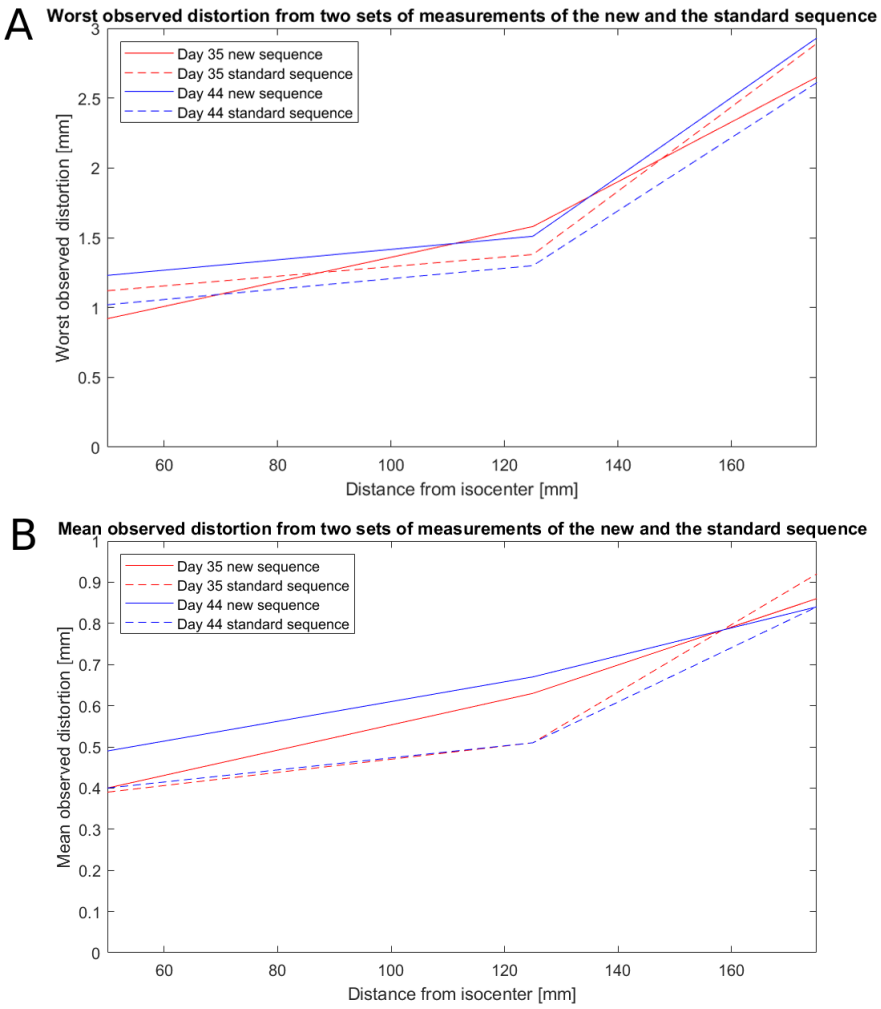


Figure 45: The worst (A) and mean (B) observed geometric distortion from two sets of measurements comparing the new 3D T2W sequence (solid line) and the standard 2D T2W sequence (dashed line).

4.3.4 Measured distortion with manual set-up

Measurements comparing manual and a laser-based phantom set-up is included in Figure 46. Both measurements were acquired on day 35 and based on the standard T2W MR sequence.

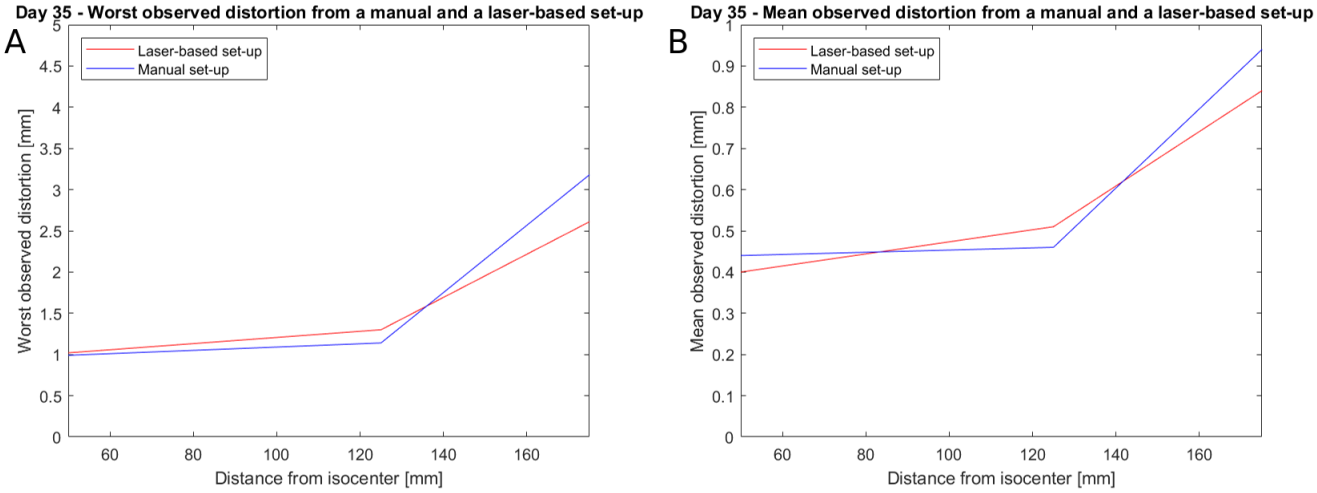


Figure 46: The worst (A) and mean (B) observed geometric distortion from two measurements, where one was a manual and one laser-based set-up, from day 35.

4.3.5 Effect of field of view shift

Figure 47 shows two MR images of the GRADE phantom, with and without a 30 mm anterior FOV shift. With the 30 mm FOV shift, the phantom is more centered in the FOV and all the spheres are entirely visible in the image. The effect of this shift is further studied in Figure 48, where the worst and mean observed distortion of images with and without this FOV shift is included.

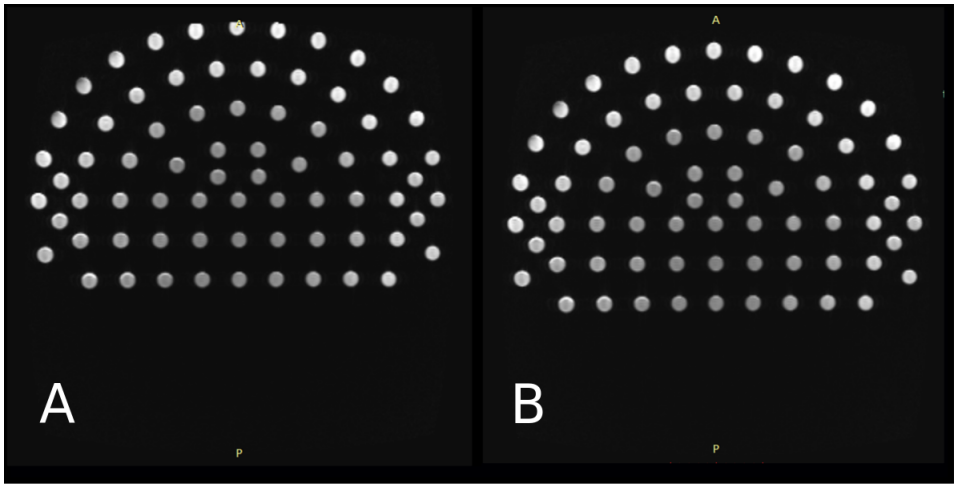


Figure 47: MR images of the GRADE phantom where the effect of a 30 mm anterior shift is illustrated. A) FOV centered at the isocenter of the scanner, and parts of the uppermost spheres are lost in this FOV. B) The 30 mm shift is applied to the FOV and all spheres are fully included in this FOV.

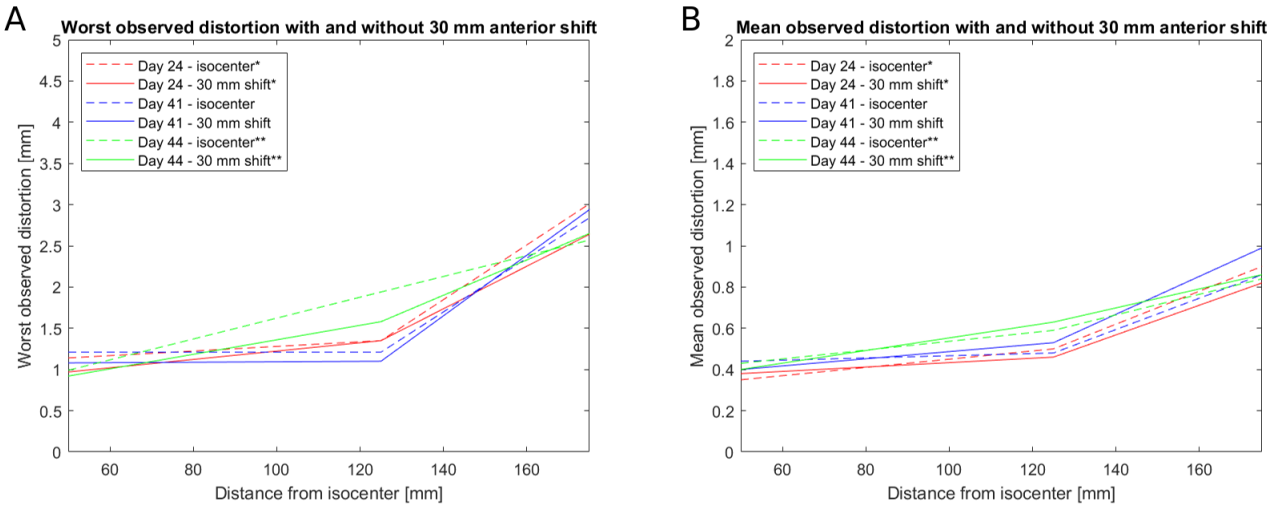


Figure 48: The worst (A) and mean (B) observed geometric distortion from three sets of measurements, where the effect of the 30 mm anterior shift is examined. Dashed lines represent measurements without this shift (FOV centered at scanner isocenter), while the 30 mm anterior FOV shift is added for the solid lines. *Measurements form day 24 are based on a manual set-up. **Day 44 measurements are acquired using the new 3D T2W sequence.

5 Discussion

5.1 Equipment for MR-based radiotherapy

Most of the equipment and software utilized in this thesis (laser bridge, GRADE phantom, GRADE analysis software, MriPlanner and flat table overlay) were new to both NTNU and St.Olavs hospital. MR-only RT is a field of great interest, but it is still relatively new and emerging. This thesis included a lot of firsts for NTNU and St. Olavs hospital, where this thesis for instance was the first to utilize the MR laser bridge on a regular basis, the first to scan and evaluate the GRADE phantom and the first to generate a pCT through MriPlanner.

Originally, the plan was an implementation of the Spectronic software (both MriPlanner and GRADE phantom analysis software) locally at the hospital. Due to the duration of the application processing at the IT department of the Central Norway regional health authority, there was still no implementation date two months before the deadline of this thesis. Spectronic then generated an online access to MriPlanner and the GRADE phantom analysis software which was utilized for this thesis. The delivery of the GRADE phantom itself was also delayed, which was a contributing factor to the relatively short 44-day measurement period, which also included the Christmas holiday.

A variety of different MR imaging sequences were tested in the first scans of the GRADE phantom, in an effort to find a suitable sequence. There were two suggested sequences included in the phantom manual, a T2W SE sequence and a gradient echo sequence, but these were generated for use by another MR vendor and were not replicable with the Siemens Biograph mMR scanner. The first round of uploads contained images from two different MR sequences, which where the closest adaptations to the suggested sequences. After the upload of these MR images to the analysis software an email was sent from the software, explaining that the analysis of the images from both sequences had failed. New sequences were tested and optimized in an effort to generate a FOV which covered the entire phantom. It was speculated that the limited FOV could be the issue as the FOV of the suggested T2W sequence covered the entire phantom. Spectronic were contacted after the second set of sequences also failed to be analyzed, and the support team located some apparent inconsistency in the slice thickness within each scan. There was no reason for such an inconsistency, so the DICOM headers of the MR scans were inspected. The DICOM header variable “Spacing Between Slices” originally had a value of 2.5 mm, which equaled the slice thickness.

It was suggested that this could be the issue, as the analysis software could possibly interpreted this value as a slice gap instead. To test this hypothesis, the value was changed to 0 mm, as there was no such slice gap in reality. After the upload of the same scans with the altered DICOM header, the analysis ran without issues for all sequences. Spectronic was informed of the cause, and was able to implement a solution where the DICOM headers no longer had to be modified.

As mentioned, the laser bridge stopped working for a period between day 1 and 29, causing a pause in the phantom scans within the 44-day measurement period. One set of measurements was still generated in this period, through a manual placement of the phantom. The issue with the laser bridge was resolved, and the laser bridge was used for phantom positioning for all the adjacent phantom scans.

An error in the DICOM header of the Mp-pCTs made the transfer of the Mp-pCTs to RayStation for RTP impossible. With help from the RaySearch support team, the error was identified and fixed through altering the "Rescale Type" in the DICOM header from "US" to "HU". This appeared to be a known issue, and a solution is probably underway or already implemented, making such alterations in the DICOM header unnecessary.

After the work with this thesis, all the RT-spesific MR equipment has been installed and tested. The geometric distortion analysis and the RTP based on pCTs is functioning, and the MR scanner is ready for MR-based RT.

5.2 Pseudo-CT

5.2.1 Bulk density versus MriPlanner approach

From the measurements of the mean absolute dosimetric differences found in Tables 12 to 15 in Appendix C, the two bd-pCTs without the delineation of adipose tissue (W-a and R-a) were found to be the most accurate of the bd-pCTs. The dosimetric differences between each of these bd-pCTs and the opCT were tested for statistical significance against the corresponding values from the Mp-pCT. The rectum and the right femur were the only ROIs where no significant differences were found for either the W-a or the R-a bd-pCT. In addition, there was not found any significant differences from the measurements of the bladder for W-a.

As presented in Table 10 and Figure 33, the Mp-pCT produced a signif-

icantly higher dosimetric accuracy from the external contour compared to the R-a bd-pCT measurements. The D_{avg} dose to the external contour from the W-a bd-pCT was however still found to be significantly more accurate than the Mp-pCT, but there was no significant difference for the D_{98} or D_2 values. Although it is possible to include an additional density to increase the size of the external contour of the Mp-pCT, this would induce extra steps in the Mp-pCT based workflow. In this workflow the pCT is intended to be ready for RTP directly after the generation.

In general, the Mp-pCT was found to be significantly more accurate than the R-a bd-pCT for at least one of the DVH values of the following ROIs: bladder, CTV70, CTV77, external contour, PTV70 and PTV77. The Mp-pCT was significantly more accurate than the W-a pCT for at least one DVH value of the following ROIs: CTV70, CTV77, PTV70 and PTV77. In Tables 10 and 11 significant differences were also found for the D_{98} dose comparison between the Mp-pCT and the bd-pCT for the left femur, but as presented in Figure 34 the dosimetric difference is very small. Although the statistical data in this thesis was based on a small number of patients and multiple uncertainties were involved, the data clearly indicates an increased dosimetric accuracy in the Mp-pCTs compared to these bd-pCTs for the majority of the ROIs.

There are different studies comparing the dosimetric accuracy of different pCTs, but there are, to the author's knowledge, no studies where bd-pCTs are compared to pCTs generated from the MriPlanner. The dosimetric accuracy of the MriPlanner software has however been tested in the larger MR-OPERA study [24], where the differences between the Mp-pCT and the opCT were found to be negligible when compared to other uncertainties in RT.

5.2.2 Delineation of adipose tissue

The decreased geometric accuracy of bd-pCTs with the delineated adipose tissue compared to the bd-pCTs without the delineation, presented in the boxplots in Figures 30 to 38, indicates the accuracy of the pure grayscale based delineations of the adipose tissue was not sufficient. An examination of the D_2 values in Table 8 shows that the bd-pCTs with the adipose tissue delineation produced significant effects for all but one measurement, where only the comparison of the rectum (R+a vs. R-a) did not result in a significant difference. This measurement still resulted in a close-to-significant difference (p-value of 0.084). Every dose measurement of the target volumes,

meaning both CTVs and both PTVs, showed a significant decrease in dosimetric accuracy for the bd-pCT where the adipose tissue was delineated.

From the D_2 comparison of the femurs in Figures 34 and 35, the addition of the adipose tissue was found to slightly improve the dosimetric accuracy for both the W and R measurements. Still, as the dosimetric accuracy of all other ROIs decreased with the inclusion of adipose tissue delineation, the accuracy of the delineation would have to be improved to be dosimetrically advantageous.

For the grayscale-based adipose tissue delineation used in the bd-pCT generation in this thesis, the misclassification of pelvic bone as adipose tissue could be a contributor to the decreased dosimetric accuracy found from these bd-pCTs. The femurs were the only bones which were delineated and assigned separate densities in the MR images, so other small bony structures were classified as adipose tissue based on their grayscale value. Still, as these smaller bones were only present in a few MR slices, and the difference between the two assigned densities (adipose tissue (+a) and WE (-a)) was only 0.05 g/cm^3, other effects are probably also contributing.

Although the addition of adipose tissue was not found to improve the dosimetric accuracy of the bd-pCTs, adipose tissue is commonly included in atlas-based pCT generation [25]. As the atlas-based methods are usually based on machine learning, the density information is automatically assigned to each voxel. The machine recognizes probable regions of adipose tissue from the atlas-patients, and through such an approach, most of the issues related to the misclassification of adipose tissue should be avoided. As the atlas-based method was found to be of higher dosimetric accuracy compared to the bd-pCTs, the inclusion of adipose tissue delineations in the bd-pCT could perhaps still improve the dosimetric accuracy of the bd-pCT if generated through a more precise method.

5.2.3 Effect of additional water

The addition of water resulted in a decrease in the dosimetric difference in the slices imaged in Figure 40. As presented in Table 9, the addition of the WE density to increase the external contour resulted in significant dosimetric differences between the R and W bd-pCTs. As expected, the addition of WE density resulted in a significant increase in the dosimetric accuracy from the external contour for all measured DVH values. The effect on the other ROIs was however more varied, where the addition of water was found to signifi-

cantly decrease the dosimetric accuracy for one measurement of the rectum (D_{98}-a), two of the bladder (D_{98} ±a) and one of the CTV77 (D_2+a), while also significantly improving the accuracy for two measurements of the right femur (D_{avg}-a and D_2-a). However, although there are significant differences, the differences are still very small when examined in Gy.

Based on the strong increase in dosimetric accuracy of the external contour found in Figure 33, it could be seen as beneficial to increase the size of the patient contour through addition of pieces of WE density. However, as the dosimetric accuracy of some ROIs was negatively impacted from this addition, the effects should be further studied before the addition of water to the external contour can be recommended for the pCT generation.

5.2.4 Methodology

Firstly, it is important to state that the low number of patients included in the pCT generation and comparison of this thesis does impact the validity of the results. Several uncertainties are involved, such as the manual organ delineation, the choice of density values, and the difference in organ positioning between the acquisition of the opCT and the MR. The effects of these uncertainties are discussed below.

The volumes of all OARs used for the bd-pCTs were manually delineated by a student without any experience. This was also the case for the femurs included the Mp-pCT. The ROI delineation should still be relatively consistent for all patients, as there delineations for all patients were generated by this one student. The bd-pCTs were generated through delineation and assignation of densities to a limited number of ROIs. Only two densities were actually assigned to the two -a type bd-pCTs, namely a density for the femurs and the WE density which was assigned to everything but the femurs. As the assigned densities were applied to the entire ROI, there were no density variations depending on whether the slice in question contained the middle or the outermost part of a ROI. This effect is particularly relevant for bony structures such as the femur, where the entire femur was assigned the same density whether the imaged part of the bone was thin or thick, solid or porous.

The delineation of a higher number of structures, and thereby a more diverse density distribution, could possibly lead to a more accurate pCT. However, as long as the delineation process is not automated, the extra delineations could complicate the pCT generation and result in a high time consumption per pCT.

After a brief examination of CT images of two prostate cancer patients which where not included in the thesis, a density value of 1.3500 g/cm^3 was assigned to the femurs for the bd-pCTs. This value was also one of the standard values available for bones in RayStation (referred to as "Cartilage2 Bone1" in RayStation). Other studies have used values ranging from 1.1900 g/cm^3 to 2.0000 g/cm^3 assigned to the femurs for bd-pCT generation, so the value chosen in this thesis is in the lower end of the spectrum [25]. The choice of this density does however seem reasonable, as the highest difference between the dose values from the bd-pCTs and the opCT is, as shown in Figures 34 and 35, found to be around 1.4 Gy.

Both CT and T2W MR images were necessary for the RTP in this thesis. A registration between the images from the two modalities was required to transfer delineations of different ROI volumes between the opCT and the pCTs. The target volumes were transferred from the opCT to the pCT and the OARs were delineated on the pCT and transferred back to the opCT to perform dose calculations. The MR images utilized in this part of the thesis where acquired with the patient positioned on a standard curved MR patient table, while the patient was placed on a flat table for the CT scan. This difference in positioning affected the placement of the different ROIs and thereby the accuracy of the dose comparison between the opCT and the pCT, as the ROIs were delineated on the MR images and later remapped back to the opCT. Another issue which further contributed to the decreased accuracy of the dose comparison was a difference in rectal and bladder filling between the MR and the CT scan. Some patients were also bloated during the acquisition of one image scan compared to the other. As the different degrees of bloating between the scans mainly affected the external contour and not the organ positioning, no patients were excluded based on this alone.

The accuracy of the dose comparison of the Mp-pCT and the bd-pCTs would probably be improved if the same ROIs were used for both the bd-pCT and the Mp-pCT. By utilizing the same ROI delineations for both the bd-pCT and the Mp-pCT, the ROI volumes would also be identical on the opCT for the pCT versus opCT dose comparisons. Such an approach would result in the potential for a pure voxel-by-voxel comparison of the density information. Nevertheless, as the long term goal for the MriPlanner is to be implemented into a clinical workflow, the ROI delineations which were generated by MriPlanner were used in this thesis. Also, the delineations from the MR images would not necessarily be a perfect match to the structures imaged in the Mp-pCT, since the Mp-pCT is generated through an atlas based on a number

of CT images. It is also known that the observed size of organs can vary depending on the image modality, where the size of bones in particular can vary between MR and CT.

The DVH values included in this thesis (D_{98}, D_{AVG} and D_2) is not necessarily the most clinically relevant values for each ROI. The values were chosen in an effort to get an overview of the dosimetric differences at a variety of dose levels, where both high, intermediate and low doses were included. Specifically, the range of dose levels was important to examine of the effect of the adipose tissue delineation and the addition of WE pieces to the external contour.

For a single patient, the RTP based on the regular sized bd-pCTs (R+a and R-a) did not fulfill the clinical goal of 66.50 Gy delivered to 98% of the PTV70. This patient was still included as this was the only ROI where the clinical goal was not met, and the three remaining pCTs resulted in acceptable RT treatment plans. Still, as the D_{98} value of the PTV70 was not sufficient, this could have affected the statistical testing of this parameter between the different pCTs. However, no significant difference was found between the Mp-pCT and the R-a bd-pCT for the D_{98} value of the PTV70. The W-a bd-pCT treatment plan, where all clinical goals where met, did however show a significant difference for the D_{98} value of the PTV70 in the comparison between the Mp-pCT and the bd-pCT.

Some of the dosimetric differences found between the pCTs and the opCT for the rectum could perhaps be caused by differences in density overrides. Since the rectum is a important dose-limiting organ in a prostate RT [26]. The radiation can damage normal tissue and severely affect the patients quality of life [26]. The existence of air filled pockets in the rectum can lead to dose buildup effects and thereby a further increase in radiation damage to the healthy tissue of the rectum. The entire inside of the rectum was assigned WE density in the bd-pCTs, and while the rectum was also automatically assigned WE density during the Mp-pCTs generation [21], no density overrides were performed for the opCTs.

5.3 Geometric distortion

5.3.1 Observed distortion over time

The measurement that stands out compared to the others in Figure 43, is the measurement from day one. Why this first measurement included such a distinct amount of geometric distortion compared to the rest of the measure-

ments is unknown. After this first measurement, the laser bridge used for positioning was down for a while due to some software issue, which is why the next scan (day 24) is based on a manual set-up. The laser bridge was later fixed, and the remaining scans were all acquired with the laser bridge used for phantom positioning. As the problem with the laser bridge was only related to the software, the laser bridge should provide identical positioning references for all measurements, including day one.

As mentioned, there was an issue related to the analysis of the first phantom scan, where the Spectronic analysis software did not accept all values included in the DICOM header of the phantom scan. In an effort to make the analysis software accept the scans, one value from the header was altered as described in section 5.1. It is however not very probable that this caused the issue, as the alteration of this value only removed a (in reality already non-existent) slice gap.

Since it is the first measurement that stands out compared to the rest, it is possible that there were some user generated error involved. Still, this scan was based on the same MR sequence as the rest of the measurements, the phantom was positioned by the same laser bridge and the distortion analysis process is fully automated. So there are not really many opportunities for human error involved in the distortion analysis. One remaining answer is perhaps that the discrepancies compared to the rest of the scans are purely random, but as the remaining six scans generate such a coherent image of the distortions it seems a bit odd that a random effect would result in such an impact.

Another interesting observation from Figure 43 is the measurements from day 24, where the laser bridge was not utilized. The manual set-up on day 24 results in the smallest mean observed distortion for isocenter distances above about 95 mm, and only the measurement from day one generates a lower distortion at isocenter distances smaller than 95 mm. The worst observed geometric distortion from the manual set-up is also in the mid range between the different laser bridge-based measurements.

5.3.2 Distortion in consecutive measurements

The mean observed geometric distortion from the consecutive scans from day 35 and 37, presented in Figure 44, showed interesting results. The first and second scan from day 37 resulted in an almost identical degree of distortion, while the amount distortion in the third scan was notably higher for all

isocenter distances. On day 35, there is an alternating tendency for which of the two scans produces the highest mean observed distortion for the different isocenter distances.

The worst observed distortion from these measurements again shows a high geometric distortion from the third scan from day 37. This does however shift from around 150 mm isocenter distance, where the third scan produces a lower distortion than all but the first from day 37.

Although it is hard to conclude from these two sets of measurements alone, there seems to be some random effects which affect the amount of the geometric distortion in an MR scan. These random effects seems to generate a difference in the worst geometric distortion of about 0.2 mm, at the isocenter distances from the MR scans used for pCT generation in this thesis (max around 54.15 mm in each direction). Although this probably would not cause issues related to RT, it would be interesting to study this effect further as there were few measurements included in this thesis.

5.3.3 Sequence dependency

A 3D MR sequence with an isotropic voxel size, meaning that the length of the voxel is equal in all three directions, provides the same image quality in the three planes. The fact that the voxels are isotropic means that there are no slice-gaps in any plane, which makes 3D MR sequences great for RT, as the delineation of ROIs is possible within any plane. The standard T2W sequence used in this thesis is a 2D MR sequence, while the second T2W sequence is a 3D MR sequence. Both of the sequences are clinically used for pelvic imaging with a relatively large FOV. However, as there were only two sets of measurements and only these two sequences were included, further studies are needed to state whether there are systematic differences between 2D and 3D MR sequences, or just these particular sequences.

Still, the measurements from day 35 and 44 indicate that there could be a sequence dependency for the geometric distortion. The mean observed geometric distortion in Figure 45 was found to be higher for the 3D MR sequence for isocenter distances between 80 and 150 mm. As there were relatively large differences between the two 3D sequence measurements, it is hard to conclude anything from these two sets of measurements alone. Torfeh et al. studied the geometric distortion from a variety of MR sequences, although with a different phantom, and also found differences depending on both the sequence weighting and 2D versus 3D sequences [27]. If a clear

sequence dependency is found for the amount of geometric distortion, this could be an important factor affecting which sequences are included in a future set of standard sequences for MR-only RT.

5.3.4 Effect of shift in field of view

As seen in Figure 47, the 30 mm anterior FOV shift places the phantom closer to the center of the FOV and thereby includes also the most distant spheres entirely within the FOV. As the analysis is automated, it is not entirely clear how the system reacts to the spheres located at the uppermost part of the phantom (in an anterior-posterior view such as in Figure 47), which are not fully included in the image without the FOV shift.

From Figure 48, the addition of a 30 mm anterior FOV shift seems to decrease the worst observed distortion for both the 2D and 3D MR sequences over all measurements until around 130 mm from the isocenter of the MR scanner. After this point the observed distortion seems to be similar with and without the addition of this FOV shift. The mean observed geometric distortion measurements are less clear in regards to the effect of the 30 mm FOV shift. The measurement from day 41 shows a higher amount of distortion from the shifted measurement at almost every isocenter distance, while the opposite is found in the measurement from day 24. Further studies are needed to get a better understanding of the effect of the FOV shift on the geometric distortion.

5.3.5 Set-up sensitivity

The set of measurements of the geometric distortion following a manual set-up versus a laser bridge-based phantom set-up, presented in Figure 46, shows small distortion differences between these set-ups (0.1 mm mean and 0.57 mm worst, both at 175 mm distance). As indications of random effects were found from other sets of measurements, the measured distortions from this lone measurement set cannot be deemed very trustworthy. Still, it could be interesting to study the effect of the set-up sensitivity further. If larger sensitivities are found, this could be important as the GRADE phantom scan would probably be included in a QA procedure to monitor the geometric distortion for the use of MR in RT.

Whyatt et al. [2] tested the set-up sensitivity of multiple GRADE phantoms on three different MR systems, including a PET/MR system. From their measurements, they reported an increased sensitivity for rotations compared

to lateral offsets, and advised a careful set-up to ensure the repeatability of the distortion measurements. This should be taken into account if analysis based on the GRADE phantom is included in a QA routine for MR-based RT.

5.3.6 Methodology

The relatively low number of measurements of the geometric distortion and the inconsistent time between each of these, were related to both the delayed phantom delivery and issues with both the laser bridge and the GRADE analysis software. A higher number of measurements acquired on a more consistent basis would provide more detailed information about the geometric distortion over time, and perhaps identify trends.

Ideas and suggestions of different effects that could be of interest for distortion measurements appeared during the measurement period of this thesis. This is another contributing factor to the few measurements available for the examination of some of these effects. Although the small number of measurements often makes room for uncertainties, these measurements and effects are still included in this thesis in an effort to highlight them and thereby hopefully encourage a new, larger study.

Only the geometric distortion at isocenter distances below 180 mm were studied in this thesis, although measurements from slices located further than 250 mm from the isocenter were included in the reports produced by the analysis software. The amount of geometric distortion was found to increase rapidly with the increased distance to the isocenter. As the MR images used for pCT generation were measured to around 10.83 cm in length (interferior-superior), the isocenter distances between 50 mm and 175 mm were the focus of this thesis. Through the removal of the measurements from the largest isocenter distances, the differences in geometric distortion at the more clinically relevant isocenter distances became more easily visible.

5.4 Clinical implications

The generation of both the R-a bd-pCT and the Mp-pCT is relatively easy. For the generation of the R-a type bd-pCT the only required work is the delineation of the hip bones, as the rest of the patient is assigned WE density. The MriPlanner software generates the pCT with additional ROI delineations automatically, so the most difficult part in relation to this is software is the implementation into the hospital systems. The bd-pCTs can be generated directly inside the existing RTP software, avoiding the need for any additional software.

Although the generation of the pCTs can be somewhat time consuming, the pCT generation can begin as soon as the T2W MR images are acquired. The cloud based MriPlanner software used in this thesis requires between 50 and 80 minutes per generated Mp-pCT, but with a locally installed version of this software, the time required per Mp-pCT generation is reported to be less than 15 minutes. The time required for the bd-pCT generation depends on the experience of the delineator and the number of delineated ROIs. With an MR-only treatment approach, there is no need to wait for images from a second modality, and the RTP could begin less than 15 minutes after the MR.

If patients did no longer require a CT for the RTP, there would be more open time slots at the CT. The patients would also receive a lower total dose to the healthy tissue, both from avoiding the dose from a CT and probably, through a more precise organ delineation, a more precise treatment dose delivery.

An implementation of an MR based RT workflow would however increase the demand for MR scans and might create the need for additional MR scanners dedicated solely to RT. Such an increased use of MR in RT would also generate a need for different work constellations, further education of the RT staff members or perhaps also additional staff members. If all RT treatments were to be based on MR, the RT-specific MR equipment would also have to be purchased and installed at more MR scanners. So compared to the CT based RTP that is common today, the transition to an MR based RTP protocol for all RT patients would require further investments in both personnel and equipment.

As the geometric distortion is a large concern for MR-only RT, a utilization of the GRADE phantom to identify MR sequences with the lowest possible amount of geometric distortion for each image region would be ideal before

the start of an MR-only regime. All equipment involved in the RTP and the RT treatment delivery should be tested regularly to ensure a sufficient accuracy. The GRADE phantom can be used to measure the scanner accuracy over time, through a regular QA measurement regime. The analysis of the GRADE phantom data is however a bit time consuming, which is not ideal if such an analysis should be included in a daily QA regime and the distortion measurements needs to be evaluated before any imaging. As Whyatt et al. [2] reported a sensitivity in the GRADE phantom measurements related to rotation, this also has to be regarded in a QA regime. Still, as the analysis software is based on artificial intelligence, the time consumption could be decreased as the technology is further developed. The utilization of a laser bridge for phantom placement should also limit the rotation in the phantom set-up.

5.5 Suggestions for future work

As this thesis only included 10 patients and there were multiple uncertainties, it would be very interesting to repeat at least parts of the measurements in a more focused study with a higher number of patients. It would also be beneficial to minimize the difference in bladder/rectal filling by limiting the time between the MR and CT image acquisition. Further improvements of such a study could be achieved by performing the MR image acquisition on a scanner equipped with a flat patient table and a laser bridge positioning system in an effort to optimize the patient positioning.

The effect of the additional 5 cm of WE density applied to the external contour of the bd-pCT seemed to improve the dosimetric values for the contour. However, choice of 5 cm additional length was chosen as a random test value. If the effect of additional water is deemed beneficial in a larger study, an effort should be made to quantify the optimal size of the additions. Examining the effect of matching the interior-superior length of the external pCT contour to the length of the opCT contour could be an interesting starting point.

Although the inclusion of adipose tissue did not improve the accuracy of the bd-pCTs generated in this thesis, the addition of the adipose tissue delineation could be interesting if measured for a larger group of patients and through a different ROI generation. Perhaps an inclusion of only the subcutaneous fat could be beneficial for the dosimetric accuracy of the bd-pCTs. A simple support volume could be delineated which covered the central bright appearing parts of the pelvis, such as the femurs, the pelvic bone, the bladder and the area surrounding the rectum. As this structure only needs to cover

these ROIs without covering the subcutaneous fat, it would be very quick to delineate, even for inexperienced users. The subcutaneous fat could then be delineated through an initial grayscale delineation followed by a subtraction of the support volume through ROI algebra.

Performing both the CT and MR imaging in the treatment position with the laser bridge used for patient positioning would reduce the differences in the delineation of both the external contour and the internal OARs. If the geometric distortion is also monitored and minimized, the delineation differences should be minimized. If there still are differences in the external contour, a possibility is to map the external contour from the image modality where it is largest (in this case the CT scans) onto the images from the other image modality. The resulting gap between the actual size of the contour and the new mapped structure could be assigned a density, for instance WE. This would result in the same size contour for all the pCTs and the opCT.

A more varied set of DVH values could be examined for a more clinical test of each pCT. In such an approach the set of DVH values could be chosen specifically for each ROI. An example of such values is D_{99} (prostate CTV), $V_{95\%}$ (the volume receiving 95% of the dose, relevant for prostate PTV), V_{70Gy} (the volume receiving a dose of 70 Gy, relevant for the rectum), V_{50Gy} (the volume receiving a dose of 50 Gy, relevant for the bladder) and D_{max} (the highest dose, relevant for both the bladder and rectum), as suggested by Largent et al [28].

As MR-based RT is an area of great interest, there are a variety of different in-house generated methods of pCT generation which are developed and studied. One interesting pCT generator is developed by Largent et al [28], which developed a patch-based pCT generator. This patch-based method generated pCTs of higher dosimetric accuracy compared to bulk density and atlas-based pCTs. Testing new methods, such as this patch-based method, or generating own methods could be interesting for research purposes. Using machine learning to develop methods for atlas-based pCT generation seems particularly promising.

Measurements of the geometric distortion performed on a more consistent basis would probably be beneficial. As random effects seemed to impact the measured values, a high number of consistent measurements seems necessary to obtain a clear image of the geometric distortion over time. Multiple measurements are also needed to obtain a detailed understanding of the dependency between the observed distortion and different variables such as set-up

accuracy and choice of MR sequence. The distortion data from the GRADE phantom measurements could be studied more in-depth, as only the table values of mean and worst observed distortion was utilized in this thesis. A programming code could be developed to utilize the information from the zip file generated with the report. From this, a more defined range of clinically interesting isocenter distances could be studied more closely. One could also choose smaller distance increments than the 50 mm increments given in the mean and worst observed distortion values from the report.

To examine the effects of geometric distortion focused on RT, measurements of the geometric distortion from a range of the MR sequences commonly used for large FOV imaging clinically could be performed. From such measurements acquired over time, a list of the most scanner specific ideal MR sequences could be developed. Such measurements could also be performed for a comparison of 2D and 3D sequences.

6 Conclusion

In this master thesis, the equipment required for MR-based RT was purchased, installed and tested. Any issues related to implementation of the new equipment was reported to the developers and later solved, and the pipeline for MR-based RT has therefore been established.

The atlas-based MriPlanner software and a bulk density-based approach generated in RayStation were used to generate pCTs for ten prostate cancer patients. Retrospective RTP was then performed based on the generated pCTs. The dosimetric accuracy of each pCT was compared, where the opCT was used as the reference for geometric accuracy. The atlas-based approach was found to generate pCTs of higher dosimetric accuracy compared to the bulk density-based pCTs.

In MR-based RT, geometric distortions in the MR images are a concern for precise volume delineation and dose calculations in pCTs. To ensure geometric accuracy in the MR images, the geometric distortion should be assessed and monitored over time. The geometric distortion was measured by imaging the GRADE phantom and uploading the images to a cloud-based analysis software. Measurements over a 44-day period showed minor variations, whereas analysis of repeated daily scans where the phantom was not moved revealed small geometric distortions assigned to random effects. Further studies of the geometric accuracy with the GRADE phantom is recommended, both to become more familiar with the phantom and the analysis software, and also to monitor any geometric distortions to ensure sufficient accuracy for MR-based RT.

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A Appendix A

The following pages contains the Phyton code developed by RaySearch for transfer of beam-sets from the pCT to CT.

```
from connect import *
import wpf, clr
clr.AddReference("System.Xml")
clr.AddReference("System.Windows.Forms")
from System import (DateTime, Windows, Globalization, IO, ComponentModel)
import sys, os
from System import Collections
from System.Collections.ObjectModel import ObservableCollection
from System.Windows import MessageBox
from System.Windows import Application, Window

from System.IO import StringReader
from System.Xml import XmlReader


xaml = """<Window xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
      xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
      Width="400"
      Height="300"
      WindowStyle="ToolWindow">
 <DockPanel LastChildFill="True">

   <Grid>
    <Grid.ColumnDefinitions>
     <ColumnDefinition Width="200"/>
     <ColumnDefinition Width="*"/>
    </Grid.ColumnDefinitions>
    <Grid.RowDefinitions>
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="Auto" />
     <RowDefinition Height="*" />
    </Grid.RowDefinitions>

    <!--               ROW 0                    -->
    <TextBlock Grid.Row="0" Grid.Column="0" Margin="5" Text="Planning image:"/>
    <TextBlock Grid.Row="0" Grid.Column="1" Margin="5" Name="PlanImage"/>
    <TextBlock Grid.Row="1" Grid.Column="0" Margin="5" Text="Plan:"/>
    <TextBlock Grid.Row="1" Grid.Column="1" Margin="5" Name="Plan"/>
    <TextBlock Grid.Row="2" Grid.Column="0" Margin="5" Text="CT image to compute dose on:"/>
    <ComboBox Grid.Row="2" Grid.Column="1" Margin="5" Name="CtImage"/>
```

```
    <Button Grid.Row="7" Grid.Column="0" Grid.ColumnSpan="2" Content="Compute dose"
Margin="5" Width="100" Height="40" Name="ButtonCompute" HorizontalAlignment="Right"
VerticalAlignment="Bottom"/>

   </Grid>
  </DockPanel>

</Window>"""


xr = XmlReader.Create(StringReader(xaml))

missing_parameters_message = "Missing input parameters"
closing_message = "Final output"
setup_message = "Wrong setup"

class MyWindow(Window):

  def compute_dose_clicked(self,sender, event):

    self.ct_image_name = self.CtImage.SelectedItem
    if self.ct_image_name is None:
      MessageBox.Show("No CT image has been selected.",missing_parameters_message)
      return

    self.fraction_dose_values =
self.plan.BeamSets[0].FractionDose.GetTransformedAndResampledDoseValues(DoseGrid =
self.plan.BeamSets[0].FractionDose.InDoseGrid)
    if len(self.fraction_dose_values) == 0:
      print("no dose values")
      sys.exit()

    for roi in self.case.PatientModel.RegionsOfInterest:
      if roi.RoiMaterial is None:
        continue
      roi.SetRoiMaterial(Material = None)

    self.plan.BeamSets[0].ComputeDoseOnAdditionalSets(ExaminationNames=[self.ct_image_name],
FractionNumbers = [0])
    self.plan.BeamSets[0].FractionDose.SetDoseValues(Array = self.fraction_dose_values,
CalculationInfo="")
    MessageBox.Show("Dose has been computed.",closing_message)

    self.Close()


  def __init__(self):
    wpf.LoadComponent(self,xr)
```

```
    self.Title = "Compute dose on CT image using densities from the image"
    self.patient = ""
    self.case = ""
    self.examination = ""
    self.plan = ""
    try:
      self.patient = get_current("Patient")
    except:
      MessageBox.Show("You need to have a patient open.",setup_message)
      sys.exit()
    try:
      self.case = get_current("Case")
    except:
      MessageBox.Show("You need to have a case open.",setup_message)
      sys.exit()
    try:
      self.plan = get_current("Plan")
    except:
      MessageBox.Show("You need to have a plan selected.",setup_message)
      sys.exit()
    try:
      self.examination = self.plan.BeamSets[0].GetPlanningExamination()
    except:
      MessageBox.Show("You need to have an examination selected.",setup_message)
      sys.exit()

    if self.plan.BeamSets[0].GetPlanningExamination() != self.examination:
      MessageBox.Show("Selected examination should be the same as the planning image for the
selected plan.",setup_message)
      sys.exit()

    self.structure_set = self.case.PatientModel.StructureSets[self.examination.Name]

    self.PlanImage.Text = self.examination.Name
    self.Plan.Text = self.plan.Name
    self.CtImage.ItemsSource = [exam.Name for exam in self.case.Examinations if
exam.EquipmentInfo.Modality == "CT"]
    self.ButtonCompute.Click += self.compute_dose_clicked


if __name__ == "__main__":

  Application().Run(MyWindow())
```

B Appendix B

B.1 MriPlanner-based pseudo CT data

All the ROI names starting with "CT" are the automatically delineated volumes from the MriPlanner software. As the treatment plans used adaptions of previous tumor volumes, certain names are not correct. In this section, the abbreviations mean:
bla - bladder
FHL - left femur
FHR - right femur
rec - rectum
CTV70-78 - CTV77
CTV70eks - CTV70
PTV70-78 - PTV77
PTV70eks - PTV70
Some figures also include CTV0-70 and PTV0-70 which were old treatment volumes which where not studied in thesis. The evaluation dose of the external contour is marked in orange because the external contour of the opCT is larger than the external contour of the pCTs.

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside grid
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: pCT150 (CT...	CT BLA	193.87	4.09	4.38	4.91	38.40	35.93	78.37	79.30	0 %
Evaluation dose (pCT1...	CT BLA	200.79	3.84	4.14	4.64	36.91	34.06	77.42	78.36	0 %
Plan dose: pCT150 (CT...	CT FH L	167.24	0.35	0.45	0.74	14.23	16.99	33.69	34.94	0 %
Evaluation dose (pCT1...	CT FH L	168.22	0.58	0.63	0.74	14.61	17.11	35.28	36.64	0 %
Plan dose: pCT150 (CT...	CT FH R	174.37	0.38	0.64	0.85	16.07	19.04	32.42	33.60	0 %
Evaluation dose (pCT1...	CT FH R	174.53	0.62	0.68	0.84	16.37	19.31	32.95	34.20	0 %
Plan dose: pCT150 (CT...	CT REC	56.27	4.51	5.40	8.58	30.34	23.15	73.28	75.20	0 %
Evaluation dose (pCT1...	CT REC	56.14	4.48	5.39	8.52	30.38	23.03	73.18	75.31	0 %
Plan dose: pCT150 (CT...	CTV 70-78	33.01	75.95	76.10	76.36	77.25	77.27	78.35	78.46	0 %
Evaluation dose (pCT1...	CTV 70-78	33.01	75.17	75.35	75.61	76.63	76.68	77.67	77.80	0 %
Plan dose: pCT150 (CT...	CTV 70eks	7.39	74.08	74.60	75.53	78.99	79.31	82.18	82.22	0 %
Evaluation dose (pCT1...	CTV 70eks	7.39	73.53	73.90	74.82	78.53	78.83	81.74	81.91	0 %
Plan dose: pCT150 (CT...	External	5791.84	0.44	0.57	0.85	16.62	12.39	75.56	77.31	0 %
Evaluation dose (pCT1...	External	6405.15	0.56	0.66	0.87	15.35	10.23	74.30	76.64	46 %
Plan dose: pCT150 (CT...	PTV 70-78	82.08	74.06	74.66	75.38	77.19	77.19	80.24	81.02	0 %
Evaluation dose (pCT1...	PTV 70-78	82.08	73.41	74.02	74.74	76.62	76.62	79.63	80.40	0 %
Plan dose: pCT150 (CT...	PTV 70eks	73.49	66.27	67.55	69.04	75.60	76.22	81.32	81.71	0 %
Evaluation dose (pCT1...	PTV 70eks	73.49	66.03	67.22	68.69	75.19	75.72	81.30	81.63	0 %

Figure 49: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 150.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT159 (CT...	CT BLA	92.31	5.65	6.24	7.92	28.25	21.70	78.70	79.50	0 %
Evaluation dose (pCT1...	CT BLA	96.88	5.06	5.60	6.73	27.04	20.84	77.86	78.72	0 %
Plan dose: pCT159 (CT...	CT FH L	196.22	0.41	0.67	0.90	14.33	17.11	28.84	29.83	0 %
Evaluation dose (pCT1...	CT FH L	196.83	0.64	0.71	0.87	14.23	16.92	28.94	29.96	0 %
Plan dose: pCT159 (CT...	CT FH R	200.45	0.41	0.71	0.95	14.77	17.61	28.23	29.20	0 %
Evaluation dose (pCT1...	CT FH R	201.07	0.66	0.74	0.93	14.64	17.52	28.05	29.07	0 %
Plan dose: pCT159 (CT...	CT REC	70.11	2.85	3.15	4.04	33.97	26.93	79.09	80.27	0 %
Evaluation dose (pCT1...	CT REC	70	2.85	3.17	4.04	33.75	26.72	78.56	79.70	0 %
Plan dose: pCT159 (CT...	CTV 0-70	35.19	74.64	75.07	75.69	77.30	77.32	79.73	80.49	0 %
Evaluation dose (pCT1...	CTV 0-70	35.19	74.11	74.54	75.16	76.67	76.65	79.29	80.04	0 %
Plan dose: pCT159 (CT...	CTV 70-78	30.6	75.52	75.67	76.08	77.32	77.33	79.04	79.46	0 %
Evaluation dose (pCT1...	CTV 70-78	30.6	74.98	75.13	75.43	76.67	76.66	78.41	78.86	0 %
Plan dose: pCT159 (CT...	CTV 70eks	1.84	74.35	74.83	75.62	78.32	77.99	82.87	83.14	0 %
Evaluation dose (pCT1...	CTV 70eks	1.84	73.83	74.28	75.08	77.86	77.55	82.28	82.71	0 %
Plan dose: pCT159 (CT...	External	7206.72	0.40	0.53	0.79	15.11	12.74	71.26	76.76	0 %
Evaluation dose (pCT1...	External	8018.4	0.48	0.57	0.79	13.93	11.16	68.40	75.90	55 %
Plan dose: pCT159 (CT...	PTV 0-70	96.76	73.78	74.35	75.14	77.52	77.36	81.44	82.05	0 %
Evaluation dose (pCT1...	PTV 0-70	96.76	73.28	73.77	74.61	76.93	76.73	80.94	81.51	0 %
Plan dose: pCT159 (CT...	PTV 70-78	82.96	74.30	74.70	75.37	77.48	77.35	81.05	81.40	0 %
Evaluation dose (pCT1...	PTV 70-78	82.96	73.70	74.09	74.79	76.85	76.69	80.46	80.83	0 %
Plan dose: pCT159 (CT...	PTV 70eks	36.66	68.64	69.45	70.89	76.28	76.42	82.22	82.74	0 %
Evaluation dose (pCT1...	PTV 70eks	36.66	68.25	69.11	70.54	75.88	75.95	81.85	82.38	0 %

Figure 50: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 159.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT161 (CT...	CT BLA	208.72	11.00	12.05	14.03	44.45	39.58	78.02	78.37	0 %
Evaluation dose (pCT1...	CT BLA	216.04	10.66	11.74	13.64	42.11	35.70	77.47	77.84	0 %
Plan dose: pCT161 (CT...	CT FH L	189.27	0.50	0.76	1.13	20.20	21.95	38.89	39.83	0 %
Evaluation dose (pCT1...	CT FH L	189.84	0.80	0.88	1.09	20.11	22.00	39.11	40.17	0 %
Plan dose: pCT161 (CT...	CT FH R	205.18	0.53	0.65	1.20	19.95	24.18	36.47	37.27	0 %
Evaluation dose (pCT1...	CT FH R	206.4	0.88	0.98	1.21	20.25	24.86	36.44	37.23	0 %
Plan dose: pCT161 (CT...	CT REC	84.66	2.83	3.17	4.31	27.05	19.37	77.68	79.82	0 %
Evaluation dose (pCT1...	CT REC	84.47	2.94	3.37	4.62	32.20	27.92	76.94	78.47	0 %
Plan dose: pCT161 (CT...	CTV 0-70	43.24	73.93	74.38	74.91	77.45	77.40	81.93	82.54	0 %
Evaluation dose (pCT1...	CTV 0-70	43.24	73.46	73.87	74.50	77.32	77.47	81.18	81.73	0 %
Plan dose: pCT161 (CT...	CTV 70-78	38.31	74.60	74.81	75.26	77.60	77.52	82.05	82.56	0 %
Evaluation dose (pCT1...	CTV 70-78	38.31	74.12	74.36	74.88	77.50	77.59	81.27	81.78	0 %
Plan dose: pCT161 (CT...	CTV 70eks	3.22	72.80	73.16	73.53	76.56	76.38	80.56	80.88	0 %
Evaluation dose (pCT1...	CTV 70eks	3.22	71.90	72.24	72.96	76.17	75.79	80.80	80.92	0 %
Plan dose: pCT161 (CT...	External	8100.69	0.48	0.65	0.96	16.79	13.59	73.06	77.10	0 %
Evaluation dose (pCT1...	External	8893.42	0.60	0.70	0.95	15.97	12.50	70.63	76.43	55 %
Plan dose: pCT161 (CT...	PTV 0-70	116.44	72.71	73.47	74.47	77.57	77.52	82.23	82.68	0 %
Evaluation dose (pCT1...	PTV 0-70	116.44	70.22	71.30	73.18	77.00	77.14	81.54	81.98	0 %
Plan dose: pCT161 (CT...	PTV 70-78	94.53	74.21	74.55	75.08	77.81	77.68	82.29	82.72	0 %
Evaluation dose (pCT1...	PTV 70-78	94.53	72.08	73.12	74.24	77.27	77.34	81.43	81.85	0 %
Plan dose: pCT161 (CT...	PTV 70eks	52.59	66.62	67.75	69.72	75.52	75.71	81.49	81.89	0 %
Evaluation dose (pCT1...	PTV 70eks	52.59	64.82	65.84	67.68	74.72	75.10	81.62	82.16	0 %

Figure 51: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 161.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT174 (CT...	CT BLA	87.16	6.33	7.10	8.42	25.64	20.29	74.64	77.52	0 %
Evaluation dose (pCT1...	CT BLA	90.36	4.98	5.71	7.35	24.81	19.71	74.17	77.19	0 %
Plan dose: pCT174 (CT...	CT FH L	184.62	0.59	1.05	1.44	18.16	19.97	31.66	32.89	0 %
Evaluation dose (pCT1...	CT FH L	185.97	0.93	1.03	1.34	18.22	20.04	32.16	33.37	0 %
Plan dose: pCT174 (CT...	CT FH R	190.98	0.57	1.05	1.46	18.20	20.52	30.11	31.07	0 %
Evaluation dose (pCT1...	CT FH R	192.22	0.88	1.00	1.38	18.48	20.97	30.68	31.62	0 %
Plan dose: pCT174 (CT...	CT REC	78.48	3.81	4.41	7.57	32.95	23.99	79.88	80.50	0 %
Evaluation dose (pCT1...	CT REC	78.31	3.81	4.38	7.40	32.19	23.42	79.65	80.19	0 %
Plan dose: pCT174 (CT...	CTV 70-78	22.72	76.74	76.84	77.01	77.81	77.81	78.89	79.08	0 %
Evaluation dose (pCT1...	CTV 70-78	22.72	76.14	76.27	76.43	77.19	77.20	78.31	78.59	0 %
Plan dose: pCT174 (CT...	CTV 70eks	6.19	74.84	75.24	75.89	79.82	80.15	82.63	82.99	0 %
Evaluation dose (pCT1...	CTV 70eks	6.19	74.67	75.14	75.70	79.64	79.91	82.64	82.99	0 %
Plan dose: pCT174 (CT...	External	7116.16	0.49	0.66	1.03	15.69	13.54	69.59	77.01	0 %
Evaluation dose (pCT1...	External	7694.55	0.67	0.79	1.08	14.80	12.52	67.61	76.25	60 %
Plan dose: pCT174 (CT...	PTV 70-78	61.41	74.51	74.97	75.68	77.77	77.76	80.61	80.95	0 %
Evaluation dose (pCT1...	PTV 70-78	61.41	74.08	74.58	75.24	77.24	77.16	80.33	80.68	0 %
Plan dose: pCT174 (CT...	PTV 70eks	54.64	68.26	69.20	70.35	76.64	77.30	82.06	82.39	0 %
Evaluation dose (pCT1...	PTV 70eks	54.64	67.93	68.74	70.10	76.42	77.04	81.89	82.28	0 %

Figure 52: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 174.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside g
Plan dose: pCT178 (CT...	CT BLA	143.31	7.33	8.09	9.95	28.94	22.91	78.49	80.01	0 %
Evaluation dose (pCT1...	CT BLA	146.94	6.07	6.93	8.83	28.14	22.33	77.84	79.41	0 %
Plan dose: pCT178 (CT...	CT FH L	222.31	0.51	0.86	1.24	16.58	18.37	30.35	31.42	0 %
Evaluation dose (pCT1...	CT FH L	223.38	0.80	0.91	1.20	16.66	18.48	30.68	31.84	0 %
Plan dose: pCT178 (CT...	CT FH R	231.66	0.53	0.92	1.34	16.09	18.69	30.47	31.76	0 %
Evaluation dose (pCT1...	CT FH R	226.79	0.79	0.87	1.11	16.24	19.11	31.06	32.59	3 %
Plan dose: pCT178 (CT...	CT REC	62.99	1.41	2.26	2.98	40.50	39.09	80.00	80.62	0 %
Evaluation dose (pCT1...	CT REC	63.81	2.08	2.25	2.87	39.68	38.25	79.40	80.01	0 %
Plan dose: pCT178 (CT...	CTV 70-78	23.68	75.75	75.89	76.09	77.30	77.28	78.91	79.18	0 %
Evaluation dose (pCT1...	CTV 70-78	23.68	75.26	75.37	75.58	76.91	76.94	78.48	78.87	0 %
Plan dose: pCT178 (CT...	CTV 70eks	5.75	72.39	72.82	73.25	77.52	77.34	82.41	82.66	0 %
Evaluation dose (pCT1...	CTV 70eks	5.75	71.61	72.12	72.49	76.90	76.67	82.04	82.20	0 %
Plan dose: pCT178 (CT...	External	7552.96	0.50	0.68	1.05	15.93	13.74	69.51	76.08	0 %
Evaluation dose (pCT1...	External	8438.99	0.60	0.72	1.02	14.62	12.13	66.80	75.06	64 %
Plan dose: pCT178 (CT...	PTV 70-78	63.48	73.65	74.08	74.74	77.40	77.34	80.88	81.59	0 %
Evaluation dose (pCT1...	PTV 70-78	63.48	73.21	73.59	74.32	76.96	76.97	80.37	80.99	0 %
Plan dose: pCT178 (CT...	PTV 70eks	64.2	65.77	66.78	68.41	74.77	75.18	81.73	82.38	0 %
Evaluation dose (pCT1...	PTV 70eks	64.2	65.36	66.36	68.04	74.25	74.63	81.17	81.94	0 %

Figure 53: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 178.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT179 (CT...	CT BLA	162.36	2.83	3.07	3.61	30.87	22.67	79.83	80.93	0 %
Evaluation dose (pCT1...	CT BLA	164.15	2.82	3.03	3.55	30.16	21.94	78.68	79.80	0 %
Plan dose: pCT179 (CT...	CT FH L	168.61	4.70	5.25	8.65	18.45	18.00	30.95	32.08	0 %
Evaluation dose (pCT1...	CT FH L	169.39	4.69	5.24	8.16	18.34	17.97	30.74	31.77	0 %
Plan dose: pCT179 (CT...	CT FH R	174.23	4.70	5.27	7.13	22.28	23.13	36.09	37.36	0 %
Evaluation dose (pCT1...	CT FH R	175	4.77	5.31	6.98	22.20	23.09	35.90	37.22	0 %
Plan dose: pCT179 (CT...	CT REC	52.18	11.68	12.84	15.24	40.94	35.10	78.57	79.19	0 %
Evaluation dose (pCT1...	CT REC	52.57	10.79	12.38	14.76	40.20	35.07	77.15	77.73	0 %
Plan dose: pCT179 (CT...	CTV 70-78	44.44	76.44	76.68	77.02	78.09	78.13	79.38	79.99	0 %
Evaluation dose (pCT1...	CTV 70-78	44.46	75.24	75.41	75.78	76.99	77.06	78.32	78.81	0 %
Plan dose: pCT179 (CT...	CTV 70eks	9.57	74.33	74.60	75.07	78.35	78.04	83.03	83.19	0 %
Evaluation dose (pCT1...	CTV 70eks	9.57	73.10	73.34	73.84	77.16	76.82	81.95	82.19	0 %
Plan dose: pCT179 (CT...	External	6921.72	1.48	1.70	2.35	19.32	16.39	75.20	77.92	0 %
Evaluation dose (pCT1...	External	7721.26	1.11	1.28	1.71	17.73	15.09	73.03	76.63	61 %
Plan dose: pCT179 (CT...	PTV 70-78	102.47	74.50	74.96	75.65	77.92	78.02	80.86	81.59	0 %
Evaluation dose (pCT1...	PTV 70-78	102.47	73.23	73.78	74.52	76.81	76.91	79.78	80.46	0 %
Plan dose: pCT179 (CT...	PTV 70eks	74.24	67.25	68.02	69.40	75.52	76.03	81.90	82.33	0 %
Evaluation dose (pCT1...	PTV 70eks	74.24	66.12	67.05	68.29	74.34	74.86	80.87	81.30	0 %

Figure 54: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 179.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT192 (CT...	CT BLA	87.68	15.96	16.96	18.98	43.92	38.45	79.20	79.88	0 %
Evaluation dose (pCT1...	CT BLA	90.68	17.08	18.11	20.33	46.79	41.99	80.10	80.63	0 %
Plan dose: pCT192 (CT...	CT FH L	161.43	0.55	0.88	1.30	21.41	22.79	39.34	40.64	0 %
Evaluation dose (pCT1...	CT FH L	162.19	0.91	1.00	1.25	21.57	22.86	40.48	41.77	0 %
Plan dose: pCT192 (CT...	CT FH R	161.79	0.56	0.99	1.34	22.33	23.21	41.01	42.15	0 %
Evaluation dose (pCT1...	CT FH R	160.63	0.87	0.94	1.15	21.83	22.47	42.01	43.26	1 %
Plan dose: pCT192 (CT...	CT REC	88.55	4.13	6.26	8.14	26.23	19.52	74.49	76.62	0 %
Evaluation dose (pCT1...	CT REC	88.45	3.39	4.81	8.60	30.57	27.04	68.38	72.16	0 %
Plan dose: pCT192 (CT...	CTV 0-70	31.72	75.83	75.99	76.25	78.07	77.50	81.74	82.15	0 %
Evaluation dose (pCT1...	CTV 0-70	31.72	75.76	75.90	76.21	78.38	77.69	82.28	82.70	0 %
Plan dose: pCT192 (CT...	CTV 70-78	22.04	75.76	75.87	76.16	77.20	77.15	79.11	79.41	0 %
Evaluation dose (pCT1...	CTV 70-78	22.05	75.66	75.80	76.08	77.32	77.27	79.71	80.06	0 %
Plan dose: pCT192 (CT...	CTV 70eks	7.12	77.46	77.62	78.24	80.18	80.26	82.78	82.83	0 %
Evaluation dose (pCT1...	CTV 70eks	7.12	78.52	78.80	79.17	80.88	80.93	82.96	83.13	0 %
Plan dose: pCT192 (CT...	External	6993.16	0.54	0.74	1.14	17.82	15.14	73.09	77.08	0 %
Evaluation dose (pCT1...	External	7790.02	0.65	0.76	1.06	17.08	14.18	71.78	76.84	50 %
Plan dose: pCT192 (CT...	PTV 0-70	104.22	73.69	74.18	74.95	77.74	77.50	81.61	82.11	0 %
Evaluation dose (pCT1...	PTV 0-70	104.22	72.19	72.90	74.27	77.71	77.50	81.93	82.41	0 %
Plan dose: pCT192 (CT...	PTV 70-78	64.92	74.07	74.42	75.04	77.38	77.22	80.67	81.15	0 %
Evaluation dose (pCT1...	PTV 70-78	64.92	72.05	72.62	73.95	77.09	77.06	81.01	81.34	0 %
Plan dose: pCT192 (CT...	PTV 70eks	78.18	66.30	68.12	70.27	76.61	77.26	81.72	82.18	0 %
Evaluation dose (pCT1...	PTV 70eks	78.18	67.82	68.91	70.84	77.19	77.82	82.12	82.58	0 %

Figure 55: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 192.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT221 (CT...	CT BLA	127.55	9.24	10.45	12.15	36.94	30.14	80.06	81.11	0 %
Evaluation dose (pCT2...	CT BLA	132.19	10.09	10.85	12.27	35.82	28.77	79.91	81.00	0 %
Plan dose: pCT221 (CT...	CT FH L	172.31	0.61	1.04	1.45	17.25	15.89	40.41	42.51	0 %
Evaluation dose (pCT2...	CT FH L	172.97	1.02	1.11	1.41	17.39	16.08	40.83	42.96	0 %
Plan dose: pCT221 (CT...	CT FH R	177.62	0.64	0.85	1.49	21.21	23.51	39.21	40.73	0 %
Evaluation dose (pCT2...	CT FH R	178.6	1.01	1.13	1.43	21.60	24.02	40.40	42.01	0 %
Plan dose: pCT221 (CT...	CT REC	76.68	1.92	2.96	4.06	25.27	16.18	78.38	79.18	0 %
Evaluation dose (pCT2...	CT REC	76.75	2.82	3.19	4.38	25.11	17.13	76.47	77.23	0 %
Plan dose: pCT221 (CT...	CTV 0-70	58.01	74.80	75.18	75.62	77.18	77.08	80.59	81.29	0 %
Evaluation dose (pCT2...	CTV 0-70	57.99	74.54	74.92	75.31	76.91	76.79	80.68	81.47	0 %
Plan dose: pCT221 (CT...	CTV 70-78	46.61	75.46	75.60	75.85	77.12	77.10	78.90	79.09	0 %
Evaluation dose (pCT2...	CTV 70-78	46.61	75.12	75.24	75.49	76.83	76.80	78.67	78.88	0 %
Plan dose: pCT221 (CT...	CTV 70eks	7.06	74.59	74.92	75.44	78.24	77.97	82.52	82.73	0 %
Evaluation dose (pCT2...	CTV 70eks	7.06	74.50	74.70	75.27	78.24	77.91	82.69	82.89	0 %
Plan dose: pCT221 (CT...	External	7894.6	0.63	0.84	1.30	17.93	15.45	73.89	76.97	0 %
Evaluation dose (pCT2...	External	8714.54	0.73	0.86	1.21	16.79	13.99	72.30	76.55	61 %
Plan dose: pCT221 (CT...	PTV 0-70	135.27	72.45	73.26	74.30	77.10	77.05	81.30	82.09	0 %
Evaluation dose (pCT2...	PTV 0-70	135.27	72.16	72.78	73.91	76.83	76.78	81.41	82.16	0 %
Plan dose: pCT221 (CT...	PTV 70-78	105.22	73.85	74.37	75.06	77.17	77.09	80.49	81.51	0 %
Evaluation dose (pCT2...	PTV 70-78	105.22	72.71	73.46	74.56	76.80	76.77	80.13	81.37	0 %
Plan dose: pCT221 (CT...	PTV 70eks	71.98	66.08	67.20	68.87	75.37	75.89	81.58	82.14	0 %
Evaluation dose (pCT2...	PTV 70eks	71.98	66.11	67.17	68.75	75.37	75.84	81.71	82.30	0 %

Figure 56: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 221.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: pCT242 (CT...	CT BLA	114.99	6.15	8.02	13.42	45.04	42.49	78.81	79.38	0 %
Evaluation dose (pCT2...	CT BLA	115.43	5.98	7.25	12.86	44.40	41.86	78.01	78.53	0 %
Plan dose: pCT242 (CT...	CT FH L	160.45	2.15	2.36	4.25	21.07	21.69	36.39	37.81	0 %
Evaluation dose (pCT2...	CT FH L	161.6	2.31	2.53	3.93	20.99	21.62	36.66	38.16	0 %
Plan dose: pCT242 (CT...	CT FH R	151.02	2.06	2.27	3.78	18.41	18.87	30.14	31.14	0 %
Evaluation dose (pCT2...	CT FH R	152.02	2.19	2.45	3.60	18.36	18.86	30.36	31.38	0 %
Plan dose: pCT242 (CT...	CT REC	73.54	4.65	6.29	11.11	34.66	25.72	79.40	79.94	0 %
Evaluation dose (pCT2...	CT REC	73.77	4.90	6.03	10.67	34.58	25.98	79.24	79.78	0 %
Plan dose: pCT242 (CT...	CTV 0-70	84.44	75.05	75.31	75.59	76.92	76.88	79.23	79.88	0 %
Evaluation dose (pCT2...	CTV 0-70	84.44	74.09	74.38	74.69	76.30	76.30	78.77	79.45	0 %
Plan dose: pCT242 (CT...	CTV 70-78	77.72	75.03	75.28	75.58	76.84	76.85	78.56	78.91	0 %
Evaluation dose (pCT2...	CTV 70-78	83.26	74.09	74.37	74.69	76.26	76.29	78.51	79.02	0 %
Plan dose: pCT242 (CT...	CTV 70eks	2.96	75.33	75.66	76.05	78.74	78.70	81.82	82.31	0 %
Evaluation dose (pCT2...	CTV 70eks	2.96	74.69	75.03	75.48	78.24	78.24	81.26	81.90	0 %
Plan dose: pCT242 (CT...	External	7612.09	2.03	2.38	3.12	19.83	16.68	75.98	77.19	0 %
Evaluation dose (pCT2...	External	8439.49	1.49	1.72	2.27	18.28	15.50	74.87	76.55	52 %
Plan dose: pCT242 (CT...	PTV 0-70	177.99	72.68	73.55	74.55	76.97	76.91	80.57	81.14	0 %
Evaluation dose (pCT2...	PTV 0-70	177.99	72.08	72.97	74.01	76.43	76.37	80.17	80.60	0 %
Plan dose: pCT242 (CT...	PTV 70-78	158.46	73.45	74.08	74.82	76.91	76.88	79.94	80.36	0 %
Evaluation dose (pCT2...	PTV 70-78	158.46	72.84	73.52	74.23	76.37	76.33	79.76	80.22	0 %
Plan dose: pCT242 (CT...	PTV 70eks	49.88	66.85	67.96	69.61	76.01	76.54	81.44	81.75	0 %
Evaluation dose (pCT2...	PTV 70eks	49.88	66.34	67.64	69.24	75.41	75.81	80.66	81.13	0 %

Figure 57: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 242.

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside grid
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: pCT254 (CT...	CT BLA	116.08	8.83	9.25	10.21	34.99	26.64	78.75	79.60	0 %
Evaluation dose (pCT2...	CT BLA	118.87	8.97	9.40	10.42	34.59	26.33	78.19	79.03	0 %
Plan dose: pCT254 (CT...	CT FH L	166.09	0.61	1.10	1.57	20.14	21.19	37.03	38.57	0 %
Evaluation dose (pCT2...	CT FH L	167.53	0.99	1.11	1.51	20.05	21.14	37.06	38.71	0 %
Plan dose: pCT254 (CT...	CT FH R	169.19	0.62	1.15	1.61	19.71	20.95	33.04	34.35	0 %
Evaluation dose (pCT2...	CT FH R	170.53	0.99	1.11	1.54	19.79	21.07	33.46	34.74	0 %
Plan dose: pCT254 (CT...	CT REC	89.15	0.93	1.09	2.07	25.11	17.35	78.64	79.87	0 %
Evaluation dose (pCT2...	CT REC	89.93	1.56	1.70	2.02	25.04	17.62	78.31	79.50	0 %
Plan dose: pCT254 (CT...	CTV 70-78	33.41	75.20	75.35	75.65	76.93	76.88	78.59	78.88	0 %
Evaluation dose (pCT2...	CTV 70-78	33.41	74.84	75.01	75.36	76.65	76.61	78.30	78.60	0 %
Plan dose: pCT254 (CT...	CTV 70eks	3.62	74.29	74.68	75.06	77.96	77.73	81.73	82.05	0 %
Evaluation dose (pCT2...	CTV 70eks	3.62	74.02	74.29	74.54	77.55	77.40	81.28	81.51	0 %
Plan dose: pCT254 (CT...	External	7952.13	0.50	0.69	1.04	16.30	14.10	69.67	76.20	0 %
Evaluation dose (pCT2...	External	8701.3	0.65	0.76	1.03	15.52	13.12	67.88	75.63	57 %
Plan dose: pCT254 (CT...	PTV 70-78	82.67	73.98	74.32	75.01	77.03	76.97	80.18	80.88	0 %
Evaluation dose (pCT2...	PTV 70-78	82.67	73.55	73.99	74.68	76.75	76.70	79.88	80.74	0 %
Plan dose: pCT254 (CT...	PTV 70eks	48.44	66.67	67.67	69.08	74.85	75.35	80.92	81.44	0 %
Evaluation dose (pCT2...	PTV 70eks	48.44	66.22	67.47	68.86	74.61	75.08	80.42	80.90	0 %

Figure 58: Dose data from Mp-pCT (plan dose) and opCT (evaluation dose) for patient 254.

B.2 Dose data from pCTs without additional water but with delineation of adipose tissue

As the treatment plans used adaptions of previous tumor volumes, certain names are not correct. In this section, the abbreviations mean:
bla - bladder
FHL - left femur
FHR - right femur
rec - rectum
CTV70-78 - CTV77
CTV0-70 - an old volume which was not used in this thesis
CTV70eks - CTV70
PTV70-78 - PTV77
PTV0-70 - an old volume which was not used in this thesis
PTV70eks - PTV70

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outsid
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: 150MR (M...	CTV 0-70	43.78	70.55	70.98	71.62	76.22	76.74	78.32	78.53	0 %
Evaluation dose (150...	CTV 0-70	43.78	69.06	69.33	69.93	74.79	75.22	77.34	77.55	0 %
Plan dose: 150MR (M...	CTV 70-78	32.97	75.13	75.36	75.76	76.93	76.87	78.40	78.62	0 %
Evaluation dose (150...	CTV 70-78	32.97	73.83	74.01	74.34	75.55	75.37	77.29	77.45	0 %
Plan dose: 150MR (M...	CTV 70eks	7.31	70.05	70.20	70.54	73.13	72.84	77.07	77.25	0 %
Evaluation dose (150...	CTV 70eks	7.34	68.49	68.77	68.94	71.47	71.13	75.36	75.84	0 %
Plan dose: 150MR (M...	External original	5500.69	0.83	0.98	1.31	18.42	14.71	73.36	76.40	0 %
Evaluation dose (150...	External original	10683.66	0.04	0.10	0.25	9.99	2.02	64.87	72.18	10 %
Plan dose: 150MR (M...	MR BLA	68.94	24.92	28.81	34.62	60.77	64.71	76.87	77.01	0 %
Evaluation dose (150...	MR BLA	68.82	24.18	28.06	33.86	59.49	63.26	75.20	75.32	0 %
Plan dose: 150MR (M...	MR FH L	127.6	1.17	1.28	1.52	20.90	26.34	37.63	38.48	0 %
Evaluation dose (150...	MR FH L	127.19	1.20	1.30	1.54	20.96	26.38	37.69	38.61	0 %
Plan dose: 150MR (M...	MR FH R	144.42	1.23	1.36	1.73	21.60	26.24	37.29	38.35	0 %
Evaluation dose (150...	MR FH R	143.32	1.10	1.23	1.56	21.03	25.39	37.23	38.28	0 %
Plan dose: 150MR (M...	MR REC	34.09	4.64	5.60	6.76	26.46	22.85	66.76	68.53	0 %
Evaluation dose (150...	MR REC	34.28	4.63	5.23	6.70	25.83	22.41	64.73	66.55	0 %
Plan dose: 150MR (M...	PTV 0-70	124.89	68.17	68.73	69.62	74.79	75.72	78.54	78.99	0 %
Evaluation dose (150...	PTV 0-70	124.89	66.84	67.29	68.09	73.33	74.24	77.31	77.65	0 %
Plan dose: 150MR (M...	PTV 70-78	82.22	72.68	73.22	73.96	76.35	76.55	78.72	79.09	0 %
Evaluation dose (150...	PTV 70-78	82.09	71.23	71.71	72.47	74.90	75.01	77.45	77.72	0 %
Plan dose: 150MR (M...	PTV 70eks	73.37	66.01	66.52	67.33	72.11	71.40	78.55	79.09	0 %
Evaluation dose (150...	PTV 70eks	73.3	64.62	65.09	65.93	70.62	69.90	77.35	77.87	0 %

Figure 59: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 150.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR159 (M...	CTV 0-70	35.22	74.72	74.98	75.26	76.27	76.35	77.47	77.65	0 %
Evaluation dose (MR1...	CTV 0-70	35.22	72.81	73.05	73.31	74.44	74.53	75.74	75.86	0 %
Plan dose: MR159 (M...	CTV 70-78	30.58	74.92	75.03	75.28	76.29	76.36	77.47	77.61	0 %
Evaluation dose (MR1...	CTV 70-78	30.58	73.00	73.07	73.35	74.46	74.56	75.74	75.88	0 %
Plan dose: MR159 (M...	CTV 70eks	1.81	74.27	74.37	74.80	76.20	76.30	77.23	77.38	0 %
Evaluation dose (MR1...	CTV 70eks	1.85	72.50	72.56	72.93	74.37	74.45	75.47	75.54	0 %
Plan dose: MR159 (M...	External original	6520.54	0.84	1.01	1.41	17.95	15.15	72.84	75.78	0 %
Evaluation dose (MR1...	External original	13797.55	0.02	0.07	0.22	9.07	2.13	55.22	70.62	23 %
Plan dose: MR159 (M...	MR BLA	33.5	9.30	10.25	11.96	36.66	28.48	76.81	77.15	0 %
Evaluation dose (MR1...	MR BLA	33.83	9.52	10.42	12.10	35.95	27.96	75.10	75.50	0 %
Plan dose: MR159 (M...	MR FH L	155.13	0.94	1.30	1.63	20.66	22.86	39.09	40.18	0 %
Evaluation dose (MR1...	MR FH L	149.11	1.21	1.33	1.60	19.84	21.69	38.54	39.71	0 %
Plan dose: MR159 (M...	MR FH R	161.57	1.16	1.33	1.73	18.90	20.83	35.40	36.53	0 %
Evaluation dose (MR1...	MR FH R	161.95	1.19	1.33	1.73	18.57	20.43	35.04	36.19	0 %
Plan dose: MR159 (M...	MR REC	49.82	22.80	23.29	24.35	46.24	43.13	74.53	75.28	0 %
Evaluation dose (MR1...	MR REC	49.83	22.40	22.89	23.93	45.17	42.15	72.53	73.30	0 %
Plan dose: MR159 (M...	PTV 0-70	96.83	71.55	72.23	73.26	75.85	76.09	77.90	78.35	0 %
Evaluation dose (MR1...	PTV 0-70	96.74	69.76	70.43	71.44	74.02	74.24	76.13	76.41	0 %
Plan dose: MR159 (M...	PTV 70-78	83.01	72.70	73.22	74.08	76.03	76.17	77.98	78.46	0 %
Evaluation dose (MR1...	PTV 70-78	82.89	70.79	71.27	72.18	74.19	74.33	76.16	76.47	0 %
Plan dose: MR159 (M...	PTV 70eks	36.71	67.78	68.47	69.64	74.39	75.11	77.49	77.64	0 %
Evaluation dose (MR1...	PTV 70eks	36.67	66.30	66.94	68.08	72.64	73.29	75.74	75.90	0 %

Figure 60: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 159.

ROI statistics POI statistics

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR161 (M...	CTV 0-70	43.06	73.88	74.09	74.71	77.01	77.01	79.57	79.87	0 %
Evaluation dose (MR1...	CTV 0-70	43.06	72.18	72.52	73.25	75.47	75.51	77.81	78.09	0 %
Plan dose: MR161 (M...	CTV 70-78	38.2	74.17	74.57	75.04	77.04	77.02	79.40	79.59	0 %
Evaluation dose (MR1...	CTV 70-78	38.2	72.78	73.09	73.59	75.54	75.56	77.72	77.86	0 %
Plan dose: MR161 (M...	CTV 70eks	3.24	73.11	73.28	73.55	76.20	76.27	80.50	80.86	0 %
Evaluation dose (MR1...	CTV 70eks	3.13	71.41	71.62	71.83	74.40	74.60	78.77	78.88	0 %
Plan dose: MR161 (M...	External original	7576.75	0.87	1.01	1.35	17.65	14.48	72.69	76.46	0 %
Evaluation dose (MR1...	External original	16164.61	0.00	0.00	0.06	9.01	2.18	53.29	69.77	17 %
Plan dose: MR161 (M...	MR BLA	130.45	16.82	17.85	20.65	54.19	57.60	79.55	79.91	0 %
Evaluation dose (MR1...	MR BLA	131.12	16.80	17.77	20.41	52.99	56.52	77.81	78.22	0 %
Plan dose: MR161 (M...	MR FH L	153.14	1.14	1.28	1.62	20.61	21.59	36.71	37.22	0 %
Evaluation dose (MR1...	MR FH L	152.58	1.15	1.28	1.64	20.63	21.55	37.03	37.58	0 %
Plan dose: MR161 (M...	MR FH R	160.82	1.13	1.27	1.67	22.49	25.80	38.92	39.71	0 %
Evaluation dose (MR1...	MR FH R	160.46	1.14	1.29	1.69	22.49	25.93	39.00	39.84	0 %
Plan dose: MR161 (M...	MR REC	61.78	12.66	12.90	13.64	27.04	21.81	61.89	64.82	0 %
Evaluation dose (MR1...	MR REC	62.09	12.79	13.09	13.86	29.20	24.85	59.38	61.10	0 %
Plan dose: MR161 (M...	PTV 0-70	116.42	71.37	72.16	73.31	76.69	76.82	79.79	80.05	0 %
Evaluation dose (MR1...	PTV 0-70	116.3	68.49	69.41	70.84	74.78	75.11	77.90	78.26	0 %
Plan dose: MR161 (M...	PTV 70-78	94.4	74.00	74.41	75.00	77.14	77.08	79.80	80.04	0 %
Evaluation dose (MR1...	PTV 70-78	94.33	70.71	71.52	72.52	75.28	75.36	77.92	78.26	0 %
Plan dose: MR161 (M...	PTV 70eks	52.61	66.23	66.93	68.12	74.03	74.11	79.71	80.22	0 %
Evaluation dose (MR1...	PTV 70eks	52.55	62.78	63.84	65.37	71.88	72.12	77.83	78.38	0 %

Figure 61: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 161.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gr
Plan dose: MR174 (M...	CTV 0-70	31.29	73.80	74.63	75.50	76.38	76.08	79.56	80.19	0 %
Evaluation dose (MR1...	CTV 0-70	31.29	72.32	73.15	73.63	74.61	74.33	77.79	78.24	0 %
Plan dose: MR174 (M...	CTV 70-78	22.76	75.44	75.51	75.61	76.06	76.01	76.87	77.04	0 %
Evaluation dose (MR1...	CTV 70-78	22.76	73.51	73.62	73.75	74.29	74.26	75.22	75.33	0 %
Plan dose: MR174 (M...	CTV 70eks	6.29	72.83	73.16	73.89	77.58	77.95	80.78	81.03	0 %
Evaluation dose (MR1...	CTV 70eks	6.26	71.40	71.69	72.46	75.80	76.09	78.82	78.93	0 %
Plan dose: MR174 (M...	External original	6447.58	1.06	1.31	1.88	18.00	15.34	72.88	76.03	0 %
Evaluation dose (MR1...	External original	13268.27	0.07	0.13	0.28	9.30	2.53	53.42	70.88	31 %
Plan dose: MR174 (M...	MR BLA	62.27	7.19	7.94	9.40	25.43	20.66	72.22	76.95	0 %
Evaluation dose (MR1...	MR BLA	64.8	6.58	7.40	8.76	24.33	19.78	70.50	74.94	0 %
Plan dose: MR174 (M...	MR FH L	142.3	1.63	1.94	3.12	22.41	24.31	34.59	35.92	0 %
Evaluation dose (MR1...	MR FH L	144.16	1.54	1.75	2.87	22.07	24.05	34.76	36.15	0 %
Plan dose: MR174 (M...	MR FH R	147.92	1.56	1.92	3.56	19.53	20.96	32.57	33.75	0 %
Evaluation dose (MR1...	MR FH R	148.46	1.56	1.89	3.45	19.68	21.13	33.09	34.35	0 %
Plan dose: MR174 (M...	MR REC	67.98	10.67	12.41	15.18	34.42	27.10	77.22	78.01	0 %
Evaluation dose (MR1...	MR REC	69.49	9.60	11.19	14.22	33.25	26.45	75.14	75.99	0 %
Plan dose: MR174 (M...	PTV 0-70	87.94	71.14	71.99	73.43	76.50	76.25	81.00	81.54	0 %
Evaluation dose (MR1...	PTV 0-70	87.83	69.60	70.35	71.89	74.72	74.48	79.18	79.64	0 %
Plan dose: MR174 (M...	PTV 70-78	61.53	75.05	75.24	75.53	76.46	76.21	78.82	80.66	0 %
Evaluation dose (MR1...	PTV 70-78	61.46	73.21	73.44	73.67	74.66	74.44	76.93	78.83	0 %
Plan dose: MR174 (M...	PTV 70eks	54.68	66.78	67.60	69.07	75.25	75.80	81.22	81.76	0 %
Evaluation dose (MR1...	PTV 70eks	54.63	65.06	66.04	67.61	73.53	74.01	79.34	79.90	0 %

Figure 62: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 174.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsid
Plan dose: 178MR (M...	CTV 0-70	30.59	73.78	74.15	74.71	77.69	77.07	85.06	85.89	0 %
Evaluation dose (178...	CTV 0-70	30.59	71.87	72.22	72.74	75.64	75.09	82.78	83.46	0 %
Plan dose: 178MR (M...	CTV 70-78	23.7	73.78	74.14	74.68	76.97	76.87	80.24	80.76	0 %
Evaluation dose (178...	CTV 70-78	23.7	71.93	72.25	72.77	75.02	74.87	78.20	78.77	0 %
Plan dose: 178MR (M...	CTV 70eks	5.68	75.38	75.84	76.55	81.16	81.27	86.44	86.74	0 %
Evaluation dose (178...	CTV 70eks	5.73	72.86	73.37	74.13	78.76	78.93	84.01	84.36	0 %
Plan dose: 178MR (M...	External original	6807.08	0.99	1.21	1.79	18.81	15.88	73.99	76.89	0 %
Evaluation dose (178...	External original	14384.09	0.04	0.10	0.25	9.51	2.50	56.89	71.64	38 %
Plan dose: 178MR (M...	MR BLA	112.86	9.81	11.22	14.03	33.37	27.59	76.51	77.80	0 %
Evaluation dose (178...	MR BLA	112.3	9.80	11.21	14.05	32.62	27.07	74.22	75.47	0 %
Plan dose: 178MR (M...	MR FH L	177.42	1.20	1.44	1.90	16.43	17.19	29.31	30.47	0 %
Evaluation dose (178...	MR FH L	178.1	1.31	1.48	1.90	16.31	16.94	29.73	30.99	0 %
Plan dose: 178MR (M...	MR FH R	185.73	1.38	1.66	2.38	19.50	23.07	30.39	30.99	0 %
Evaluation dose (178...	MR FH R	187.29	1.45	1.68	2.37	19.22	22.81	30.27	30.94	0 %
Plan dose: 178MR (M...	MR REC	41.99	11.63	13.30	15.89	46.03	44.69	79.63	81.50	0 %
Evaluation dose (178...	MR REC	43.13	10.11	11.94	14.69	44.10	43.13	77.29	79.16	0 %
Plan dose: 178MR (M...	PTV 0-70	95.06	72.28	73.02	74.06	77.60	77.19	84.00	85.27	0 %
Evaluation dose (178...	PTV 0-70	94.93	70.36	71.01	72.09	75.52	75.15	81.68	82.88	0 %
Plan dose: 178MR (M...	PTV 70-78	63.47	72.74	73.40	74.09	76.72	76.67	80.20	80.53	0 %
Evaluation dose (178...	PTV 70-78	63.39	71.01	71.53	72.19	74.73	74.65	78.12	78.47	0 %
Plan dose: 178MR (M...	PTV 70eks	64.26	66.41	67.85	70.37	77.26	77.22	84.57	85.58	0 %
Evaluation dose (178...	PTV 70eks	64.2	64.71	65.93	68.38	75.12	75.09	82.35	83.18	0 %

Figure 63: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 178.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gr
Plan dose: 179MR (M...	CTV 0-70	58.16	75.99	76.26	76.61	77.24	77.20	78.52	78.91	0 %
Evaluation dose (179...	CTV 0-70	58.14	72.20	72.47	72.91	74.26	74.27	76.03	76.48	0 %
Plan dose: 179MR (M...	CTV 70-78	44.39	76.45	76.58	76.74	77.19	77.18	77.82	77.90	0 %
Evaluation dose (179...	CTV 70-78	44.38	72.75	72.99	73.26	74.29	74.29	75.57	75.67	0 %
Plan dose: 179MR (M...	CTV 70eks	9.76	75.11	75.61	76.03	77.51	77.47	80.12	80.50	0 %
Evaluation dose (179...	CTV 70eks	9.78	71.56	71.77	72.32	74.42	74.47	77.46	77.78	0 %
Plan dose: 179MR (M...	External original	6401.64	1.13	1.33	2.01	22.02	18.48	75.68	77.09	0 %
Evaluation dose (179...	External original	14055.19	0.06	0.12	0.29	10.84	3.19	63.97	72.17	28 %
Plan dose: 179MR (M...	MR BLA	121.93	2.61	3.07	3.80	35.85	30.39	77.93	78.23	0 %
Evaluation dose (179...	MR BLA	122.04	3.32	3.59	4.19	33.62	27.71	75.31	75.69	0 %
Plan dose: 179MR (M...	MR FH L	121.65	7.45	9.21	13.39	28.14	29.24	42.10	43.12	0 %
Evaluation dose (179...	MR FH L	121.68	6.30	8.36	11.93	27.27	28.43	41.30	42.35	0 %
Plan dose: 179MR (M...	MR FH R	129.24	7.53	8.99	13.57	30.57	31.19	45.45	46.83	0 %
Evaluation dose (179...	MR FH R	128.97	6.55	7.84	12.28	29.84	30.48	45.25	46.59	0 %
Plan dose: 179MR (M...	MR REC	24.69	13.64	14.30	15.83	45.49	46.56	76.43	76.73	0 %
Evaluation dose (179...	MR REC	24.7	12.07	12.67	14.19	42.40	43.66	72.65	73.20	0 %
Plan dose: 179MR (M...	PTV 0-70	138.4	72.95	73.58	74.37	76.73	77.01	79.04	79.70	0 %
Evaluation dose (179...	PTV 0-70	138.15	69.51	70.20	71.05	73.73	73.93	76.42	76.89	0 %
Plan dose: 179MR (M...	PTV 70-78	102.53	73.93	74.41	75.05	76.84	77.05	78.29	78.67	0 %
Evaluation dose (179...	PTV 70-78	102.5	70.57	71.08	71.84	73.86	74.00	75.82	76.21	0 %
Plan dose: 179MR (M...	PTV 70eks	74.62	67.82	69.00	70.65	75.44	76.06	79.63	80.34	0 %
Evaluation dose (179...	PTV 70eks	74.55	65.04	65.88	67.53	72.33	72.79	76.73	77.53	0 %

Figure 64: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 179.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 192MR (M...	CTV 0-70	31.64	74.39	74.61	74.94	76.64	76.14	81.80	82.57	0 %
Evaluation dose (192...	CTV 0-70	31.68	72.93	73.15	73.73	75.97	75.60	80.69	81.30	0 %
Plan dose: 192MR (M...	CTV 70-78	22.07	74.63	74.81	75.00	75.99	75.99	77.21	77.33	0 %
Evaluation dose (192...	CTV 70-78	22.08	72.81	72.99	73.45	75.24	75.34	76.95	77.10	0 %
Plan dose: 192MR (M...	CTV 70eks	7.31	74.05	74.38	74.97	78.82	79.04	82.81	83.12	0 %
Evaluation dose (192...	CTV 70eks	7.17	74.19	74.61	75.18	78.29	78.40	81.69	81.98	0 %
Plan dose: 192MR (M...	External original	6930.4	0.68	0.81	1.12	17.70	14.95	71.94	75.55	0 %
Evaluation dose (192...	External original	13901.71	0.00	0.01	0.10	10.24	3.27	58.90	71.47	11 %
Plan dose: 192MR (M...	MR BLA	39.31	19.26	20.12	21.61	51.89	52.63	79.50	80.23	0 %
Evaluation dose (192...	MR BLA	39.1	19.40	20.20	21.66	51.37	51.93	78.59	79.19	0 %
Plan dose: 192MR (M...	MR FAT	2798.79	1.08	1.33	1.92	18.30	14.89	72.73	75.64	0 %
Evaluation dose (192...	MR FAT									
Plan dose: 192MR (M...	MR FH L	117.61	1.28	1.39	1.91	23.76	24.53	43.43	44.66	0 %
Evaluation dose (192...	MR FH L	117.51	1.29	1.41	1.92	23.91	24.60	44.21	45.45	0 %
Plan dose: 192MR (M...	MR FH R	115.35	1.35	1.48	2.08	24.14	24.75	41.76	42.90	0 %
Evaluation dose (192...	MR FH R	115.53	1.37	1.50	2.09	24.56	25.23	43.00	44.15	0 %
Plan dose: 192MR (M...	MR REC	110.81	15.19	15.84	17.06	41.75	35.70	76.95	77.89	0 %
Evaluation dose (192...	MR REC	110.65	16.40	17.13	18.63	44.03	41.76	75.26	76.52	0 %
Plan dose: 192MR (M...	PTV 0-70	104.44	71.22	71.98	73.00	76.13	75.90	81.22	81.89	0 %
Evaluation dose (192...	PTV 0-70	104.31	68.39	69.46	71.45	75.13	75.06	80.35	80.81	0 %
Plan dose: 192MR (M...	PTV 70-78	65	72.83	73.18	73.84	75.81	75.78	79.47	80.23	0 %
Evaluation dose (192...	PTV 70-78	64.91	68.06	69.05	71.64	74.55	74.83	77.76	78.76	0 %
Plan dose: 192MR (M...	PTV 70eks	78.42	60.58	64.89	68.00	74.18	74.96	81.49	82.23	0 %
Evaluation dose (192...	PTV 70eks	78.34	65.09	66.34	68.24	74.60	74.81	80.84	81.48	0 %

Figure 65: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 192.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsi
Plan dose: 221MR (M...	CTV 0-70	58.09	69.54	69.87	70.53	76.11	76.63	78.92	79.11	0 %
Evaluation dose (221...	CTV 0-70	58.13	68.48	68.80	69.40	74.73	75.22	77.53	77.88	0 %
Plan dose: 221MR (M...	CTV 70-78	46.91	75.12	75.24	75.55	76.94	76.86	79.06	79.29	0 %
Evaluation dose (221...	CTV 70-78	46.91	73.61	73.82	74.07	75.49	75.44	77.70	78.05	0 %
Plan dose: 221MR (M...	CTV 70eks	7.26	68.10	68.43	69.13	71.04	70.75	74.70	75.17	0 %
Evaluation dose (221...	CTV 70eks	7.26	67.12	67.46	68.07	69.91	69.53	73.48	73.88	0 %
Plan dose: 221MR (M...	MR BLA	90.78	9.12	10.15	12.30	36.92	30.06	78.84	79.28	0 %
Evaluation dose (221...	MR BLA	92.71	8.85	9.83	11.90	35.90	29.11	77.24	77.72	0 %
Plan dose: 221MR (M...	MR FH L	133.86	1.94	2.20	3.23	22.62	22.94	38.19	39.33	0 %
Evaluation dose (221...	MR FH L	135.51	1.61	1.86	2.72	22.47	23.08	38.19	39.30	0 %
Plan dose: 221MR (M...	MR FH R	134.85	1.73	1.97	2.73	22.34	23.72	39.06	40.25	0 %
Evaluation dose (221...	MR FH R	137.09	1.52	1.67	2.30	22.22	23.83	39.51	40.78	0 %
Plan dose: 221MR (M...	MR REC	63.89	8.00	8.68	10.25	28.67	22.50	73.68	74.71	0 %
Evaluation dose (221...	MR REC	63.93	7.98	8.72	10.27	28.52	22.63	70.82	72.51	0 %
Plan dose: 221MR (M...	orginal external	6927.47	1.48	1.78	2.53	19.22	16.44	72.94	76.42	0 %
Evaluation dose (221...	orginal external	15001.49	0.10	0.16	0.30	9.56	2.64	55.63	70.25	33 %
Plan dose: 221MR (M...	PTV 0-70	135.26	66.21	66.97	68.30	75.20	76.34	79.42	79.75	0 %
Evaluation dose (221...	PTV 0-70	135.12	64.99	65.72	67.03	73.73	74.83	78.02	78.33	0 %
Plan dose: 221MR (M...	PTV 70-78	105.64	72.60	73.23	74.45	76.77	76.74	79.54	79.88	0 %
Evaluation dose (221...	PTV 70-78	105.54	70.64	71.56	72.84	75.23	75.24	78.13	78.41	0 %
Plan dose: 221MR (M...	PTV 70eks	72.21	57.39	59.79	62.29	70.27	70.12	78.18	78.62	0 %
Evaluation dose (221...	PTV 70eks	72.13	56.19	58.60	61.09	69.05	68.86	77.11	77.68	0 %

Figure 66: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 221.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gri
Plan dose: MR242 (M...	CTV 0-70	84.43	74.63	74.94	75.28	76.22	76.17	77.85	78.30	0 %
Evaluation dose (MR2...	CTV 0-70	84.43	73.11	73.43	73.83	74.81	74.77	76.39	76.79	0 %
Plan dose: MR242 (M...	CTV 70-78	77.75	74.78	75.01	75.33	76.18	76.15	77.44	77.59	0 %
Evaluation dose (MR2...	CTV 70-78	83.26	73.26	73.51	73.87	74.82	74.77	76.35	76.77	0 %
Plan dose: MR242 (M...	CTV 70eks	2.97	72.26	72.99	73.48	76.18	76.14	78.81	78.98	0 %
Evaluation dose (MR2...	CTV 70eks	2.96	70.64	71.32	71.79	74.53	74.59	77.10	77.34	0 %
Plan dose: MR242 (M...	External original	7492.4	2.12	2.43	3.18	21.72	18.45	75.54	76.32	0 %
Evaluation dose (MR2...	External original	15494.11	0.17	0.23	0.36	11.14	3.09	65.99	74.05	12 %
Plan dose: MR242 (M...	MR BLA	53.53	14.69	17.14	22.90	54.79	60.15	76.61	77.44	0 %
Evaluation dose (MR2...	MR BLA	53.49	14.47	16.84	22.37	53.55	58.92	74.95	75.72	0 %
Plan dose: MR242 (M...	MR FH L	141.23	2.74	3.66	5.27	29.83	32.53	44.33	45.40	0 %
Evaluation dose (MR2...	MR FH L	141.99	2.64	2.89	4.88	29.80	32.50	44.80	45.89	0 %
Plan dose: MR242 (M...	MR FH R	128.27	2.75	3.10	5.21	26.71	28.25	42.03	43.10	0 %
Evaluation dose (MR2...	MR FH R	128.95	2.67	2.87	4.81	26.52	28.25	42.32	43.41	0 %
Plan dose: MR242 (M...	MR REC	44.41	20.57	20.95	21.72	41.26	35.63	74.16	74.89	0 %
Evaluation dose (MR2...	MR REC	44.48	20.33	20.80	21.58	40.58	35.37	72.65	73.38	0 %
Plan dose: MR242 (M...	PTV 0-70	178.13	70.51	71.41	72.98	75.86	76.08	78.17	78.63	0 %
Evaluation dose (MR2...	PTV 0-70	177.97	68.92	69.72	71.25	74.39	74.67	76.65	77.05	0 %
Plan dose: MR242 (M...	PTV 70-78	158.47	72.70	73.36	74.32	76.10	76.14	78.17	78.65	0 %
Evaluation dose (MR2...	PTV 70-78	158.35	71.13	71.82	72.84	74.66	74.73	76.66	77.08	0 %
Plan dose: MR242 (M...	PTV 70eks	49.96	66.23	66.84	67.93	73.78	74.31	78.56	78.74	0 %
Evaluation dose (MR2...	PTV 70eks	49.9	64.58	65.29	66.25	72.04	72.54	76.91	77.12	0 %

Figure 67: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 242.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: 254MR (M...	CTV 0-70	38.71	76.39	76.49	76.64	77.30	77.15	79.24	79.48	0 %
Evaluation dose (254...	CTV 0-70	38.71	73.51	73.71	73.95	75.11	75.06	76.73	77.03	0 %
Plan dose: 254MR (M...	CTV 70-78	33.45	76.44	76.51	76.64	77.15	77.10	78.33	78.73	0 %
Evaluation dose (254...	CTV 70-78	33.45	73.60	73.78	73.96	75.04	75.00	76.46	76.55	0 %
Plan dose: 254MR (M...	CTV 70eks	3.73	75.66	75.86	76.46	78.20	78.44	79.74	79.83	0 %
Evaluation dose (254...	CTV 70eks	3.63	72.53	72.81	73.44	75.36	75.50	77.04	77.19	0 %
Plan dose: 254MR (M...	External original	7736.44	0.16	0.24	0.46	16.64	14.32	70.39	76.43	0 %
Evaluation dose (254...	External original	16180.48	0.00	0.01	0.10	8.57	2.21	48.93	67.49	20 %
Plan dose: 254MR (M...	MR BLA	84.29	9.47	9.93	11.09	35.95	29.23	78.50	79.55	0 %
Evaluation dose (254...	MR BLA	84.56	9.21	9.65	10.67	33.70	26.68	76.92	77.79	0 %
Plan dose: 254MR (M...	MR FH L	131.33	0.50	0.79	2.22	23.41	24.16	37.83	38.98	0 %
Evaluation dose (254...	MR FH L	131.53	1.13	1.37	2.18	22.74	23.42	37.21	38.42	0 %
Plan dose: 254MR (M...	MR FH R	131.57	0.51	0.91	2.91	23.52	24.32	39.79	41.39	0 %
Evaluation dose (254...	MR FH R	132.37	1.19	1.47	2.73	22.96	23.86	39.98	41.77	0 %
Plan dose: 254MR (M...	MR REC	87.17	15.46	15.80	16.71	34.15	27.50	73.46	74.22	0 %
Evaluation dose (254...	MR REC	89.08	14.13	14.62	15.57	31.93	25.49	70.72	71.88	0 %
Plan dose: 254MR (M...	PTV 0-70	104.95	72.24	72.88	73.96	76.81	76.98	79.85	80.28	0 %
Evaluation dose (254...	PTV 0-70	104.84	69.22	70.00	71.19	74.45	74.59	78.00	78.54	0 %
Plan dose: 254MR (M...	PTV 70-78	82.9	73.94	74.29	74.96	77.01	77.03	79.99	80.39	0 %
Evaluation dose (254...	PTV 70-78	82.84	71.47	71.85	72.53	74.78	74.70	78.13	78.65	0 %
Plan dose: 254MR (M...	PTV 70eks	48.53	66.61	67.38	68.69	74.80	75.32	79.82	80.12	0 %
Evaluation dose (254...	PTV 70eks	48.46	63.55	64.41	65.84	72.10	72.52	77.91	78.30	0 %

Figure 68: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 254.

B.3 Dose data from pCTs with without water and without the delineation of adipose tissue

As the treatment plans used adaptions of previous tumor volumes, certain names are not correct. In this section, the abbreviations mean:
bla - bladder
FHL - left femur
FHR - right femur
rec - rectum
CTV70-78 - CTV77
CTV0-70 - an old volume which was not used in this thesis
CTV70eks - CTV70
PTV70-78 - PTV77
PTV0-70 - an old volume which was not used in this thesis
PTV70eks - PTV70

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside gr
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: 150MR (M...	CTV 0-70	43.78	70.19	70.65	71.13	76.25	76.74	78.92	79.15	0 %
Evaluation dose (150...	CTV 0-70	43.78	69.13	69.43	69.97	75.47	75.93	78.65	78.99	0 %
Plan dose: 150MR (M...	CTV 70-78	32.97	75.07	75.29	75.56	77.00	76.93	78.95	79.16	0 %
Evaluation dose (150...	CTV 70-78	32.97	74.29	74.46	74.73	76.21	76.04	78.56	78.85	0 %
Plan dose: 150MR (M...	CTV 70eks	7.31	69.27	69.76	70.05	72.85	71.96	78.22	78.49	0 %
Evaluation dose (150...	CTV 70eks	7.34	68.42	68.85	69.14	71.92	71.06	77.05	77.31	0 %
Plan dose: 150MR (M...	External original	5466.99	0.84	0.99	1.33	18.57	14.79	73.41	76.35	0 %
Evaluation dose (150...	External original	10683.66	0.04	0.10	0.24	10.08	2.03	65.59	72.82	10 %
Plan dose: 150MR (M...	MR BLA	68.94	24.83	28.31	34.57	60.77	64.79	76.90	77.00	0 %
Evaluation dose (150...	MR BLA	68.82	24.39	27.77	34.04	59.95	63.82	75.79	75.90	0 %
Plan dose: 150MR (M...	MR FH L	127.6	1.17	1.27	1.50	20.53	25.65	37.56	38.50	0 %
Evaluation dose (150...	MR FH L	127.19	1.18	1.29	1.52	20.71	25.88	37.87	38.82	0 %
Plan dose: 150MR (M...	MR FH R	144.42	1.24	1.36	1.72	21.83	26.75	37.83	38.97	0 %
Evaluation dose (150...	MR FH R	143.32	1.10	1.22	1.56	21.35	26.05	38.06	39.28	0 %
Plan dose: 150MR (M...	MR REC	34.09	4.79	5.96	7.04	26.76	22.10	66.59	68.47	0 %
Evaluation dose (150...	MR REC	34.28	4.77	5.39	7.06	26.34	21.93	65.20	67.19	0 %
Plan dose: 150MR (M...	PTV 0-70	124.89	68.18	68.60	69.31	74.75	75.62	79.13	79.50	0 %
Evaluation dose (150...	PTV 0-70	124.89	67.30	67.70	68.41	73.92	74.75	78.61	79.05	0 %
Plan dose: 150MR (M...	PTV 70-78	82.22	72.81	73.25	74.00	76.39	76.48	79.26	79.60	0 %
Evaluation dose (150...	PTV 70-78	82.09	71.90	72.33	73.11	75.55	75.58	78.79	79.11	0 %
Plan dose: 150MR (M...	PTV 70eks	73.37	66.31	66.77	67.47	72.04	71.04	78.99	79.46	0 %
Evaluation dose (150...	PTV 70eks	73.3	65.39	65.92	66.57	71.23	70.25	78.61	79.09	0 %

Figure 69: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 150.

ROI statistics | POI statistics

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR159 (M...	CTV 0-70	35.22	74.78	75.11	75.39	76.45	76.46	77.78	77.95	0 %
Evaluation dose (MR1...	CTV 0-70	35.22	73.75	73.86	74.16	75.40	75.41	76.86	76.99	0 %
Plan dose: MR159 (M...	CTV 70-78	30.58	75.10	75.18	75.43	76.46	76.45	77.75	77.91	0 %
Evaluation dose (MR1...	CTV 70-78	30.58	73.81	73.94	74.17	75.38	75.38	76.83	76.97	0 %
Plan dose: MR159 (M...	CTV 70eks	1.81	73.76	73.99	74.37	76.31	76.55	78.01	78.09	0 %
Evaluation dose (MR1...	CTV 70eks	1.85	73.07	73.47	73.61	75.57	75.74	77.33	77.40	0 %
Plan dose: MR159 (M...	External original	6520.54	0.83	1.00	1.41	17.93	15.40	72.99	75.93	0 %
Evaluation dose (MR1...	External original	13797.55	0.02	0.07	0.22	9.13	2.14	55.78	71.49	23 %
Plan dose: MR159 (M...	MR BLA	33.5	9.38	10.32	12.14	36.79	28.46	77.37	77.68	0 %
Evaluation dose (MR1...	MR BLA	33.83	9.68	10.60	12.40	36.50	28.22	76.54	76.84	0 %
Plan dose: MR159 (M...	MR FH L	155.13	0.92	1.29	1.62	20.10	22.62	37.60	38.54	0 %
Evaluation dose (MR1...	MR FH L	149.11	1.20	1.32	1.58	19.49	21.77	37.46	38.56	0 %
Plan dose: MR159 (M...	MR FH R	161.57	1.16	1.32	1.72	18.60	20.97	34.14	35.23	0 %
Evaluation dose (MR1...	MR FH R	161.95	1.19	1.32	1.72	18.42	20.72	34.13	35.24	0 %
Plan dose: MR159 (M...	MR REC	49.82	22.41	23.14	24.22	46.34	43.03	74.73	75.39	0 %
Evaluation dose (MR1...	MR REC	49.83	22.27	22.92	24.03	45.75	42.47	73.56	74.29	0 %
Plan dose: MR159 (M...	PTV 0-70	96.83	71.40	72.11	73.13	76.03	76.22	78.99	80.11	0 %
Evaluation dose (MR1...	PTV 0-70	96.74	70.74	71.33	72.27	75.01	75.16	78.00	78.65	0 %
Plan dose: MR159 (M...	PTV 70-78	83.01	72.90	73.40	74.11	76.24	76.29	79.23	80.15	0 %
Evaluation dose (MR1...	PTV 70-78	82.89	71.82	72.34	73.00	75.16	75.22	77.97	78.73	0 %
Plan dose: MR159 (M...	PTV 70eks	36.71	67.95	68.46	69.57	74.45	75.01	78.37	78.69	0 %
Evaluation dose (MR1...	PTV 70eks	36.67	67.30	67.88	68.99	73.70	74.25	77.72	78.06	0 %

Figure 70: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 159.

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: MR161 (M...	CTV 0-70	43.06	74.15	74.55	75.01	77.11	77.08	79.53	79.84	0 %
Evaluation dose (MR1...	CTV 0-70	43.06	73.75	74.17	74.72	76.65	76.56	79.04	79.32	0 %
Plan dose: MR161 (M...	CTV 70-78	38.2	74.72	74.84	75.37	77.16	77.13	79.37	79.58	0 %
Evaluation dose (MR1...	CTV 70-78	38.2	74.42	74.61	74.97	76.72	76.61	78.93	79.07	0 %
Plan dose: MR161 (M...	CTV 70eks	3.24	73.42	73.54	73.83	76.18	76.04	81.60	81.74	0 %
Evaluation dose (MR1...	CTV 70eks	3.13	72.87	73.07	73.37	75.65	75.61	80.96	81.28	0 %
Plan dose: MR161 (M...	External original	7576.75	0.88	1.02	1.36	17.84	14.69	72.61	76.44	0 %
Evaluation dose (MR1...	External original	16164.61	0.00	0.00	0.07	9.19	2.22	54.28	70.76	17 %
Plan dose: MR161 (M...	MR BLA	130.45	17.02	17.96	20.76	54.29	57.80	79.72	80.15	0 %
Evaluation dose (MR1...	MR BLA	131.12	17.13	18.13	20.73	53.83	57.49	79.09	79.55	0 %
Plan dose: MR161 (M...	MR FH L	153.14	1.22	1.36	1.74	22.18	25.06	37.01	37.55	0 %
Evaluation dose (MR1...	MR FH L	152.58	1.23	1.38	1.76	22.45	25.25	37.77	38.36	0 %
Plan dose: MR161 (M...	MR FH R	160.82	1.16	1.31	1.74	23.13	25.90	40.22	41.22	0 %
Evaluation dose (MR1...	MR FH R	160.46	1.19	1.35	1.77	23.41	26.21	40.88	41.98	0 %
Plan dose: MR161 (M...	MR REC	61.78	12.70	13.06	13.77	27.42	22.21	62.31	65.11	0 %
Evaluation dose (MR1...	MR REC	62.09	12.98	13.30	14.12	29.79	25.47	60.30	61.96	0 %
Plan dose: MR161 (M...	PTV 0-70	116.42	71.42	72.07	73.12	76.62	76.82	79.83	80.22	0 %
Evaluation dose (MR1...	PTV 0-70	116.3	69.38	70.38	71.84	75.84	76.10	79.20	79.58	0 %
Plan dose: MR161 (M...	PTV 70-78	94.4	74.02	74.47	74.99	77.10	77.06	79.77	80.12	0 %
Evaluation dose (MR1...	PTV 70-78	94.33	71.47	72.25	73.54	76.32	76.37	79.16	79.46	0 %
Plan dose: MR161 (M...	PTV 70eks	52.61	66.24	66.96	68.03	73.85	73.97	79.91	80.51	0 %
Evaluation dose (MR1...	PTV 70eks	52.55	63.76	64.66	66.35	72.90	73.30	79.39	80.08	0 %

Figure 71: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 161.

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: MR174 (M...	CTV 0-70	31.29	73.81	74.78	75.64	76.52	76.25	80.09	80.81	0 %
Evaluation dose (MR1...	CTV 0-70	31.29	73.47	74.33	74.88	75.82	75.52	79.72	80.23	0 %
Plan dose: MR174 (M...	CTV 70-78	22.76	75.62	75.67	75.78	76.23	76.21	77.07	77.23	0 %
Evaluation dose (MR1...	CTV 70-78	22.76	74.82	74.85	74.97	75.47	75.45	76.21	76.33	0 %
Plan dose: MR174 (M...	CTV 70eks	6.29	72.82	73.12	73.87	77.66	77.97	81.53	81.71	0 %
Evaluation dose (MR1...	CTV 70eks	6.26	72.54	72.81	73.51	77.15	77.43	80.85	81.09	0 %
Plan dose: MR174 (M...	External original	6447.58	1.07	1.32	1.91	18.14	15.50	73.36	76.25	0 %
Evaluation dose (MR1...	External original	13268.27	0.07	0.14	0.28	9.44	2.50	54.50	72.37	31 %
Plan dose: MR174 (M...	MR BLA	62.27	6.36	7.09	8.56	25.30	20.64	72.64	77.81	0 %
Evaluation dose (MR1...	MR BLA	64.8	5.87	6.57	7.88	24.36	19.92	71.89	77.10	0 %
Plan dose: MR174 (M...	MR FH L	142.3	1.66	1.98	3.10	22.78	25.02	34.80	35.93	0 %
Evaluation dose (MR1...	MR FH L	144.16	1.58	1.79	2.87	22.64	24.95	35.36	36.55	0 %
Plan dose: MR174 (M...	MR FH R	147.92	1.59	1.95	3.54	19.61	20.93	32.67	33.79	0 %
Evaluation dose (MR1...	MR FH R	148.46	1.58	1.91	3.50	19.98	21.36	33.49	34.75	0 %
Plan dose: MR174 (M...	MR REC	67.98	10.00	11.51	14.33	34.24	27.14	77.55	78.23	0 %
Evaluation dose (MR1...	MR REC	69.49	8.87	10.34	13.42	33.44	26.74	76.41	77.21	0 %
Plan dose: MR174 (M...	PTV 0-70	87.94	71.16	72.09	73.75	76.71	76.41	81.16	81.69	0 %
Evaluation dose (MR1...	PTV 0-70	87.83	70.78	71.74	73.36	76.03	75.67	80.58	81.18	0 %
Plan dose: MR174 (M...	PTV 70-78	61.53	75.31	75.50	75.68	76.64	76.36	79.28	80.59	0 %
Evaluation dose (MR1...	PTV 70-78	61.46	74.59	74.76	74.89	75.88	75.61	78.35	79.86	0 %
Plan dose: MR174 (M...	PTV 70eks	54.68	66.95	67.76	69.36	75.55	76.05	81.53	82.01	0 %
Evaluation dose (MR1...	PTV 70eks	54.63	66.30	67.09	68.85	74.98	75.35	80.99	81.51	0 %

Figure 72: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 174.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsid
Plan dose: 178MR (M...	CTV 0-70	30.59	74.56	74.75	75.20	77.96	77.50	84.89	85.67	0 %
Evaluation dose (178...	CTV 0-70	30.59	73.80	73.94	74.36	77.11	76.65	84.09	84.73	0 %
Plan dose: 178MR (M...	CTV 70-78	23.7	74.54	74.70	75.13	77.17	77.25	79.57	79.78	0 %
Evaluation dose (178...	CTV 70-78	23.7	73.80	73.92	74.25	76.33	76.39	78.72	78.97	0 %
Plan dose: 178MR (M...	CTV 70eks	5.68	75.90	76.62	77.46	81.47	81.59	86.17	86.71	0 %
Evaluation dose (178...	CTV 70eks	5.73	75.02	75.70	76.55	80.54	80.70	85.17	85.77	0 %
Plan dose: 178MR (M...	External original	6807.08	0.96	1.19	1.76	18.74	15.68	74.24	77.44	0 %
Evaluation dose (178...	External original	14384.09	0.04	0.10	0.25	9.59	2.51	57.21	73.01	38 %
Plan dose: 178MR (M...	MR BLA	112.86	9.93	11.43	14.35	33.06	27.29	77.13	78.57	0 %
Evaluation dose (178...	MR BLA	112.3	9.97	11.52	14.55	32.76	27.09	76.21	77.63	0 %
Plan dose: 178MR (M...	MR FH L	177.42	1.17	1.43	1.90	16.99	17.89	30.21	31.00	0 %
Evaluation dose (178...	MR FH L	178.1	1.31	1.48	1.90	17.07	17.86	30.96	31.90	0 %
Plan dose: 178MR (M...	MR FH R	185.73	1.36	1.65	2.36	19.33	22.62	31.56	32.72	0 %
Evaluation dose (178...	MR FH R	187.29	1.43	1.67	2.35	19.26	22.57	31.75	32.98	0 %
Plan dose: 178MR (M...	MR REC	41.99	12.11	14.07	16.36	45.97	44.09	80.24	81.71	0 %
Evaluation dose (178...	MR REC	43.13	10.77	12.63	15.32	44.83	42.92	79.14	80.73	0 %
Plan dose: 178MR (M...	PTV 0-70	95.06	72.33	73.16	74.48	78.03	77.70	84.11	84.97	0 %
Evaluation dose (178...	PTV 0-70	94.93	71.71	72.51	73.80	77.22	76.87	83.32	84.28	0 %
Plan dose: 178MR (M...	PTV 70-78	63.47	72.86	73.69	74.58	77.18	77.25	80.27	80.59	0 %
Evaluation dose (178...	PTV 70-78	63.39	72.32	72.96	73.86	76.36	76.42	79.42	79.64	0 %
Plan dose: 178MR (M...	PTV 70eks	64.26	66.44	67.89	70.44	77.70	77.86	84.73	85.36	0 %
Evaluation dose (178...	PTV 70eks	64.2	65.92	67.25	69.79	76.96	77.08	83.86	84.66	0 %

Figure 73: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 178.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 179MR (M...	CTV 0-70	58.16	74.40	74.76	74.97	76.28	76.18	78.85	79.22	0 %
Evaluation dose (179...	CTV 0-70	58.14	73.26	73.45	73.70	75.03	74.89	77.71	78.07	0 %
Plan dose: 179MR (M...	CTV 70-78	44.39	74.76	74.84	75.00	76.02	76.01	77.35	77.51	0 %
Evaluation dose (179...	CTV 70-78	44.38	73.36	73.49	73.70	74.75	74.73	76.13	76.29	0 %
Plan dose: 179MR (M...	CTV 70eks	9.76	73.73	73.95	74.55	77.11	77.28	79.49	79.70	0 %
Evaluation dose (179...	CTV 70eks	9.78	72.79	72.96	73.57	75.99	76.15	78.48	78.62	0 %
Plan dose: 179MR (M...	External original	6401.64	1.40	1.76	2.53	22.19	18.67	75.14	76.23	0 %
Evaluation dose (179...	External original	14055.19	0.07	0.13	0.31	11.19	3.26	65.57	73.66	28 %
Plan dose: 179MR (M...	MR BLA	121.93	3.25	3.58	4.23	35.09	28.52	77.57	78.56	0 %
Evaluation dose (179...	MR BLA	122.04	3.43	3.71	4.32	34.49	27.97	76.38	77.36	0 %
Plan dose: 179MR (M...	MR FH L	121.65	6.26	7.75	12.13	29.28	31.00	43.46	44.25	0 %
Evaluation dose (179...	MR FH L	121.68	6.20	7.74	12.11	29.23	30.92	43.64	44.46	0 %
Plan dose: 179MR (M...	MR FH R	129.24	6.56	7.77	12.03	30.44	31.21	44.79	45.71	0 %
Evaluation dose (179...	MR FH R	128.97	6.67	7.84	12.13	30.43	31.16	45.07	46.09	0 %
Plan dose: 179MR (M...	MR REC	24.69	12.45	12.90	14.25	44.17	44.74	76.29	77.14	0 %
Evaluation dose (179...	MR REC	24.7	12.35	12.80	14.11	43.57	45.10	74.08	75.02	0 %
Plan dose: 179MR (M...	PTV 0-70	138.4	70.65	72.00	73.31	75.90	76.03	78.84	79.26	0 %
Evaluation dose (179...	PTV 0-70	138.15	70.58	71.34	72.34	74.76	74.79	77.80	78.21	0 %
Plan dose: 179MR (M...	PTV 70-78	102.53	71.52	73.53	74.43	76.05	76.11	78.38	78.75	0 %
Evaluation dose (179...	PTV 70-78	102.5	72.25	72.67	73.38	74.90	74.86	77.37	77.79	0 %
Plan dose: 179MR (M...	PTV 70eks	74.62	66.99	68.11	69.62	74.72	75.14	79.14	79.42	0 %
Evaluation dose (179...	PTV 70eks	74.55	65.95	66.77	68.37	73.53	73.97	78.01	78.35	0 %

Figure 74: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 179.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsid
Plan dose: 192MR (M...	CTV 0-70	31.64	74.71	74.84	74.98	76.33	75.98	79.93	80.35	0 %
Evaluation dose (192...	CTV 0-70	31.68	73.41	73.83	74.28	76.34	76.08	79.83	80.29	0 %
Plan dose: 192MR (M...	CTV 70-78	22.07	74.72	74.84	74.97	75.80	75.77	77.01	77.16	0 %
Evaluation dose (192...	CTV 70-78	22.08	73.14	73.61	74.02	75.66	75.78	77.07	77.23	0 %
Plan dose: 192MR (M...	CTV 70eks	7.31	74.59	74.99	75.53	77.94	78.01	80.50	80.60	0 %
Evaluation dose (192...	CTV 70eks	7.17	75.55	75.87	76.26	78.32	78.41	80.47	80.68	0 %
Plan dose: 192MR (M...	External original	6930.4	0.69	0.81	1.13	17.83	15.16	72.04	75.39	0 %
Evaluation dose (192...	External original	13901.71	0.00	0.01	0.11	10.37	3.26	59.75	72.20	11 %
Plan dose: 192MR (M...	MR BLA	39.31	19.68	20.59	22.26	52.26	53.61	78.88	79.61	0 %
Evaluation dose (192...	MR BLA	39.1	19.86	20.78	22.38	52.13	53.39	78.69	79.64	0 %
Plan dose: 192MR (M...	MR FH L	117.61	1.30	1.41	1.88	23.65	24.27	43.90	45.22	0 %
Evaluation dose (192...	MR FH L	117.51	1.30	1.42	1.89	23.95	24.48	44.89	46.30	0 %
Plan dose: 192MR (M...	MR FH R	115.35	1.34	1.47	2.04	23.39	24.04	40.57	41.65	0 %
Evaluation dose (192...	MR FH R	115.53	1.37	1.50	2.07	24.00	24.72	42.10	43.30	0 %
Plan dose: 192MR (M...	MR REC	110.81	16.51	17.00	18.05	41.98	35.98	75.82	76.77	0 %
Evaluation dose (192...	MR REC	110.65	17.74	18.40	19.68	44.75	42.54	75.62	76.22	0 %
Plan dose: 192MR (M...	PTV 0-70	104.44	71.23	72.07	73.08	75.80	75.74	79.86	80.35	0 %
Evaluation dose (192...	PTV 0-70	104.31	69.33	70.24	72.13	75.54	75.64	79.66	80.18	0 %
Plan dose: 192MR (M...	PTV 70-78	65	72.77	73.19	73.81	75.69	75.66	79.18	79.82	0 %
Evaluation dose (192...	PTV 70-78	64.91	69.27	70.09	72.37	75.11	75.35	78.19	79.25	0 %
Plan dose: 192MR (M...	PTV 70eks	78.42	60.19	64.73	67.76	73.83	74.89	79.95	80.37	0 %
Evaluation dose (192...	PTV 70eks	78.34	65.77	67.08	68.93	75.05	75.58	80.19	80.68	0 %

Figure 75: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 192.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gr
Plan dose: 221MR (M...	CTV 0-70	58.09	69.33	69.65	70.38	75.94	76.56	78.42	78.69	0 %
Evaluation dose (221...	CTV 0-70	58.13	69.26	69.56	70.29	75.44	75.98	77.95	78.18	0 %
Plan dose: 221MR (M...	CTV 70-78	46.91	74.88	75.03	75.27	76.74	76.80	78.57	78.77	0 %
Evaluation dose (221...	CTV 70-78	46.91	74.26	74.39	74.66	76.15	76.16	78.09	78.26	0 %
Plan dose: 221MR (M...	CTV 70eks	7.26	68.51	68.69	69.04	70.98	70.70	74.59	74.93	0 %
Evaluation dose (221...	CTV 70eks	7.26	68.43	68.54	68.94	70.79	70.45	74.34	74.67	0 %
Plan dose: 221MR (M...	MR BLA	90.78	9.73	10.57	12.63	36.85	29.84	78.37	78.95	0 %
Evaluation dose (221...	MR BLA	92.71	9.32	10.39	12.32	36.22	29.11	77.82	78.37	0 %
Plan dose: 221MR (M...	MR FH L	133.86	2.11	2.41	3.57	23.10	23.92	39.07	40.23	0 %
Evaluation dose (221...	MR FH L	135.51	1.73	1.99	3.07	23.16	24.20	39.62	40.67	0 %
Plan dose: 221MR (M...	MR FH R	134.85	1.91	2.26	3.31	21.84	22.87	38.60	39.87	0 %
Evaluation dose (221...	MR FH R	137.09	1.67	1.84	2.65	21.92	23.11	39.51	40.87	0 %
Plan dose: 221MR (M...	MR REC	63.89	7.73	8.28	9.45	28.56	22.89	73.54	74.78	0 %
Evaluation dose (221...	MR REC	63.93	7.81	8.40	9.59	28.71	23.22	71.72	73.43	0 %
Plan dose: 221MR (M...	orginal external	6927.47	1.66	1.97	2.74	19.44	16.57	72.77	76.37	0 %
Evaluation dose (221...	orginal external	15001.49	0.13	0.20	0.33	9.77	2.79	56.42	71.06	33 %
Plan dose: 221MR (M...	PTV 0-70	135.26	66.41	67.18	68.32	75.10	76.28	79.40	79.89	0 %
Evaluation dose (221...	PTV 0-70	135.12	66.14	66.83	68.02	74.52	75.65	78.69	79.13	0 %
Plan dose: 221MR (M...	PTV 70-78	105.64	72.66	73.20	74.42	76.65	76.72	79.63	80.03	0 %
Evaluation dose (221...	PTV 70-78	105.54	71.48	72.35	73.58	75.99	76.06	78.83	79.26	0 %
Plan dose: 221MR (M...	PTV 70eks	72.21	57.70	59.93	62.34	70.22	70.04	77.92	78.22	0 %
Evaluation dose (221...	PTV 70eks	72.13	57.11	59.48	61.91	69.91	69.71	77.76	78.13	0 %

Figure 76: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 221.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gri
Plan dose: MR242 (M...	CTV 0-70	84.43	74.44	74.62	74.96	76.08	76.05	77.62	77.84	0 %
Evaluation dose (MR2...	CTV 0-70	84.43	73.67	73.92	74.26	75.46	75.46	76.99	77.33	0 %
Plan dose: MR242 (M...	CTV 70-78	77.75	74.56	74.75	75.01	76.06	76.04	77.44	77.68	0 %
Evaluation dose (MR2...	CTV 70-78	83.26	73.69	73.95	74.27	75.46	75.45	76.98	77.27	0 %
Plan dose: MR242 (M...	CTV 70eks	2.97	72.99	73.51	74.09	76.17	76.33	78.19	78.37	0 %
Evaluation dose (MR2...	CTV 70eks	2.96	72.36	72.94	73.43	75.59	75.77	77.51	77.68	0 %
Plan dose: MR242 (M...	External original	7492.4	2.22	2.54	3.32	21.99	18.73	75.37	76.27	0 %
Evaluation dose (MR2...	External original	15494.11	0.20	0.27	0.39	11.40	3.28	66.94	74.67	12 %
Plan dose: MR242 (M...	MR BLA	53.53	16.18	18.62	23.49	55.06	59.76	77.34	77.88	0 %
Evaluation dose (MR2...	MR BLA	53.49	16.14	18.68	23.24	54.43	59.11	76.50	77.01	0 %
Plan dose: MR242 (M...	MR FH L	141.23	2.80	3.86	5.52	30.83	33.76	45.56	46.65	0 %
Evaluation dose (MR2...	MR FH L	141.99	2.71	2.97	5.19	30.98	33.91	46.40	47.55	0 %
Plan dose: MR242 (M...	MR FH R	128.27	2.78	3.11	5.23	26.84	29.39	40.25	41.26	0 %
Evaluation dose (MR2...	MR FH R	128.95	2.68	2.93	4.84	26.86	29.38	40.95	42.02	0 %
Plan dose: MR242 (M...	MR REC	44.41	20.49	20.80	21.76	41.27	36.00	74.58	75.20	0 %
Evaluation dose (MR2...	MR REC	44.48	20.54	20.85	21.91	41.05	35.97	73.83	74.37	0 %
Plan dose: MR242 (M...	PTV 0-70	178.13	70.78	71.72	73.26	75.80	75.96	78.12	78.42	0 %
Evaluation dose (MR2...	PTV 0-70	177.97	70.18	71.08	72.55	75.17	75.35	77.49	77.76	0 %
Plan dose: MR242 (M...	PTV 70-78	158.47	72.80	73.47	74.29	75.99	76.01	78.13	78.44	0 %
Evaluation dose (MR2...	PTV 70-78	158.35	72.12	72.75	73.59	75.37	75.41	77.52	77.82	0 %
Plan dose: MR242 (M...	PTV 70eks	49.96	66.45	67.00	68.23	73.88	74.62	78.17	78.39	0 %
Evaluation dose (MR2...	PTV 70eks	49.9	65.73	66.48	67.59	73.16	73.89	77.60	77.75	0 %

Figure 77: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 242.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: 254MR (M...	CTV 0-70	38.71	75.44	75.66	75.92	77.17	76.88	80.72	81.26	0 %
Evaluation dose (254...	CTV 0-70	38.71	74.36	74.51	74.82	76.03	75.75	79.45	79.94	0 %
Plan dose: 254MR (M...	CTV 70-78	33.45	75.40	75.58	75.86	76.79	76.77	78.09	78.25	0 %
Evaluation dose (254...	CTV 70-78	33.45	74.25	74.49	74.75	75.67	75.65	76.99	77.16	0 %
Plan dose: 254MR (M...	CTV 70eks	3.73	77.39	77.77	78.09	79.88	79.82	82.12	82.15	0 %
Evaluation dose (254...	CTV 70eks	3.63	76.46	76.69	76.93	78.61	78.51	80.76	80.82	0 %
Plan dose: 254MR (M...	External original	7736.44	0.73	0.86	1.16	16.66	14.25	70.94	76.21	0 %
Evaluation dose (254...	External original	16180.48	0.00	0.01	0.10	8.75	2.25	50.05	69.22	20 %
Plan dose: 254MR (M...	MR BLA	84.29	7.68	8.20	9.47	34.95	27.96	78.68	79.56	0 %
Evaluation dose (254...	MR BLA	84.56	8.02	8.53	9.82	34.45	27.64	77.52	78.30	0 %
Plan dose: 254MR (M...	MR FH L	131.33	1.17	1.40	2.23	23.22	24.00	37.75	39.14	0 %
Evaluation dose (254...	MR FH L	131.53	1.15	1.39	2.19	23.12	23.82	37.83	39.14	0 %
Plan dose: 254MR (M...	MR FH R	131.57	1.26	1.52	2.96	23.44	24.42	40.10	42.06	0 %
Evaluation dose (254...	MR FH R	132.37	1.21	1.48	2.91	23.45	24.47	40.51	42.52	0 %
Plan dose: 254MR (M...	MR REC	87.17	12.05	12.90	14.15	32.78	26.16	73.34	74.29	0 %
Evaluation dose (254...	MR REC	89.08	12.37	13.00	14.21	32.34	25.97	72.30	73.23	0 %
Plan dose: 254MR (M...	PTV 0-70	104.95	72.86	73.39	74.19	76.90	76.75	80.83	81.20	0 %
Evaluation dose (254...	PTV 0-70	104.84	71.79	72.32	73.13	75.76	75.63	79.65	79.94	0 %
Plan dose: 254MR (M...	PTV 70-78	82.9	73.00	73.50	74.23	76.66	76.66	80.51	80.83	0 %
Evaluation dose (254...	PTV 70-78	82.84	71.97	72.43	73.20	75.53	75.52	79.32	79.69	0 %
Plan dose: 254MR (M...	PTV 70eks	48.53	67.53	68.29	69.99	76.02	76.44	81.18	81.42	0 %
Evaluation dose (254...	PTV 70eks	48.46	66.26	67.27	68.92	74.91	75.31	79.87	80.18	0 %

Figure 78: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 254.

B.4 Dose data from pCTs with additional water and delineation of adipose tissue

As the treatment plans used adaptions of previous tumor volumes, certain names are not correct. In this section, the abbreviations mean:
bla - bladder
FHL - left femur
FHR - right femur
rec - rectum
CTV70-78 - CTV77
CTV0-70 - an old volume which was not used in this thesis
CTV70eks - CTV70
PTV70-78 - PTV77
PTV0-70 - an old volume which was not used in this thesis
PTV70eks - PTV70

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside gr
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: 150MR (M...	CTV 0-70	43.78	70.16	70.83	72.02	76.59	77.12	79.16	79.67	0 %
Evaluation dose (150...	CTV 0-70	43.78	68.93	69.46	70.55	75.13	75.57	77.83	78.13	0 %
Plan dose: 150MR (M...	CTV 70-78	32.97	75.38	75.61	75.85	77.19	77.21	78.88	79.06	0 %
Evaluation dose (150...	CTV 70-78	32.97	73.95	74.11	74.45	75.68	75.60	77.53	77.78	0 %
Plan dose: 150MR (M...	CTV 70eks	7.31	69.34	69.57	70.12	73.86	73.00	80.45	80.75	0 %
Evaluation dose (150...	CTV 70eks	7.34	67.99	68.21	68.67	72.18	71.27	78.32	78.62	0 %
Plan dose: 150MR (M...	External	10323.13	0.12	0.17	0.30	10.33	2.04	67.65	74.89	0 %
Evaluation dose (150...	External	10683.66	0.04	0.10	0.24	10.09	2.04	65.82	73.21	10 %
Plan dose: 150MR (M...	MR BLA	68.94	23.22	27.83	34.26	60.93	64.57	77.25	77.40	0 %
Evaluation dose (150...	MR BLA	68.82	22.93	27.10	33.62	59.64	63.18	75.52	75.67	0 %
Plan dose: 150MR (M...	MR FH L	127.6	1.15	1.24	1.48	20.75	25.91	35.42	36.12	0 %
Evaluation dose (150...	MR FH L	127.19	1.17	1.27	1.51	20.80	25.98	35.55	36.30	0 %
Plan dose: 150MR (M...	MR FH R	144.42	1.24	1.37	1.76	21.29	24.71	37.96	39.01	0 %
Evaluation dose (150...	MR FH R	143.32	1.11	1.24	1.59	20.71	24.10	37.78	38.97	0 %
Plan dose: 150MR (M...	MR REC	34.09	4.93	6.61	7.59	26.53	22.37	68.05	70.07	0 %
Evaluation dose (150...	MR REC	34.28	4.84	5.44	7.51	25.96	22.00	66.34	68.19	0 %
Plan dose: 150MR (M...	PTV 0-70	124.89	68.36	68.85	69.85	75.39	76.28	79.58	80.16	0 %
Evaluation dose (150...	PTV 0-70	124.89	66.99	67.51	68.48	73.89	74.78	77.96	78.31	0 %
Plan dose: 150MR (M...	PTV 70-78	82.22	72.92	73.52	74.39	76.76	76.94	79.22	79.75	0 %
Evaluation dose (150...	PTV 70-78	82.09	71.41	72.04	72.84	75.25	75.38	77.85	78.10	0 %
Plan dose: 150MR (M...	PTV 70eks	73.37	66.50	66.96	67.83	73.01	72.26	79.89	80.51	0 %
Evaluation dose (150...	PTV 70eks	73.3	65.10	65.65	66.46	71.55	70.77	78.29	78.62	0 %

Figure 79: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 150.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsid
Plan dose: MR159 (M...	CTV 0-70	35.22	76.17	76.36	76.60	77.06	77.05	77.94	78.20	0 %
Evaluation dose (MR1...	CTV 0-70	35.22	72.52	72.73	73.02	74.41	74.56	75.71	75.92	0 %
Plan dose: MR159 (M...	CTV 70-78	30.58	76.40	76.53	76.66	77.03	77.04	77.49	77.62	0 %
Evaluation dose (MR1...	CTV 70-78	30.58	72.50	72.68	73.00	74.39	74.56	75.64	75.74	0 %
Plan dose: MR159 (M...	CTV 70eks	1.81	75.14	75.31	75.83	77.31	77.57	78.59	78.64	0 %
Evaluation dose (MR1...	CTV 70eks	1.85	73.23	73.43	73.59	74.78	74.84	76.18	76.23	0 %
Plan dose: MR159 (M...	External	13121.63	0.04	0.09	0.21	9.45	2.24	58.09	73.10	0 %
Evaluation dose (MR1...	External	13797.55	0.01	0.07	0.21	8.99	2.11	54.93	70.72	23 %
Plan dose: MR159 (M...	MR BLA	33.5	9.52	10.41	12.30	37.44	29.76	76.81	77.09	0 %
Evaluation dose (MR1...	MR BLA	33.83	9.53	10.26	12.17	36.49	28.97	74.66	74.93	0 %
Plan dose: MR159 (M...	MR FH L	155.13	0.96	1.05	1.29	20.04	23.08	36.59	37.50	0 %
Evaluation dose (MR1...	MR FH L	149.11	1.18	1.29	1.56	19.39	21.93	36.34	37.38	0 %
Plan dose: MR159 (M...	MR FH R	161.57	1.07	1.21	1.65	18.56	20.45	34.08	35.03	0 %
Evaluation dose (MR1...	MR FH R	161.95	1.16	1.30	1.70	18.10	20.01	33.72	34.78	0 %
Plan dose: MR159 (M...	MR REC	49.82	22.53	23.05	24.26	46.70	43.46	75.40	75.80	0 %
Evaluation dose (MR1...	MR REC	49.83	21.69	22.30	23.31	44.76	40.79	72.30	72.75	0 %
Plan dose: MR159 (M...	PTV 0-70	96.83	72.26	72.87	73.99	76.59	76.87	79.60	80.69	0 %
Evaluation dose (MR1...	PTV 0-70	96.74	70.18	70.79	71.69	74.08	74.24	77.05	77.97	0 %
Plan dose: MR159 (M...	PTV 70-78	83.01	73.51	74.12	74.96	76.77	76.91	80.09	80.80	0 %
Evaluation dose (MR1...	PTV 70-78	82.89	70.84	71.34	72.22	74.18	74.29	77.04	78.11	0 %
Plan dose: MR159 (M...	PTV 70eks	36.71	68.28	68.89	70.14	75.06	75.72	78.56	78.70	0 %
Evaluation dose (MR1...	PTV 70eks	36.67	66.52	67.11	68.49	72.94	73.46	76.28	77.00	0 %

Figure 80: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 159.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: MR161 (M...	CTV 0-70	43.06	74.14	74.41	74.92	76.92	77.00	79.09	80.11	0 %
Evaluation dose (MR1...	CTV 0-70	43.06	72.14	72.50	73.18	75.26	75.30	77.15	77.99	0 %
Plan dose: MR161 (M...	CTV 70-78	38.2	74.63	74.97	75.41	76.99	77.05	78.87	79.05	0 %
Evaluation dose (MR1...	CTV 70-78	38.2	72.99	73.35	73.96	75.37	75.36	76.99	77.12	0 %
Plan dose: MR161 (M...	CTV 70eks	3.24	73.23	73.42	73.74	75.90	75.19	82.18	82.61	0 %
Evaluation dose (MR1...	CTV 70eks	3.13	71.47	71.62	71.82	73.86	73.26	80.25	80.36	0 %
Plan dose: MR161 (M...	External	15194.21	0.00	0.00	0.06	9.56	2.46	56.38	72.50	0 %
Evaluation dose (MR1...	External	16164.61	0.00	0.00	0.07	9.04	2.19	53.53	69.63	17 %
Plan dose: MR161 (M...	MR BLA	130.45	16.62	17.83	20.73	54.24	57.54	79.59	80.78	0 %
Evaluation dose (MR1...	MR BLA	131.12	16.18	17.36	20.18	52.71	55.86	77.57	78.86	0 %
Plan dose: MR161 (M...	MR FH L	153.14	1.15	1.28	1.66	21.57	22.94	39.34	40.05	0 %
Evaluation dose (MR1...	MR FH L	152.58	1.16	1.29	1.66	21.56	22.80	39.72	40.52	0 %
Plan dose: MR161 (M...	MR FH R	160.82	1.14	1.28	1.69	22.33	25.10	38.50	39.21	0 %
Evaluation dose (MR1...	MR FH R	160.46	1.16	1.31	1.71	22.27	25.16	38.52	39.23	0 %
Plan dose: MR161 (M...	MR REC	61.78	12.29	12.78	13.57	27.01	21.60	61.65	64.85	0 %
Evaluation dose (MR1...	MR REC	62.09	12.32	12.77	13.69	28.98	24.60	59.42	61.18	0 %
Plan dose: MR161 (M...	PTV 0-70	116.42	71.26	71.88	72.77	76.51	76.81	79.95	80.84	0 %
Evaluation dose (MR1...	PTV 0-70	116.3	67.83	68.99	70.38	74.48	74.97	77.87	79.01	0 %
Plan dose: MR161 (M...	PTV 70-78	94.4	73.97	74.43	74.99	77.02	77.05	79.83	80.76	0 %
Evaluation dose (MR1...	PTV 70-78	94.33	70.47	71.20	72.20	75.06	75.22	77.70	78.85	0 %
Plan dose: MR161 (M...	PTV 70eks	52.61	66.36	67.05	68.20	73.70	73.66	80.71	81.26	0 %
Evaluation dose (MR1...	PTV 70eks	52.55	62.28	63.22	64.82	71.34	71.46	78.69	79.42	0 %

Figure 81: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 161.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR174 (M...	CTV 0-70	31.29	69.17	69.45	69.95	75.62	76.76	77.91	78.08	0 %
Evaluation dose (MR1...	CTV 0-70	31.29	67.73	67.98	68.42	73.94	75.06	76.13	76.31	0 %
Plan dose: MR174 (M...	CTV 70-78	22.76	75.71	75.97	76.27	76.94	76.89	77.98	78.14	0 %
Evaluation dose (MR1...	CTV 70-78	22.76	73.92	74.18	74.51	75.22	75.21	76.17	76.33	0 %
Plan dose: MR174 (M...	CTV 70eks	6.29	68.91	68.99	69.17	71.09	70.63	74.24	74.50	0 %
Evaluation dose (MR1...	CTV 70eks	6.26	67.44	67.51	67.71	69.59	69.17	72.52	72.80	0 %
Plan dose: MR174 (M...	External	12862.43	0.13	0.19	0.33	9.74	2.73	55.58	69.46	0 %
Evaluation dose (MR1...	External	13268.27	0.10	0.17	0.32	9.39	2.61	53.70	67.78	31 %
Plan dose: MR174 (M...	MR BLA	62.27	7.68	8.49	9.73	25.56	19.61	68.10	69.21	0 %
Evaluation dose (MR1...	MR BLA	64.8	6.88	7.65	9.06	24.35	18.58	66.58	67.64	0 %
Plan dose: MR174 (M...	MR FH L	142.3	1.83	2.13	3.43	24.46	26.81	37.12	38.24	0 %
Evaluation dose (MR1...	MR FH L	144.16	1.70	1.92	3.16	24.05	26.50	37.02	38.19	0 %
Plan dose: MR174 (M...	MR FH R	147.92	1.81	2.24	4.24	22.76	24.67	35.23	36.42	0 %
Evaluation dose (MR1...	MR FH R	148.46	1.80	2.20	4.11	22.89	25.00	35.74	37.01	0 %
Plan dose: MR174 (M...	MR REC	67.98	11.59	13.13	14.44	35.37	29.17	73.19	74.27	0 %
Evaluation dose (MR1...	MR REC	69.49	9.99	11.60	13.82	34.05	28.11	71.36	72.43	0 %
Plan dose: MR174 (M...	PTV 0-70	87.94	68.59	68.85	69.28	74.39	75.74	77.63	77.87	0 %
Evaluation dose (MR1...	PTV 0-70	87.83	66.92	67.35	67.82	72.74	74.03	75.87	76.10	0 %
Plan dose: MR174 (M...	PTV 70-78	61.53	72.96	73.27	73.83	76.13	76.47	77.72	77.91	0 %
Evaluation dose (MR1...	PTV 70-78	61.46	71.34	71.64	72.20	74.43	74.75	75.96	76.13	0 %
Plan dose: MR174 (M...	PTV 70eks	54.68	66.63	67.08	67.79	70.93	70.21	76.90	77.08	0 %
Evaluation dose (MR1...	PTV 70eks	54.63	64.69	65.18	66.28	69.36	68.69	75.14	75.33	0 %

Figure 82: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 174.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 178MR (M...	CTV 0-70	30.59	73.95	74.41	75.05	76.68	76.58	80.71	81.05	0 %
Evaluation dose (178...	CTV 0-70	30.59	71.99	72.41	73.21	75.00	74.95	78.43	78.78	0 %
Plan dose: 178MR (M...	CTV 70-78	23.7	75.11	75.18	75.38	76.52	76.57	77.87	78.13	0 %
Evaluation dose (178...	CTV 70-78	23.7	73.63	73.70	73.87	74.96	74.97	76.29	76.55	0 %
Plan dose: 178MR (M...	CTV 70eks	5.68	73.46	73.70	73.95	77.42	77.33	81.43	81.56	0 %
Evaluation dose (178...	CTV 70eks	5.73	71.50	71.70	71.96	75.26	75.14	79.11	79.33	0 %
Plan dose: 178MR (M...	External	13664.42	0.11	0.16	0.29	9.83	2.47	58.76	71.91	0 %
Evaluation dose (178...	External	14384.09	0.06	0.12	0.27	9.32	2.33	56.15	69.82	38 %
Plan dose: 178MR (M...	MR BLA	112.86	9.09	9.78	11.65	32.18	27.10	76.17	77.21	0 %
Evaluation dose (178...	MR BLA	112.3	8.87	9.50	11.35	31.48	26.58	74.66	75.76	0 %
Plan dose: 178MR (M...	MR FH L	177.42	1.62	1.84	2.52	22.16	24.90	37.78	38.40	0 %
Evaluation dose (178...	MR FH L	178.1	1.62	1.83	2.50	22.07	24.53	38.27	38.93	0 %
Plan dose: 178MR (M...	MR FH R	185.73	1.75	2.03	2.95	25.05	26.65	43.93	44.36	0 %
Evaluation dose (178...	MR FH R	187.29	1.74	2.03	2.95	24.73	26.12	43.98	44.47	0 %
Plan dose: 178MR (M...	MR REC	41.99	7.46	8.75	11.58	45.02	44.93	77.42	78.90	0 %
Evaluation dose (178...	MR REC	43.13	6.61	7.50	9.70	43.10	42.68	75.01	76.50	0 %
Plan dose: 178MR (M...	PTV 0-70	95.06	70.92	71.57	72.61	76.01	76.19	80.35	80.87	0 %
Evaluation dose (178...	PTV 0-70	94.93	69.11	69.75	70.69	74.29	74.58	78.25	78.67	0 %
Plan dose: 178MR (M...	PTV 70-78	63.47	73.30	73.70	74.31	76.34	76.42	78.60	78.89	0 %
Evaluation dose (178...	PTV 70-78	63.39	71.75	72.16	72.79	74.74	74.82	76.82	77.08	0 %
Plan dose: 178MR (M...	PTV 70eks	64.26	66.49	67.29	68.47	74.16	74.25	80.68	81.03	0 %
Evaluation dose (178...	PTV 70eks	64.2	64.74	65.57	66.80	72.28	72.37	78.50	78.81	0 %

Figure 83: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 178.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gric
Plan dose: 179MR (M...	CTV 0-70	58.16	74.70	75.22	75.56	76.79	76.72	78.66	79.07	0 %
Evaluation dose (179...	CTV 0-70	58.14	72.44	72.87	73.28	74.48	74.46	76.13	76.53	0 %
Plan dose: 179MR (M...	CTV 70-78	44.39	75.38	75.48	75.74	76.74	76.68	78.36	78.56	0 %
Evaluation dose (179...	CTV 70-78	44.38	72.97	73.19	73.46	74.45	74.43	75.82	76.01	0 %
Plan dose: 179MR (M...	CTV 70eks	9.76	73.94	74.20	74.65	77.02	77.13	79.50	79.61	0 %
Evaluation dose (179...	CTV 70eks	9.78	71.78	72.07	72.50	74.71	74.75	77.17	77.35	0 %
Plan dose: 179MR (M...	External	12642.96	0.19	0.28	0.45	12.06	4.16	68.00	75.09	0 %
Evaluation dose (179...	External	14055.19	0.06	0.12	0.29	10.88	3.22	63.65	72.30	28 %
Plan dose: 179MR (M...	MR BLA	121.93	3.30	3.59	4.20	34.41	27.70	77.37	78.19	0 %
Evaluation dose (179...	MR BLA	122.04	3.28	3.58	4.18	33.39	26.82	75.24	75.99	0 %
Plan dose: 179MR (M...	MR FH L	121.65	6.13	7.77	12.40	27.39	29.37	40.18	41.17	0 %
Evaluation dose (179...	MR FH L	121.68	6.00	7.64	12.15	27.03	28.93	39.83	40.85	0 %
Plan dose: 179MR (M...	MR FH R	129.24	6.60	7.57	11.41	28.98	30.07	42.14	43.17	0 %
Evaluation dose (179...	MR FH R	128.97	6.58	7.55	11.31	28.72	29.78	42.10	43.22	0 %
Plan dose: 179MR (M...	MR REC	24.69	12.30	12.94	14.48	43.76	43.55	76.64	77.44	0 %
Evaluation dose (179...	MR REC	24.7	12.06	12.69	14.16	42.63	42.82	73.69	74.37	0 %
Plan dose: 179MR (M...	PTV 0-70	138.4	72.22	72.72	73.63	76.29	76.42	79.20	79.70	0 %
Evaluation dose (179...	PTV 0-70	138.15	70.04	70.52	71.44	73.98	74.15	76.74	77.25	0 %
Plan dose: 179MR (M...	PTV 70-78	102.53	73.05	73.58	74.31	76.37	76.46	78.71	79.06	0 %
Evaluation dose (179...	PTV 70-78	102.5	70.87	71.37	72.06	74.06	74.20	76.17	76.61	0 %
Plan dose: 179MR (M...	PTV 70eks	74.62	67.87	68.70	70.07	74.98	75.55	79.44	79.87	0 %
Evaluation dose (179...	PTV 70eks	74.55	65.51	66.44	67.93	72.70	73.26	77.06	77.60	0 %

Figure 84: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 179.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gr
Plan dose: 192MR (M...	CTV 0-70	31.64	74.67	75.17	75.51	77.22	76.95	81.40	81.76	0 %
Evaluation dose (192...	CTV 0-70	31.68	72.81	73.21	73.78	75.79	75.68	78.98	79.45	0 %
Plan dose: 192MR (M...	CTV 70-78	22.07	75.31	75.40	75.63	76.74	76.75	78.22	78.45	0 %
Evaluation dose (192...	CTV 70-78	22.08	72.77	73.09	73.67	75.32	75.40	76.97	77.18	0 %
Plan dose: 192MR (M...	CTV 70eks	7.31	73.78	74.44	74.82	78.59	78.72	82.35	82.49	0 %
Evaluation dose (192...	CTV 70eks	7.17	73.34	73.85	74.25	77.06	77.20	79.74	79.85	0 %
Plan dose: 192MR (M...	External	13362.97	0.00	0.01	0.10	10.42	3.44	58.42	72.42	0 %
Evaluation dose (192...	External	13901.71	0.00	0.01	0.11	10.09	3.19	56.31	70.03	11 %
Plan dose: 192MR (M...	MR BLA	39.31	17.34	18.34	20.43	50.92	51.77	78.61	78.84	0 %
Evaluation dose (192...	MR BLA	39.1	17.29	18.16	20.05	49.75	50.44	77.07	77.45	0 %
Plan dose: 192MR (M...	MR FH L	117.61	1.32	1.43	1.94	23.33	24.27	41.45	42.88	0 %
Evaluation dose (192...	MR FH L	117.51	1.31	1.43	1.93	23.48	24.43	42.29	43.74	0 %
Plan dose: 192MR (M...	MR FH R	115.35	1.38	1.51	2.09	23.97	24.98	39.26	40.45	0 %
Evaluation dose (192...	MR FH R	115.53	1.38	1.51	2.06	24.29	25.45	40.29	41.51	0 %
Plan dose: 192MR (M...	MR REC	110.81	12.40	12.84	13.60	38.11	30.36	76.47	77.86	0 %
Evaluation dose (192...	MR REC	110.65	12.93	13.41	14.58	40.46	38.23	72.98	74.40	0 %
Plan dose: 192MR (M...	PTV 0-70	104.44	70.83	71.57	72.73	76.35	76.40	81.06	81.43	0 %
Evaluation dose (192...	PTV 0-70	104.31	68.02	68.78	70.12	74.48	74.77	78.53	78.94	0 %
Plan dose: 192MR (M...	PTV 70-78	65	72.79	73.18	73.85	76.41	76.46	79.61	80.45	0 %
Evaluation dose (192...	PTV 70-78	64.91	68.49	69.37	71.28	74.60	74.88	77.60	77.84	0 %
Plan dose: 192MR (M...	PTV 70eks	78.42	66.03	67.03	68.54	74.74	75.00	81.32	81.67	0 %
Evaluation dose (192...	PTV 70eks	78.34	63.13	64.17	66.15	72.86	73.34	78.73	79.13	0 %

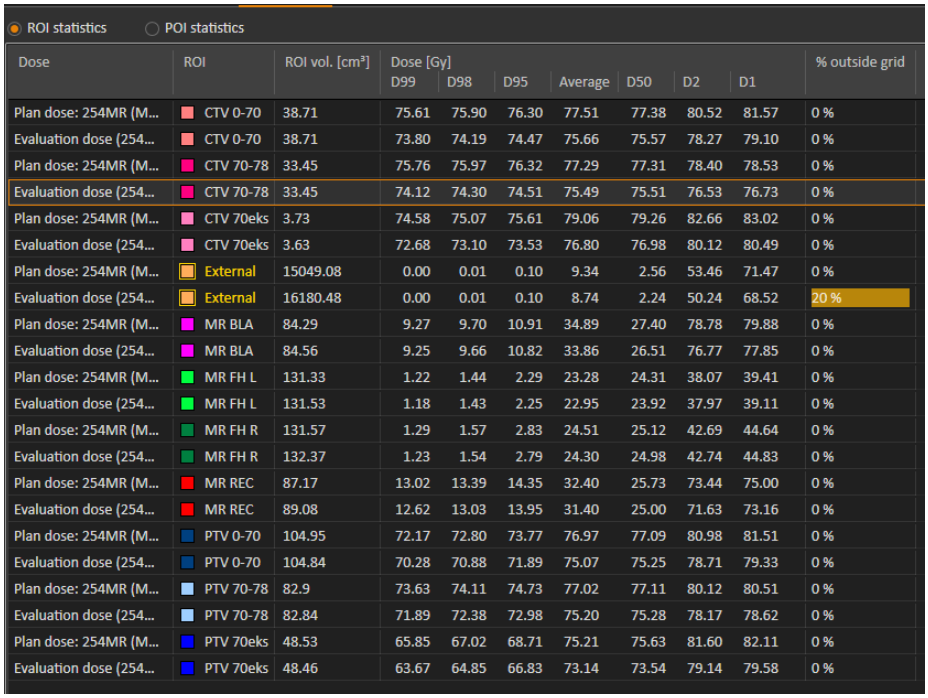
Figure 85: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 192.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 221MR (M...	CTV 0-70	58.09	69.46	69.71	70.25	76.03	76.56	78.69	78.85	0 %
Evaluation dose (221...	CTV 0-70	58.13	68.47	68.69	69.22	74.67	75.19	77.15	77.40	0 %
Plan dose: 221MR (M...	CTV 70-78	46.91	74.64	74.85	75.26	76.85	76.81	78.84	79.08	0 %
Evaluation dose (221...	CTV 70-78	46.91	73.03	73.28	73.75	75.40	75.38	77.40	77.59	0 %
Plan dose: 221MR (M...	CTV 70eks	7.26	68.43	68.71	69.21	70.96	70.49	74.80	75.29	0 %
Evaluation dose (221...	CTV 70eks	7.26	67.37	67.73	68.20	69.92	69.39	73.72	74.13	0 %
Plan dose: 221MR (M...	External	13890.32	0.21	0.27	0.39	10.55	3.34	60.17	73.02	0 %
Evaluation dose (221...	External	15001.49	0.13	0.20	0.33	9.81	2.81	56.63	70.42	33 %
Plan dose: 221MR (M...	MR BLA	90.78	9.02	10.06	12.49	37.02	29.92	78.60	79.34	0 %
Evaluation dose (221...	MR BLA	92.71	8.34	9.45	11.76	35.84	28.85	76.91	77.70	0 %
Plan dose: 221MR (M...	MR FH L	133.86	2.22	2.72	4.08	25.11	27.29	40.15	41.00	0 %
Evaluation dose (221...	MR FH L	135.51	1.84	2.12	3.43	24.89	27.34	40.21	41.11	0 %
Plan dose: 221MR (M...	MR FH R	134.85	2.02	2.44	3.60	24.52	26.79	40.91	42.22	0 %
Evaluation dose (221...	MR FH R	137.09	1.77	1.94	2.82	24.38	26.88	41.40	42.74	0 %
Plan dose: 221MR (M...	MR REC	63.89	7.56	8.36	9.87	28.10	21.96	73.70	74.93	0 %
Evaluation dose (221...	MR REC	63.93	7.52	8.39	9.86	27.93	22.04	70.78	72.93	0 %
Plan dose: 221MR (M...	PTV 0-70	135.26	66.22	67.12	68.35	75.17	76.35	79.46	79.98	0 %
Evaluation dose (221...	PTV 0-70	135.12	65.05	65.91	67.15	73.71	74.87	77.76	78.24	0 %
Plan dose: 221MR (M...	PTV 70-78	105.64	72.77	73.35	74.48	76.75	76.78	79.61	80.09	0 %
Evaluation dose (221...	PTV 70-78	105.54	70.61	71.71	72.83	75.21	75.28	77.94	78.37	0 %
Plan dose: 221MR (M...	PTV 70eks	72.21	57.69	59.77	62.30	70.31	70.04	78.06	78.34	0 %
Evaluation dose (221...	PTV 70eks	72.13	56.27	58.43	61.06	69.13	68.84	76.97	77.33	0 %

Figure 86: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 221.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: MR242 (M...	CTV 0-70	84.43	75.41	75.82	76.38	77.05	77.07	77.96	78.19	0 %
Evaluation dose (MR2...	CTV 0-70	84.43	72.84	73.21	73.68	74.82	74.84	76.21	76.45	0 %
Plan dose: MR242 (M...	CTV 70-78	77.75	76.01	76.25	76.52	77.07	77.07	77.79	77.99	0 %
Evaluation dose (MR2...	CTV 70-78	83.26	72.86	73.22	73.69	74.82	74.84	76.12	76.40	0 %
Plan dose: MR242 (M...	CTV 70eks	2.97	73.96	74.32	74.53	76.73	76.65	79.12	79.15	0 %
Evaluation dose (MR2...	CTV 70eks	2.96	71.69	71.73	72.39	74.70	74.72	77.04	77.08	0 %
Plan dose: MR242 (M...	External	14516.64	0.00	0.00	0.00	11.52	3.00	68.63	76.00	0 %
Evaluation dose (MR2...	External	15494.11	0.16	0.22	0.36	11.08	3.08	65.35	73.47	12 %
Plan dose: MR242 (M...	MR BLA	53.53	14.79	17.14	21.98	55.74	61.55	77.56	78.21	0 %
Evaluation dose (MR2...	MR BLA	53.49	13.38	15.73	20.58	53.31	58.83	75.28	76.13	0 %
Plan dose: MR242 (M...	MR FH L	141.23	2.28	2.99	5.30	30.59	32.56	44.27	45.09	0 %
Evaluation dose (MR2...	MR FH L	141.99	2.50	2.78	4.57	30.30	32.62	44.28	45.21	0 %
Plan dose: MR242 (M...	MR FH R	128.27	2.54	3.12	4.99	27.13	29.75	41.18	42.29	0 %
Evaluation dose (MR2...	MR FH R	128.95	2.59	2.81	4.67	26.49	29.45	41.12	42.34	0 %
Plan dose: MR242 (M...	MR REC	44.41	20.31	20.80	21.58	41.01	35.51	75.04	75.84	0 %
Evaluation dose (MR2...	MR REC	44.48	19.38	19.79	20.51	39.19	33.23	73.47	74.22	0 %
Plan dose: MR242 (M...	PTV 0-70	178.13	71.91	72.73	73.98	76.56	76.88	78.93	79.29	0 %
Evaluation dose (MR2...	PTV 0-70	177.97	69.74	70.64	71.73	74.36	74.57	77.06	77.94	0 %
Plan dose: MR242 (M...	PTV 70-78	158.47	73.27	73.98	74.75	76.72	76.92	78.90	79.40	0 %
Evaluation dose (MR2...	PTV 70-78	158.35	71.13	71.65	72.38	74.54	74.64	77.14	78.11	0 %
Plan dose: MR242 (M...	PTV 70eks	49.96	67.16	67.74	69.24	74.81	75.62	78.93	79.13	0 %
Evaluation dose (MR2...	PTV 70eks	49.9	64.82	65.53	66.90	72.52	73.22	76.66	76.87	0 %

Figure 87: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 242.



ROI statistics | POI statistics

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside grid
Plan dose: 254MR (M...	CTV 0-70	38.71	75.61	75.90	76.30	77.51	77.38	80.52	81.57	0 %
Evaluation dose (254...	CTV 0-70	38.71	73.80	74.19	74.47	75.66	75.57	78.27	79.10	0 %
Plan dose: 254MR (M...	CTV 70-78	33.45	75.76	75.97	76.32	77.29	77.31	78.40	78.53	0 %
Evaluation dose (254...	CTV 70-78	33.45	74.12	74.30	74.51	75.49	75.51	76.53	76.73	0 %
Plan dose: 254MR (M...	CTV 70eks	3.73	74.58	75.07	75.61	79.06	79.26	82.66	83.02	0 %
Evaluation dose (254...	CTV 70eks	3.63	72.68	73.10	73.53	76.80	76.98	80.12	80.49	0 %
Plan dose: 254MR (M...	External	15049.08	0.00	0.01	0.10	9.34	2.56	53.46	71.47	0 %
Evaluation dose (254...	External	16180.48	0.00	0.01	0.10	8.74	2.24	50.24	68.52	20 %
Plan dose: 254MR (M...	MR BLA	84.29	9.27	9.70	10.91	34.89	27.40	78.78	79.88	0 %
Evaluation dose (254...	MR BLA	84.56	9.25	9.66	10.82	33.86	26.51	76.77	77.85	0 %
Plan dose: 254MR (M...	MR FH L	131.33	1.22	1.44	2.29	23.28	24.31	38.07	39.41	0 %
Evaluation dose (254...	MR FH L	131.53	1.18	1.43	2.25	22.95	23.92	37.97	39.11	0 %
Plan dose: 254MR (M...	MR FH R	131.57	1.29	1.57	2.83	24.51	25.12	42.69	44.64	0 %
Evaluation dose (254...	MR FH R	132.37	1.23	1.54	2.79	24.30	24.98	42.74	44.83	0 %
Plan dose: 254MR (M...	MR REC	87.17	13.02	13.39	14.35	32.40	25.73	73.44	75.00	0 %
Evaluation dose (254...	MR REC	89.08	12.62	13.03	13.95	31.40	25.00	71.63	73.16	0 %
Plan dose: 254MR (M...	PTV 0-70	104.95	72.17	72.80	73.77	76.97	77.09	80.98	81.51	0 %
Evaluation dose (254...	PTV 0-70	104.84	70.28	70.88	71.89	75.07	75.25	78.71	79.33	0 %
Plan dose: 254MR (M...	PTV 70-78	82.9	73.63	74.11	74.73	77.02	77.11	80.12	80.51	0 %
Evaluation dose (254...	PTV 70-78	82.84	71.89	72.38	72.98	75.20	75.28	78.17	78.62	0 %
Plan dose: 254MR (M...	PTV 70eks	48.53	65.85	67.02	68.71	75.21	75.63	81.60	82.11	0 %
Evaluation dose (254...	PTV 70eks	48.46	63.67	64.85	66.83	73.14	73.54	79.14	79.58	0 %

Figure 88: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 254.

B.5 Dose data from pCTs with additional water but without the delineation of adipose tissue

As the treatment plans used adaptions of previous tumor volumes, certain names are not correct. In this section, the abbreviations mean:
bla - bladder
FHL - left femur
FHR - right femur
rec - rectum
CTV70-78 - CTV77
CTV0-70 - an old volume which was not used in this thesis
CTV70eks - CTV70
PTV70-78 - PTV77
PTV0-70 - an old volume which was not used in this thesis
PTV70eks - PTV70

Dose	ROI	ROI vol. [cm³]	Dose [Gy]							% outside
			D99	D98	D95	Average	D50	D2	D1	
Plan dose: 150MR (M...	CTV 0-70	43.78	69.62	70.12	71.18	76.34	76.91	78.85	79.25	0 %
Evaluation dose (150...	CTV 0-70	43.78	68.97	69.35	70.25	75.58	76.16	78.28	78.61	0 %
Plan dose: 150MR (M...	CTV 70-78	32.97	75.58	75.73	75.95	77.02	77.02	78.41	78.79	0 %
Evaluation dose (150...	CTV 70-78	32.97	74.73	74.87	75.16	76.29	76.21	77.99	78.31	0 %
Plan dose: 150MR (M...	CTV 70eks	7.31	69.07	69.32	69.50	73.24	72.33	80.25	80.61	0 %
Evaluation dose (150...	CTV 70eks	7.34	68.60	68.68	68.90	72.24	71.26	78.71	79.14	0 %
Plan dose: 150MR (M...	External	10323.13	0.12	0.17	0.31	10.42	2.07	67.78	74.76	0 %
Evaluation dose (150...	External	10683.66	0.04	0.10	0.25	10.23	2.07	66.63	73.74	10 %
Plan dose: 150MR (M...	MR BLA	68.94	23.58	27.49	34.26	60.84	64.53	77.07	77.30	0 %
Evaluation dose (150...	MR BLA	68.82	23.23	27.12	33.76	60.07	63.71	76.07	76.24	0 %
Plan dose: 150MR (M...	MR FH L	127.6	1.18	1.28	1.52	21.36	27.30	36.91	37.93	0 %
Evaluation dose (150...	MR FH L	127.19	1.20	1.31	1.55	21.52	27.48	37.25	38.31	0 %
Plan dose: 150MR (M...	MR FH R	144.42	1.29	1.43	1.81	22.19	26.31	39.08	40.15	0 %
Evaluation dose (150...	MR FH R	143.32	1.16	1.29	1.64	21.70	25.56	39.08	40.36	0 %
Plan dose: 150MR (M...	MR REC	34.09	4.89	6.27	7.32	26.48	22.49	67.33	69.87	0 %
Evaluation dose (150...	MR REC	34.28	4.85	5.42	7.21	26.12	22.23	66.14	68.68	0 %
Plan dose: 150MR (M...	PTV 0-70	124.89	68.49	68.84	69.54	75.10	76.12	78.99	79.44	0 %
Evaluation dose (150...	PTV 0-70	124.89	67.80	68.21	68.96	74.33	75.35	78.22	78.57	0 %
Plan dose: 150MR (M...	PTV 70-78	82.22	72.90	73.61	74.45	76.55	76.71	78.87	79.24	0 %
Evaluation dose (150...	PTV 70-78	82.09	72.01	72.69	73.55	75.78	75.91	78.21	78.54	0 %
Plan dose: 150MR (M...	PTV 70eks	73.37	66.83	67.28	67.96	72.67	71.69	79.38	79.90	0 %
Evaluation dose (150...	PTV 70eks	73.3	65.94	66.47	67.29	71.88	70.89	78.47	78.84	0 %

Figure 89: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 150.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR159 (M...	CTV 0-70	35.22	75.05	75.15	75.40	76.45	76.34	78.63	78.96	0 %
Evaluation dose (MR1...	CTV 0-70	35.22	73.92	74.09	74.23	75.40	75.33	77.84	78.19	0 %
Plan dose: MR159 (M...	CTV 70-78	30.58	75.08	75.18	75.40	76.31	76.27	77.54	77.80	0 %
Evaluation dose (MR1...	CTV 70-78	30.58	73.92	74.09	74.21	75.23	75.20	76.67	76.80	0 %
Plan dose: MR159 (M...	CTV 70eks	1.81	74.79	75.43	75.83	77.97	78.20	79.52	79.59	0 %
Evaluation dose (MR1...	CTV 70eks	1.85	74.28	74.87	75.28	77.20	77.37	78.73	78.87	0 %
Plan dose: MR159 (M...	External	13121.63	0.03	0.08	0.21	9.66	2.30	59.18	73.15	0 %
Evaluation dose (MR1...	External	13797.55	0.01	0.07	0.23	9.27	2.17	56.84	71.75	23 %
Plan dose: MR159 (M...	MR BLA	33.5	9.32	10.19	12.06	36.77	28.01	77.10	77.35	0 %
Evaluation dose (MR1...	MR BLA	33.83	9.32	10.10	11.97	36.35	27.75	76.29	76.52	0 %
Plan dose: MR159 (M...	MR FH L	155.13	1.30	1.43	1.73	22.27	26.00	41.30	42.41	0 %
Evaluation dose (MR1...	MR FH L	149.11	1.29	1.41	1.70	21.59	24.59	41.13	42.34	0 %
Plan dose: MR159 (M...	MR FH R	161.57	1.26	1.41	1.83	20.09	23.17	35.58	36.49	0 %
Evaluation dose (MR1...	MR FH R	161.95	1.25	1.40	1.83	19.86	22.88	35.47	36.41	0 %
Plan dose: MR159 (M...	MR REC	49.82	22.06	22.71	23.92	46.11	42.39	74.90	75.46	0 %
Evaluation dose (MR1...	MR REC	49.83	21.86	22.45	23.74	45.50	41.92	73.71	74.46	0 %
Plan dose: MR159 (M...	PTV 0-70	96.83	72.30	72.93	73.80	76.09	76.14	78.83	79.21	0 %
Evaluation dose (MR1...	PTV 0-70	96.74	71.50	72.07	72.83	75.07	75.08	77.93	78.28	0 %
Plan dose: MR159 (M...	PTV 70-78	83.01	73.26	73.66	74.29	76.13	76.15	78.42	78.94	0 %
Evaluation dose (MR1...	PTV 70-78	82.89	72.08	72.53	73.22	75.06	75.06	77.39	77.80	0 %
Plan dose: MR159 (M...	PTV 70eks	36.71	68.56	69.18	70.46	75.10	75.51	79.06	79.40	0 %
Evaluation dose (MR1...	PTV 70eks	36.67	67.78	68.53	69.82	74.35	74.73	78.41	78.71	0 %

Figure 90: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 159.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR161 (M...	CTV 0-70	43.06	74.13	74.37	74.90	76.89	76.84	79.26	79.80	0 %
Evaluation dose (MR1...	CTV 0-70	43.06	73.48	73.72	74.33	76.25	76.27	78.48	79.01	0 %
Plan dose: MR161 (M...	CTV 70-78	38.2	74.18	74.48	75.04	76.87	76.84	78.99	79.26	0 %
Evaluation dose (MR1...	CTV 70-78	38.2	73.60	73.90	74.55	76.27	76.29	78.26	78.49	0 %
Plan dose: MR161 (M...	CTV 70eks	3.24	73.68	73.79	74.17	76.76	76.76	81.88	82.11	0 %
Evaluation dose (MR1...	CTV 70eks	3.13	73.07	73.23	73.39	75.86	75.93	81.07	81.29	0 %
Plan dose: MR161 (M...	External	15194.21	0.00	0.00	0.06	9.58	2.48	56.18	72.65	0 %
Evaluation dose (MR1...	External	16164.61	0.00	0.00	0.07	9.15	2.22	53.99	70.67	17 %
Plan dose: MR161 (M...	MR BLA	130.45	17.02	18.13	20.86	54.21	57.49	79.63	80.63	0 %
Evaluation dose (MR1...	MR BLA	131.12	16.72	17.81	20.52	53.38	56.53	78.73	79.81	0 %
Plan dose: MR161 (M...	MR FH L	153.14	1.15	1.28	1.67	21.34	22.78	38.44	39.08	0 %
Evaluation dose (MR1...	MR FH L	152.58	1.16	1.30	1.68	21.52	22.79	39.22	39.88	0 %
Plan dose: MR161 (M...	MR FH R	160.82	1.14	1.28	1.70	22.56	25.69	39.08	39.78	0 %
Evaluation dose (MR1...	MR FH R	160.46	1.17	1.31	1.72	22.72	25.84	39.45	40.30	0 %
Plan dose: MR161 (M...	MR REC	61.78	12.20	12.65	13.43	26.83	21.42	61.36	64.46	0 %
Evaluation dose (MR1...	MR REC	62.09	12.35	12.83	13.63	29.26	24.75	60.28	62.06	0 %
Plan dose: MR161 (M...	PTV 0-70	116.42	71.76	72.38	73.33	76.60	76.69	79.88	80.73	0 %
Evaluation dose (MR1...	PTV 0-70	116.3	69.50	70.48	71.86	75.62	75.88	78.96	79.87	0 %
Plan dose: MR161 (M...	PTV 70-78	94.4	73.97	74.30	74.89	77.00	76.93	79.81	80.65	0 %
Evaluation dose (MR1...	PTV 70-78	94.33	71.58	72.46	73.48	76.07	76.16	78.92	79.83	0 %
Plan dose: MR161 (M...	PTV 70eks	52.61	66.24	66.98	68.15	74.02	74.18	80.31	81.10	0 %
Evaluation dose (MR1...	PTV 70eks	52.55	63.48	64.57	65.92	72.70	73.01	79.55	80.33	0 %

Figure 91: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 161.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR174 (M...	CTV 0-70	31.29	75.18	75.58	75.90	77.09	76.79	80.97	81.42	0 %
Evaluation dose (MR1...	CTV 0-70	31.29	74.57	74.87	75.18	76.38	76.04	80.46	80.88	0 %
Plan dose: MR174 (M...	CTV 70-78	22.76	75.70	75.85	76.01	76.74	76.70	77.91	78.05	0 %
Evaluation dose (MR1...	CTV 70-78	22.76	74.98	75.11	75.25	75.97	75.96	77.00	77.15	0 %
Plan dose: MR174 (M...	CTV 70eks	6.29	73.96	74.37	75.24	78.59	78.99	81.93	81.98	0 %
Evaluation dose (MR1...	CTV 70eks	6.26	73.67	74.04	74.82	78.08	78.57	81.43	81.52	0 %
Plan dose: MR174 (M...	External	12862.43	0.11	0.16	0.29	9.76	2.67	56.16	73.18	0 %
Evaluation dose (MR1...	External	13268.27	0.07	0.14	0.29	9.52	2.58	54.80	72.17	31 %
Plan dose: MR174 (M...	MR BLA	62.27	7.73	8.51	9.89	25.55	20.75	72.40	77.00	0 %
Evaluation dose (MR1...	MR BLA	64.8	6.76	7.69	9.04	24.61	19.93	71.62	76.43	0 %
Plan dose: MR174 (M...	MR FH L	142.3	1.75	2.02	3.07	23.51	25.23	37.32	38.79	0 %
Evaluation dose (MR1...	MR FH L	144.16	1.63	1.84	2.83	23.37	25.18	37.76	39.31	0 %
Plan dose: MR174 (M...	MR FH R	147.92	1.64	1.95	3.37	20.18	21.91	32.21	33.27	0 %
Evaluation dose (MR1...	MR FH R	148.46	1.63	1.94	3.32	20.53	22.39	33.00	34.14	0 %
Plan dose: MR174 (M...	MR REC	67.98	11.24	12.91	14.82	34.48	27.27	76.60	77.46	0 %
Evaluation dose (MR1...	MR REC	69.49	9.79	11.35	14.06	33.61	26.56	75.62	76.51	0 %
Plan dose: MR174 (M...	PTV 0-70	87.94	71.33	72.29	73.79	76.92	76.87	81.03	81.61	0 %
Evaluation dose (MR1...	PTV 0-70	87.83	70.80	71.72	73.20	76.23	76.11	80.52	81.05	0 %
Plan dose: MR174 (M...	PTV 70-78	61.53	75.32	75.52	75.76	77.02	76.87	79.63	80.44	0 %
Evaluation dose (MR1...	PTV 70-78	61.46	74.53	74.80	75.01	76.26	76.10	79.07	79.82	0 %
Plan dose: MR174 (M...	PTV 70eks	54.68	67.02	67.75	69.14	75.34	75.99	81.23	81.66	0 %
Evaluation dose (MR1...	PTV 70eks	54.63	66.24	67.11	68.62	74.73	75.32	80.71	81.13	0 %

Figure 92: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 174.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 178MR (M...	CTV 0-70	30.59	74.33	74.70	75.19	78.04	77.92	82.97	83.53	0 %
Evaluation dose (178...	CTV 0-70	30.59	73.55	73.99	74.55	77.45	77.34	82.55	83.07	0 %
Plan dose: 178MR (M...	CTV 70-78	23.7	74.22	74.65	75.15	77.66	77.72	80.72	80.92	0 %
Evaluation dose (178...	CTV 70-78	23.7	73.47	73.91	74.40	77.04	77.14	80.03	80.40	0 %
Plan dose: 178MR (M...	CTV 70eks	5.68	75.17	75.66	76.50	80.07	80.01	84.50	84.82	0 %
Evaluation dose (178...	CTV 70eks	5.73	74.63	75.02	75.94	79.56	79.62	84.10	84.29	0 %
Plan dose: 178MR (M...	External	13664.42	0.05	0.11	0.24	9.91	2.63	59.07	74.01	0 %
Evaluation dose (178...	External	14384.09	0.03	0.09	0.23	9.53	2.49	56.93	72.95	38 %
Plan dose: 178MR (M...	MR BLA	112.86	10.50	12.18	14.91	33.19	27.65	77.68	79.25	0 %
Evaluation dose (178...	MR BLA	112.3	10.33	11.90	14.86	32.86	27.41	77.08	78.62	0 %
Plan dose: 178MR (M...	MR FH L	177.42	1.30	1.47	1.94	20.41	22.63	35.27	36.60	0 %
Evaluation dose (178...	MR FH L	178.1	1.28	1.46	1.94	20.52	22.72	35.87	37.07	0 %
Plan dose: 178MR (M...	MR FH R	185.73	1.36	1.61	2.31	18.24	19.77	33.07	33.86	0 %
Evaluation dose (178...	MR FH R	187.29	1.37	1.61	2.31	18.18	19.78	32.98	33.77	0 %
Plan dose: 178MR (M...	MR REC	41.99	13.15	14.78	17.24	46.29	44.81	79.12	80.02	0 %
Evaluation dose (178...	MR REC	43.13	11.35	13.20	15.88	45.30	43.67	78.48	79.57	0 %
Plan dose: 178MR (M...	PTV 0-70	95.06	72.16	72.97	74.28	78.08	77.98	83.68	84.42	0 %
Evaluation dose (178...	PTV 0-70	94.93	71.59	72.30	73.63	77.51	77.41	83.18	83.95	0 %
Plan dose: 178MR (M...	PTV 70-78	63.47	72.59	73.26	74.32	77.47	77.56	81.23	82.03	0 %
Evaluation dose (178...	PTV 70-78	63.39	71.92	72.66	73.64	76.84	76.95	80.55	81.09	0 %
Plan dose: 178MR (M...	PTV 70eks	64.26	66.34	67.95	70.68	77.63	77.90	84.07	84.68	0 %
Evaluation dose (178...	PTV 70eks	64.2	66.16	67.73	70.27	77.20	77.45	83.68	84.22	0 %

Figure 93: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 178.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: 179MR (M...	CTV 0-70	58.16	74.70	74.90	75.32	76.63	76.49	78.94	79.21	0 %
Evaluation dose (179...	CTV 0-70	58.14	73.26	73.55	73.90	75.26	75.14	77.65	78.00	0 %
Plan dose: 179MR (M...	CTV 70-78	44.39	74.97	75.15	75.41	76.47	76.38	78.28	78.62	0 %
Evaluation dose (179...	CTV 70-78	44.38	73.42	73.62	73.94	75.06	75.02	76.63	76.84	0 %
Plan dose: 179MR (M...	CTV 70eks	9.76	73.36	73.72	74.61	77.15	77.36	79.59	79.81	0 %
Evaluation dose (179...	CTV 70eks	9.78	72.36	72.71	73.54	75.95	76.06	78.35	78.51	0 %
Plan dose: 179MR (M...	External	12642.96	0.20	0.28	0.46	12.41	4.26	69.33	75.71	0 %
Evaluation dose (179...	External	14055.19	0.07	0.13	0.31	11.27	3.33	65.79	73.98	28 %
Plan dose: 179MR (M...	MR BLA	121.93	3.43	3.72	4.35	35.29	28.76	77.74	78.81	0 %
Evaluation dose (179...	MR BLA	122.04	3.43	3.71	4.32	34.65	28.20	76.61	77.62	0 %
Plan dose: 179MR (M...	MR FH L	121.65	6.42	8.14	13.05	27.82	29.82	43.62	44.74	0 %
Evaluation dose (179...	MR FH L	121.68	6.35	8.11	12.95	27.71	29.66	43.73	44.88	0 %
Plan dose: 179MR (M...	MR FH R	129.24	6.84	7.90	12.20	31.14	32.56	45.11	45.98	0 %
Evaluation dose (179...	MR FH R	128.97	6.91	8.01	12.23	31.09	32.52	45.43	46.35	0 %
Plan dose: 179MR (M...	MR REC	24.69	13.31	13.85	14.95	44.39	44.93	76.34	77.05	0 %
Evaluation dose (179...	MR REC	24.7	13.15	13.66	14.75	43.69	45.28	74.19	74.95	0 %
Plan dose: 179MR (M...	PTV 0-70	138.4	71.95	72.72	73.80	76.43	76.43	79.43	79.90	0 %
Evaluation dose (179...	PTV 0-70	138.15	70.74	71.45	72.55	75.05	75.08	78.01	78.46	0 %
Plan dose: 179MR (M...	PTV 70-78	102.53	74.01	74.60	75.14	76.70	76.53	79.52	80.10	0 %
Evaluation dose (179...	PTV 70-78	102.5	72.61	73.11	73.65	75.26	75.15	77.91	78.47	0 %
Plan dose: 179MR (M...	PTV 70eks	74.62	67.22	68.23	69.71	74.85	75.39	79.06	79.41	0 %
Evaluation dose (179...	PTV 70eks	74.55	65.95	66.82	68.48	73.59	74.15	77.87	78.24	0 %

Figure 94: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 179.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside gri
Plan dose: 192MR (M...	CTV 0-70	31.64	75.46	75.63	75.86	77.29	76.82	81.38	81.68	0 %
Evaluation dose (192...	CTV 0-70	31.68	74.17	74.50	74.89	76.77	76.45	80.41	80.81	0 %
Plan dose: 192MR (M...	CTV 70-78	22.07	75.58	75.67	75.84	76.64	76.66	77.49	77.65	0 %
Evaluation dose (192...	CTV 70-78	22.08	73.93	74.36	74.77	76.10	76.17	77.35	77.57	0 %
Plan dose: 192MR (M...	CTV 70eks	7.31	74.60	75.09	76.05	79.30	79.59	81.77	81.78	0 %
Evaluation dose (192...	CTV 70eks	7.17	74.87	75.48	76.07	78.80	79.04	81.20	81.44	0 %
Plan dose: 192MR (M...	External	13362.97	0.00	0.01	0.10	10.85	3.62	62.36	73.87	0 %
Evaluation dose (192...	External	13901.71	0.00	0.01	0.11	10.58	3.36	60.49	72.41	11 %
Plan dose: 192MR (M...	MR BLA	39.31	19.72	20.43	22.17	52.49	54.63	79.00	79.33	0 %
Evaluation dose (192...	MR BLA	39.1	19.58	20.36	21.98	51.77	53.45	78.05	78.53	0 %
Plan dose: 192MR (M...	MR FH L	117.61	1.38	1.50	2.05	23.41	23.75	41.15	42.09	0 %
Evaluation dose (192...	MR FH L	117.51	1.36	1.49	2.03	23.70	24.08	41.95	42.91	0 %
Plan dose: 192MR (M...	MR FH R	115.35	1.36	1.50	2.09	24.92	28.05	42.37	43.28	0 %
Evaluation dose (192...	MR FH R	115.53	1.35	1.49	2.08	25.22	28.39	43.14	44.14	0 %
Plan dose: 192MR (M...	MR REC	110.81	15.01	15.52	16.64	41.82	35.53	77.27	78.44	0 %
Evaluation dose (192...	MR REC	110.65	16.00	16.46	17.93	44.33	42.45	75.71	76.64	0 %
Plan dose: 192MR (M...	PTV 0-70	104.44	72.25	72.93	73.84	76.79	76.57	81.19	81.58	0 %
Evaluation dose (192...	PTV 0-70	104.31	69.20	70.37	72.03	75.88	75.95	80.14	80.45	0 %
Plan dose: 192MR (M...	PTV 70-78	65	73.18	73.60	74.37	76.34	76.39	79.54	80.64	0 %
Evaluation dose (192...	PTV 70-78	64.91	68.66	70.33	72.31	75.46	75.72	78.40	79.01	0 %
Plan dose: 192MR (M...	PTV 70eks	78.42	69.12	69.70	70.88	76.18	76.35	81.51	81.77	0 %
Evaluation dose (192...	PTV 70eks	78.34	66.38	67.63	69.23	75.28	75.79	80.44	80.86	0 %

Figure 95: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 192.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outsid
Plan dose: 221MR (M...	CTV 0-70	58.09	69.79	70.23	70.79	76.09	76.57	78.70	79.03	0 %
Evaluation dose (221...	CTV 0-70	58.13	69.74	70.12	70.70	75.53	75.95	78.21	78.50	0 %
Plan dose: 221MR (M...	CTV 70-78	46.91	75.06	75.16	75.42	76.86	76.78	79.02	79.32	0 %
Evaluation dose (221...	CTV 70-78	46.91	74.24	74.34	74.66	76.20	76.12	78.50	78.77	0 %
Plan dose: 221MR (M...	CTV 70eks	7.26	68.66	69.14	69.45	71.46	71.27	75.06	75.46	0 %
Evaluation dose (221...	CTV 70eks	7.26	68.53	68.85	69.24	71.21	70.91	74.85	75.07	0 %
Plan dose: 221MR (M...	External	13890.32	0.16	0.23	0.35	10.28	3.14	59.24	72.92	0 %
Evaluation dose (221...	External	15001.49	0.10	0.16	0.30	9.65	2.66	56.15	71.20	33 %
Plan dose: 221MR (M...	MR BLA	90.78	9.34	10.35	12.49	37.04	30.02	79.11	79.59	0 %
Evaluation dose (221...	MR BLA	92.71	8.74	9.79	11.78	36.22	29.24	78.44	78.87	0 %
Plan dose: 221MR (M...	MR FH L	133.86	1.98	2.23	3.33	23.29	24.01	38.78	39.75	0 %
Evaluation dose (221...	MR FH L	135.51	1.63	1.89	2.79	23.33	24.20	39.17	40.25	0 %
Plan dose: 221MR (M...	MR FH R	134.85	1.73	1.97	2.72	21.70	22.76	38.50	39.78	0 %
Evaluation dose (221...	MR FH R	137.09	1.53	1.69	2.31	21.76	23.02	39.38	40.59	0 %
Plan dose: 221MR (M...	MR REC	63.89	7.35	8.00	9.41	28.53	22.81	73.93	75.04	0 %
Evaluation dose (221...	MR REC	63.93	7.42	8.09	9.56	28.62	23.12	71.68	73.82	0 %
Plan dose: 221MR (M...	PTV 0-70	135.26	66.20	67.05	68.46	75.25	76.34	79.54	79.94	0 %
Evaluation dose (221...	PTV 0-70	135.12	65.68	66.61	68.08	74.60	75.64	78.87	79.28	0 %
Plan dose: 221MR (M...	PTV 70-78	105.64	72.74	73.42	74.49	76.75	76.73	79.70	80.12	0 %
Evaluation dose (221...	PTV 70-78	105.54	71.54	72.43	73.63	76.03	76.04	79.00	79.37	0 %
Plan dose: 221MR (M...	PTV 70eks	72.21	57.88	59.87	62.47	70.47	70.37	77.95	78.43	0 %
Evaluation dose (221...	PTV 70eks	72.13	57.05	59.33	62.00	70.07	70.04	77.76	78.27	0 %

Figure 96: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 221.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside
Plan dose: MR242 (M...	CTV 0-70	84.43	74.90	75.27	75.60	76.65	76.63	78.40	78.65	0 %
Evaluation dose (MR2...	CTV 0-70	84.43	74.32	74.64	75.04	76.05	76.02	77.86	78.10	0 %
Plan dose: MR242 (M...	CTV 70-78	77.75	75.10	75.34	75.63	76.61	76.61	78.04	78.34	0 %
Evaluation dose (MR2...	CTV 70-78	83.26	74.47	74.71	75.06	76.06	76.02	77.84	78.10	0 %
Plan dose: MR242 (M...	CTV 70eks	2.97	72.33	73.00	73.58	76.54	76.80	78.68	78.76	0 %
Evaluation dose (MR2...	CTV 70eks	2.96	71.75	72.36	72.98	75.97	76.26	78.09	78.19	0 %
Plan dose: MR242 (M...	External	14516.64	0.26	0.34	0.46	12.06	3.70	69.49	75.96	0 %
Evaluation dose (MR2...	External	15494.11	0.20	0.27	0.40	11.46	3.30	67.41	75.25	12 %
Plan dose: MR242 (M...	MR BLA	53.53	15.84	18.32	23.47	55.77	60.61	77.61	78.26	0 %
Evaluation dose (MR2...	MR BLA	53.49	15.83	18.19	23.16	55.19	60.03	76.92	77.57	0 %
Plan dose: MR242 (M...	MR FH L	141.23	2.88	3.75	5.38	30.22	32.50	44.31	45.52	0 %
Evaluation dose (MR2...	MR FH L	141.99	2.71	2.97	5.04	30.36	32.72	45.15	46.38	0 %
Plan dose: MR242 (M...	MR FH R	128.27	2.87	3.21	5.32	26.71	28.36	39.99	40.92	0 %
Evaluation dose (MR2...	MR FH R	128.95	2.72	2.95	4.91	26.74	28.47	40.73	41.75	0 %
Plan dose: MR242 (M...	MR REC	44.41	19.48	20.22	21.63	41.39	35.95	74.31	74.87	0 %
Evaluation dose (MR2...	MR REC	44.48	19.49	20.26	21.75	41.15	35.98	73.54	74.11	0 %
Plan dose: MR242 (M...	PTV 0-70	178.13	70.93	71.77	73.47	76.29	76.50	78.69	79.08	0 %
Evaluation dose (MR2...	PTV 0-70	177.97	70.30	71.16	72.79	75.69	75.91	78.11	78.50	0 %
Plan dose: MR242 (M...	PTV 70-78	158.47	73.22	73.89	74.74	76.53	76.57	78.72	79.13	0 %
Evaluation dose (MR2...	PTV 70-78	158.35	72.59	73.24	74.10	75.93	75.98	78.16	78.56	0 %
Plan dose: MR242 (M...	PTV 70eks	49.96	66.77	67.38	68.34	74.23	74.78	78.72	78.89	0 %
Evaluation dose (MR2...	PTV 70eks	49.9	66.18	66.67	67.73	73.54	74.09	78.17	78.30	0 %

Figure 97: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 242.

Dose	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1	% outside g
Plan dose: 254MR (M...	CTV 0-70	38.71	75.81	75.98	76.24	77.61	77.36	81.07	81.71	0 %
Evaluation dose (254...	CTV 0-70	38.71	74.74	74.86	75.10	76.43	76.20	79.67	80.24	0 %
Plan dose: 254MR (M...	CTV 70-78	33.45	75.78	75.92	76.20	77.25	77.25	78.58	78.67	0 %
Evaluation dose (254...	CTV 70-78	33.45	74.70	74.83	75.03	76.09	76.10	77.41	77.53	0 %
Plan dose: 254MR (M...	CTV 70eks	3.73	77.46	77.83	78.33	80.24	80.26	82.47	82.64	0 %
Evaluation dose (254...	CTV 70eks	3.63	76.20	76.58	77.02	78.79	78.76	81.01	81.16	0 %
Plan dose: 254MR (M...	External	15049.08	0.00	0.01	0.09	9.34	2.59	53.08	71.68	0 %
Evaluation dose (254...	External	16180.48	0.00	0.01	0.10	8.79	2.27	50.16	69.33	20 %
Plan dose: 254MR (M...	MR BLA	84.29	8.56	9.10	10.47	35.40	28.42	78.67	79.38	0 %
Evaluation dose (254...	MR BLA	84.56	8.58	9.13	10.44	34.63	27.67	77.29	78.03	0 %
Plan dose: 254MR (M...	MR FH L	131.33	1.18	1.42	2.25	22.96	23.65	37.17	38.47	0 %
Evaluation dose (254...	MR FH L	131.53	1.15	1.39	2.21	22.81	23.43	37.27	38.49	0 %
Plan dose: 254MR (M...	MR FH R	131.57	1.26	1.55	2.98	23.05	23.81	38.81	40.53	0 %
Evaluation dose (254...	MR FH R	132.37	1.21	1.49	2.92	22.99	23.80	39.11	41.06	0 %
Plan dose: 254MR (M...	MR REC	87.17	12.05	13.06	14.54	33.25	26.54	73.79	74.58	0 %
Evaluation dose (254...	MR REC	89.08	11.69	12.67	14.26	32.49	26.04	72.60	73.40	0 %
Plan dose: 254MR (M...	PTV 0-70	104.95	73.39	73.77	74.45	77.25	77.21	81.12	81.47	0 %
Evaluation dose (254...	PTV 0-70	104.84	72.16	72.60	73.32	76.04	76.01	79.78	80.09	0 %
Plan dose: 254MR (M...	PTV 70-78	82.9	73.57	73.95	74.63	77.03	77.08	80.74	81.11	0 %
Evaluation dose (254...	PTV 70-78	82.84	72.45	72.84	73.50	75.87	75.92	79.42	79.85	0 %
Plan dose: 254MR (M...	PTV 70eks	48.53	68.16	68.90	70.61	76.41	76.89	81.50	81.94	0 %
Evaluation dose (254...	PTV 70eks	48.46	66.19	67.54	69.23	75.05	75.53	80.14	80.46	0 %

Figure 98: Dose data from bd-pCT (plan dose) and opCT (evaluation dose) for patient 254.

C Appendix C

C.1 Mean absolute dosimetric difference for the generated pseudo-CTs

Table 12: Table presenting the mean of the absolute value of the dosimetric difference between the pCT and opCT in Gy for the D_{98}.

ROI	Water and adipose tissue	Water without adipose tissue	Regular size with adipose tissue	Regular size without adipose tissue	MriPlanner
Bladder	0.472	0.268	0.305	0.249	0.625
CTV70	1.678	0.631	1.860	0.680	0.950
CTV77	2.111	0.939	1.963	0.900	0.778
External contour	0.060	0.041	1.118	1.140	0.194
Femur left	0.145	0.145	0.287	0.165	0.203
Femur right	0.115	0.091	0.247	0.098	0.142
PTV70	2.140	1.136	1.687	0.602	0.549
PTV77	2.238	1.272	2.311	1.227	0.863
Rectum	0.693	0.608	0.783	0.541	0.500
Total	9.652	5.131	10.561	5.602	4.804
Total without external contour	9.592	5.090	9.443	4.462	4.610

Table 13: Table presenting the mean of the absolute value of the dosimetric difference between the pCT and opCT in Gy for the D_{AVG}.

ROI	Water and adipose tissue	Water without adipose tissue	Regular size with adipose tissue	Regular size without adipose tissue	MriPlanner
Bladder	1.251	0.654	1.230	0.530	1.241
CTV70	1.908	0.666	1.874	0.718	0.575
CTV77	1.826	0.812	1.700	0.763	0.463
External contour	0.539	0.482	9.090	9.0420	1.143
Femur left	0.256	0.200	0.323	0.212	0.151
Femur right	0.312	0.179	0.335	0.211	0.239
PTV70	1.909	0.651	1.759	0.593	0.428
PTV77	1.902	0.896	1.639	0.842	0.806
Rectum	1.419	0.956	1.540	0.950	1.357
Total	11.322	5.490	19.490	13.861	6.403
Total without external contour	10.783	5.014	10.400	4.819	5.260

Table 14: Table presenting the mean of the absolute value of the dosimetric difference between the pCT and opCT in Gy for the D_2.

ROI	Water and adipose tissue	Water without adipose tissue	Regular size with adipose tissue	Regular size without adipose tissue	MriPlanner
Bladder	1.858	0.891	1.750	0.817	0.702
CTV70	2.115	0.811	1.899	0.750	0.491
CTV77	1.924	0.730	1.504	0.672	0.326
External contour	3.883	2.268	15.516	14.677	1.914
Femur left	0.271	0.457	0.419	0.504	0.554
Femur right	0.279	0.437	0.351	0.574	0.499
PTV70	2.063	0.779	1.711	0.590	0.558
PTV77	2.002	0.915	1.790	0.872	0.558
Rectum	2.402	1.300	2.698	1.283	1.270
Total	16.797	8.588	27.638	20.739	6.597
Total without external contour	12.914	6.320	12.122	6.062	4.683

Table 15: Table presenting the mean of the absolute value of the dosimetric difference between the pCT and opCT in Gy. All DVH values (D_{98}, D_{AVG} and D_2) are included in the calculation of the mean.

ROI	Water and adipose tissue	Water without adipose tissue	Regular size with adipose tissue	Regular size without adipose tissue	MriPlanner
Bladder	3.581	1.813	3.285	1.596	2.568
CTV70	5.701	2.108	5.633	2.148	2.106
CTV77	5.861	2.481	5.167	2.335	1.567
External contour	4.482	2.791	25.724	24.859	3.251
Femur left	0.672	0.802	1.029	0.881	0.908
Femur right	0.706	0.707	0.933	0.883	0.880
PTV70	6.112	2.566	5.157	1.785	1.260
PTV77	6.142	3.083	5.740	2.941	2.227
Rectum	4.515	2.864	5.021	2.774	3.127
Total	37.772	19.215	57.689	40.202	17.804
Total without external contour	33.289	16.424	31.965	15.343	14.553

D Appendix D

Table 16: Worst observed geometric distortion. * For the 3D SPACE T2W sequence, the last measurements were sampled at in the slices located 250 mm from the isocenter of the scanner, which is why the > 250 mm measurements equals the measurements for 200-250 mm.

				Worst observed distortion at distance from scanner isocenter [mm]				
Day	Manual set-up	MRI sequence	FOV 30 mm anterior shift or isocenter	< 100	100 - 150	150 - 200	200 - 250	> 250
1		Standard	Shift	0.86	2.03	3.79	17.77	26.94
24	x	Standard	Shift	0.97	1.35	2.64	4.81	24.79
	x	Standard	Isocenter	1.14	1.35	3.01	4.72	24.75
29		Standard	Shift	1.18	1.5	3.14	5.58	24.57
		Standard	Shift	1.39	1.39	3.06	7.56	24.22
35		Standard	Shift	1.02	1.3	2.61	9.09	25.36
	x	Standard	Shift	0.99	1.14	3.18	6.0	24.89
	x	Standard	Shift	1.13	1.25	3.24	4.74	24.13
		New 3D	Shift	1.23	1.51	2.93	2.95	2.95*
37		Standard	Shift	0.97	1.16	2.65	7.39	24.84
		Standard	Shift	1.14	1.38	3.02	7.65	25.02
		Standard	Shift	1.01	1.59	2.84	5.75	24.51
41		Standard	Shift	1.08	1.10	2.94	10.92	24.56
		Standard	Shift	1.38	1.38	2.93	5.42	24.63
		Standard	Isocenter	1.21	1.21	2.84	5.75	24.44
44		Standard	Shift	1.12	1.38	2.89	5.26	24.44
		New 3D	Shift	0.92	1.58	2.65	3.02	3.02*
		New 3D	Isocenter	0.99	1.94	2.57	3.24	3.24*

Table 17: Mean observed geometric distortion. * For the 3D SPACE T2W sequence, the last measurements were sampled at in the slices located 250 mm from the isocenter of the scanner, which is why there are no mean value for slices located at distances > 250 mm from the isocenter.

				Mean observed distortion at distance from scanner isocenter [mm]				
Day	Manual set-up	MRI sequence	FOV 30 mm anterior shift or isocenter	< 100	100 - 150	150 - 200	200 - 250	> 250
1		Standard	Shift	0.33	0.5	1.05	2.18	16.87
24	x	Standard	Shift	0.38	0.46	0.82	1.78	14.26
	x	Standard	Isocenter	0.35	0.5	0.9	1.83	13.23
29		Standard	Shift	0.39	0.53	0.96	1.94	15.75
		Standard	Shift	0.39	0.49	0.89	1.98	15.47
35		Standard	Shift	0.4	0.51	0.84	1.96	14.91
	x	Standard	Shift	0.44	0.46	0.94	1.92	14.67
	x	Standard	Shift	0.4	0.51	0.84	1.83	14.74
		New 3D	Shift	0.49	0.67	0.84	1.47	-*
37		Standard	Shift	0.38	0.48	0.90	1.99	15.33
		Standard	Shift	0.38	0.49	0.90	1.89	15.45
		Standard	Shift	0.4	0.56	1.00	1.98	15.59
41		Standard	Shift	0.40	0.53	0.99	2.07	14.76
		Standard	Shift	0.48	0.49	0.93	1.93	15.11
		Standard	Isocenter	0.44	0.48	0.86	1.84	13.88
44		Standard	Shift	0.39	0.51	0.92	1.88	15.24
		New 3D	Shift	0.4	0.63	0.86	1.55	-*
		New 3D	Isocenter	0.43	0.59	0.84	1.48	-*